Monte Carlo simulation of a container terminal project investment decision

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ABSTRACT

The objective of this paper has been to investigate the ability of Monte Carlo simulation to mitigate the adverse effects of 'planning fallacy' for large container terminal investment decisions which are based upon discounted cash flow analysis.

Company executives are mandated to grow the economic value of their organisations. One key growth avenue for executives, is that of portfolio expansion, by investing in financially attractive new operations in order to achieve long-term economic company growth. This notion is further complicated for the container terminal industry, where opportunities for new container terminal developments are continuously diminishing due to their inherent topographical and geographical requirements. This scarcity of potential projects leads to much contention for investment appraisals, where project risk is often downplayed due to the element of 'planning fallacy'. This becomes an ever more critical concern when considering the vast capital requirements of a container terminal project, where in some cases the total expenditure approaches USD 3 billion (World Bank, 2016). These investments are typically analysed using discounted cash flows, with the net present value outcome used as the criterion for the investment decision. The chief limitation of this form of financial investment appraisal is its inability to provide insight into the project's risk profile, hence this investigation's focus on the ability of Monte Carlo simulation to provide an exhaustive view of project risk and thereby mitigate the element of 'planning fallacy' for container terminal investment decisions.

This paper is based upon an actual container terminal investment case, which used discounted cash flows and net present value as its decision criterion. The investigation then built upon the discounted cash flow model provided and used Monte Carlo simulation to provide an insight into the risk profile of the project.

The simulation's results were then contrasted to those provided by other risk assessment methods.

The investigation found that while Monte Carlo simulation cannot provide a clear 'accept' or 'reject' decision outcome, it did provide a clear view of the project's inherent risk, which the other risk assessment tools of sensitivity and scenario analysis could not clearly articulate. Although the project which was used for this paper's investigation warranted an 'accept' decision based on the net present value criterion, the results of the Monte Carlo simulation found an 'accept' decision would be imprudent due to the low probability that the project would in fact create economic value.

All investment decisions duly require exhaustive consideration and very few are more so deserving than that of container terminal investment decisions. It would be irresponsible for executives not to consider Monte Carlo simulation for project risk appraisal, as Monte Carlo simulation provides colour to a previously black and white decision.

DECLARATION

I, Mark Neel, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Mark Neel

Signed at Vredehoek, Cape Town

On the 31st day of March 2017

DEDICATION

This research project is dedicated to Jane for her unwavering support, consistent understanding and never-ending encouragement.

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This research would not have come into being without the sound guidance provided by my supervisor Anthony Stacey, for which I am extremely grateful.

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CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

The purpose of this research is to evaluate whether a stochastic model could safe guard companies from being inadvertently mislead by their executive's zeal for company expansion.

1.2 Context of the study

This paper will take the form of a single project investigation for an actual container terminal project valuation. The study sets out to analyse and discuss the potential ramifications of the project's inherent risk elements.

Executives of private terminal organisations are continuously faced with the demanding obligation of having to make large capital investment decisions which typically range between USD 50 million and USD 3 billion (World Bank, 2016) and are undeniably plagued by vast amounts of uncertainty. Container terminal projects require even higher levels of analysis due to the nature of their business model, where the upside potential is limited by their volume throughput capacity (physical infrastructure), but their downside is virtually unlimited.

One method to value potential 'risky' projects is to use the Discounted Cash Flow (DCF) methodology, which discounts the future cash flows of the project, at an appropriate discount rate which embodies the level of risk of the project (Brealey & Myers, 2000) which then produces a Net Present Value (NPV) outcome. The project which was used for this paper's research, used the NPV criterion for its decision-making basis, therefore this study will not deviate from this method, and will perform simulations of the DCF model as the final deterministic outcome to evaluate project potential.

Only using the deterministic NPV evaluation method is concerning for projects with such a high degree of uncertainty, as ignoring the correlation between variables and selecting static input variable movements for sensitivity and scenario analyses, leaves the company vulnerable to bias and over optimism.

History is littered with many examples of large-infrastructure development projects which have not lived up to the expectations set out in their initial project valuation model. Flyvbjerg's research on large transportation project costs, showed that the average cost overrun versus the forecast was 44.7% (Flyvbjerg, 2007, p. 579). This is extremely concerning for projects of this immense capital expenditure, as few organisations would be able to absorb that level increased capital outlay without endangering their other and overall business' sustainability. While there is no definitive research regarding the common determinates for large discrepancies between the actual performance of container terminal infrastructure projects versus their initial project valuations, Flyvbjerg (2007) notes that even though his research focused on rail, road, bridges and tunnels, the comparative research shows that the problems and causes identified are in line with other large-infrastructure projects (Flyvbjerg, 2007), which terminals form part of.

Container terminal projects are very susceptible to planning fallacy, due to the limitations of project availability. Work done by Olivier, Parola, Slack, and Wang (2007) noted that the amount of potential container terminal investment opportunities is indeed diminishing (2007), as each country is limited by their geographical, topographical structure, and the existing hinterland infrastructure links. Due to the scarcity of these opportunities, executives are prone to over value the potential benefits of the project and downplay the costs and risk aspects.

Executives are duly mandated to increase company value and all decisions should always have that commonality, therefore can stochastic modelling provide the competitive advantage for executives to make sound investment decisions, which can be unanimously agreed by the Board based on the company's risk appetite?

1.3 Problem statement

1.3.1 *Main problem*

Using risk analysis modelling to determine the key risk insights into the numerous uncertainties for a container terminal project investment decision, which mitigate the shortcomings of NPV modelling and the element of ‘planning fallacy’.

1.3.2 *Sub-problems*

<u>The first sub-problem</u> is …. To determine the elements of uncertainty for a container terminal green field project.

<u>The second sub-problem</u> is …. To determine the ability of risk analysis modelling to mitigate the limitations of NPV modelling and the pertinence of the ‘planning fallacy’ effect for container terminal investment decision making.

1.4 Significance of the study

This research will model the full spectrum of potential NPV outcomes for the project analysed, using risk analysis modelling. Container terminal investment valuations are extremely complex and difficult projects to forecast due to the multitude of diverse and complex variables at play and their various degrees of correlation which is often completely ignored. The investigation will aim to provide an innovative perspective for the complete risk profile of the selected container terminal project.

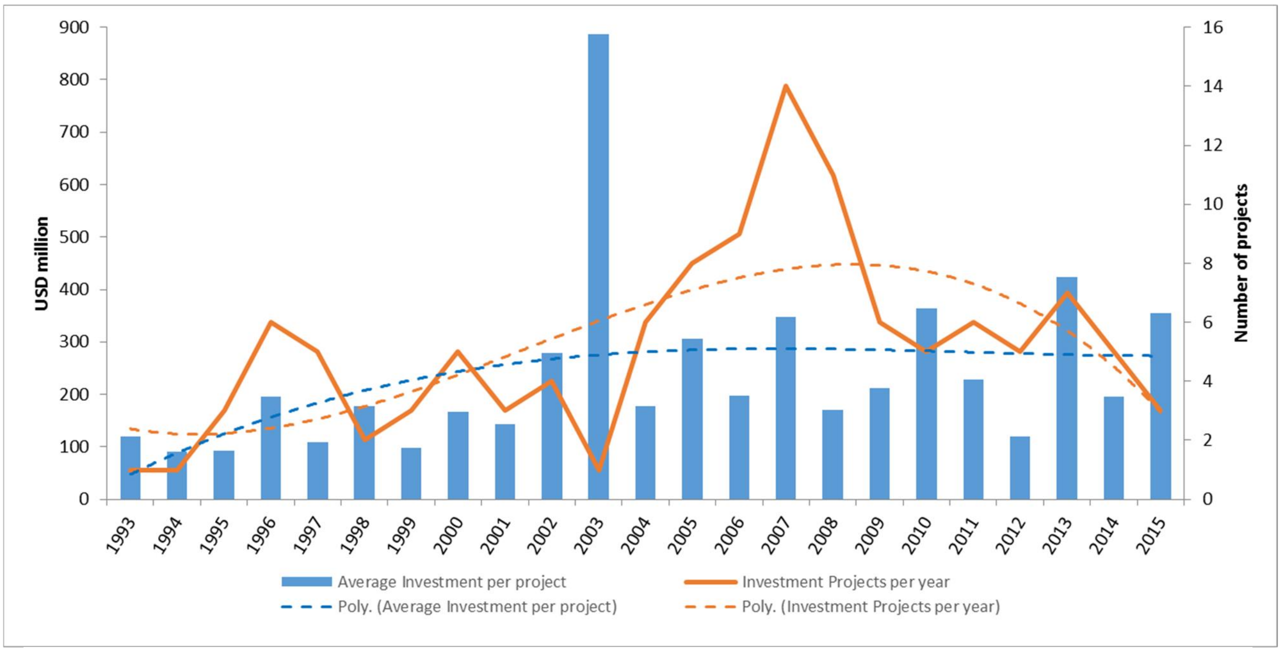

Figure 1 **Maritime terminal investments** *(World Bank, 2016)*

The findings of this study are intended to be most notably relevant for key investment decision makers in the specialisation of maritime terminal development. As the competition between container terminal developers over the past few decades been exponentially increasing as the number and feasibility of potential locations/opportunities declines (see Figure 1).

There is a gap for this form of insight in determining the feasibility and probability of potential container terminal projects. It is the intention that the development of the model and its subsequent findings will not be limited to the container terminal development sector, as learnings could be transferable to other maritime terminal development projects i.e. oil & gas, bulk and multipurpose, which experience similar primary causes of uncertainty.

1.5 Delimitations

- This paper will be delimited to focus solely on the selected project in the container terminal sector of the maritime industry.

- The basis of the assumptions management used to quantify the project input variables will not be changed or modified from the assumptions used for the original case decision, in order to enable just accurate comparison with the original investment decision based on the NPV outcome.

- The original case’s discount rate only included systematic risk in the discount rate used and the unsystematic risk (project specific risk) was rather accounted for by its static cash flow estimates. Therefore, this study’s stochastic model will focus upon the variability and uncertainty regarding the DCF model’s input variables (cash flows) and will not adjust the original discount rate (the rate will be assumed to be reasonable and accurate which only includes systematic risk).

- This research will be delimited to only use NPV as the determinate of success, other financial investment decisions theories will not be modelled and calculated as the original case decisions basis used NPV as the determinate of project attractiveness (positive NPV would equal an attractive project).

- Other strategic reasons will be ignored as a basis for decision making i.e. competitor sabotage, decision to maintain monopolistic status etc.

1.6 Definition of terms

Table 1 **Definition and explanation of terms**

CAPEX	Capital expenditure
Container terminal	For the context of this paper, this refers to a shipping terminal which loads and offloads containerized cargo from container vessels, consisting of the infrastructure and superstructure.
DCF	Discounted Cash Flow
Deterministic model	"A deterministic model predicts a single outcome from a given set of circumstances" (Taylor & Karlin, 2014).
FFE	Forty-foot equivalent unit. This describes a 40-foot shipping container, when determining a terminal through put, it is counted as two TEU
Green field project	A project where a company develops its operations in a foreign country which requires the building of all infrastructure from the ground up.
NPV	Net Present Value
Stochastic model	"A stochastic model predicts a set of possible outcomes weighted by their likelihoods, or probabilities" (Taylor & Karlin, 2014).
Superstructure	"Includes all the facilities aimed at loading and unloading ships, and moving goods to and from other modes of transport" (African Bank, 2010).
TEU	Twenty-foot equivalent unit. This is the description of a 20-foot shipping container, and is used as the global standard for describing throughput of a port terminal.
Throughput	A measure of volume denoted by the amount of TEU which a container terminal handles per year.
WACC	Weighted Average Cost of Capital is the company prescribed rate of return used to discount future cash flows to calculated the NPV of the project.

1.7 Assumptions

- This research will be unable to verify whether input data has been modified from the original NPV model used for the decision basis. The research will thus assume *bone fide* data and case provided is *de facto*. As it is not in the interest of the company concerned to alter or modify input data and information, as the findings of this research can only stand to better inform their future decision basis'.

- The simulation and its consequential analysis will assume no abnormal events such as, 'acts of god' will occur during the project lifetime. The probability of an 'act of God' event occurring is naturally extremely rare, and there is no proven method to forecast or even 'somewhat' accurately model the occurrence for projects of this nature. In addition, the financial effect of an 'act of God' would be immense and thus could skew the findings and dilute the effectiveness of this research.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The need to ensure the enduring success of a container terminal project far supersedes that of the financial performance for the respective investing company concerned. These projects have a major irreversible effect on the environment and the local community (Brooks, Pallis, & Perkins, 2014). Container terminals greatly impact the economic development of the surrounding area and the hinterland it feeds (Ho & Ho, 2006) and in turn the national economy, therefore container terminals have the ability to either significantly constrain or enhance the country's capacity of trade. For these reasons, company decision makers need to ensure that they have duly applied just and exhaustive reasoning in their basis for decision, for all container terminal projects, as an ill-conceived decision will also cause great negative effects not only for the company but the country and its constituents.

For a thorough opinion to be formulated, regarding the ability of an appropriate risk analysis model to enhance the selection basis for container terminal investment decisions, a suitable foundation of understanding needs to be established from a detailed review of literature.

The following literature review will investigate, present and contrast the paramount theories and leading opinions dealing with the various aspects of container terminal investment decisions. The core topics which will be covered are;

- The uncertainty of container terminal investment variables
- The 'planning fallacy' effect on large infrastructure projects
- The limitations of NPV modelled decisions
- The application of risk analysis models for Container Terminal projects

2.2 Definition of topic

Decisions for container terminal investments have to be based upon accurate and well informed financial models and risk assessment, in order to understand the key variables and the associated level of risk. This study will determine the ability of the appropriate risk modelling to enhance this decision basis, and seeks to identify the key focus variables for the selected container terminal investment case, which can be used in future similar investment decisions.

2.3 The elements of uncertainty for a container terminal green field project.

Risk management literature encompasses much debate regarding the distinction between uncertainty and risk in projects. There is much argument whether the majority of risks facing a project can be fully and accurately quantified using statistical data, as nearly all business decisions regarding risk have an element of informed opinion, degrees of belief and professional judgement (Loosemore et al., 2006). This is visually demonstrated by Figure 2, where “risk is at the ‘assessable’ end of the continuum where there may be statistical data to produce an evaluation whereas uncertainty is at the ‘less assessable’ end where evaluations will need to rely on informed opinion” (Loosemore et al., 2006, p. 9).

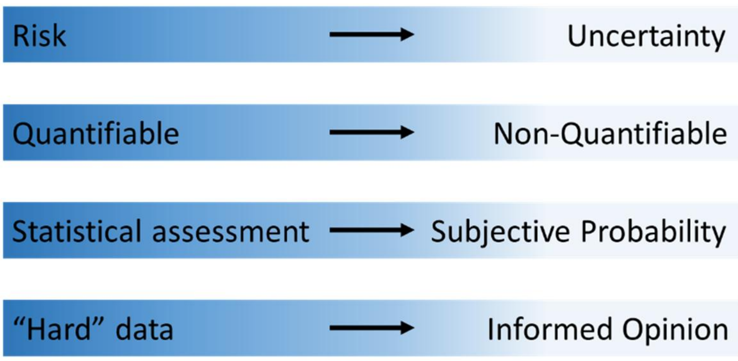

Figure 2 **The risk-uncertainty continuum** *(Loosemore, Raftery, & Reilly, 2006)*

Risk for projects of this nature can be viewed as the volatility which is derived from the uncertainty where the actual results are worse than planned (Irwin, 1997). In order to simplify this matter, for the purposes of this study, it will adopt Loosemore et al. (2006, p. 10)'s all-encompassing definition of risk which includes uncertainty; "a potential future event which is uncertain in likelihood and consequence and if occurs could affect the company's ability to achieve its project objectives"

The underlying source of the high level of uncertainty regarding container terminal investments, predominately stem from the long expected economic life of the project which ranges from 20 years to 100 years in some conditions (Wiegmans, Ubbels, Rietveld, & Nijkamp, 2002) and the very limited alternate uses for the infrastructure and superstructure (Banister & Berechman, 2000, cited by (Acciaro, 2004). The payback period for these projects is also very long, generally being between 15 and 30 years (Wiegmans et al., 2002) all of which pushes up the overall risk factor of the project.

However, there are arguments that, in comparison of other infrastructure investments, the factors reducing the overall risk of container terminals actually outweigh the factors enhancing the risk level (Farrell, 1999; Wiegmans et al., 2002) but it must be noted that these opinions are based on terminals in Europe which offer different concerns versus that of emerging markets where the vast majority of opportunities exist.

In order to effectively discuss the various risk aspects related to the project in question, it must be determined how the various variables should be categorised. The projects risks can be categorized according to their source criteria commonalities. Using this approach, risks for large-infrastructure projects can be broken down into nine categories; revenue, technical, construction, regulatory/political, operating, environmental, financial, force major, and project default (Chapman & Ward, 2003; Kerzner, 2013). More specifically for port infrastructure projects the risk categories are further defined into six categories; technical, revenue, construction, financial, operating and other risks (OECD & ITF, 2015).

Based on the prior input, this paper will discuss the various risks using the following categories; construction, technical, revenue, political, operating, and other risk.

2.3.1 *Construction risks*

No two container terminal projects are alike, as they are characterized by different geographic, technical, environmental and social conditions (Wiegmans et al., 2002). Even building and operating the same terminal design with similar customers, still present vast disparities in setup and operating climates from country to country. This presents the problem that it is extremely difficult to apply the learning from past project mistakes to other projects (Wiegmans et al., 2002), adding to the risk element of the project.

Container terminals require large amounts of capital investment and in most cases high loans have to be acquired which can be at high interest rates (Wiegmans et al., 2002) due to the size of the loan required and the uniqueness/uncertainty of the project. Furthermore, these projects require an extremely long period from when the initial capital payment is made until the first 'dollar' of revenue is received, this is due to the long construction time required for green fields. Further increasing the risk, is that interest and other costs continue to accumulate during this protracted period of zero revenue.

Due to the irreversible and illiquid nature of the infrastructure, if the project for any reason has to be cancelled or discontinued, this would result is substantial loss of capital (Wiegmans et al., 2002) and could spell the end for the company as a whole.

2.3.2 *Technical risks*

A container terminal's infrastructure is indivisible in nature, meaning that they cannot quickly adapt to changes in, therefore the infrastructure should be designed with minimum requirements in order to meet potential demand (Hidalgo Gallego, Núñez-Sánchez, & Coto-Millán, 2015).

This 'lumpy' nature of port terminal investments means that capacity can only be added in large units due to the nature of the physical infrastructure required in order to meet upward changes in demand. This is because capacity expansions take time, being further complicated by decision-making, financing and construction complexities which inhibit the agility of the business. Therefore it is extremely difficult to match capacity with demand, thus inevitably resulting in prolonged periods of either under or over capacity (Brooks et al., 2014).

Seasonality of demand is one of the biggest risks for container terminals, which creates the problem of either building excess capacity to deal with spikes in demand but then presents a great opportunity cost for an extended period of low demand. Or design a terminal to handle a reasonable consistent level of demand, but then encounter the high probability of congestion, inefficiency costs, generating reputation issues and potential loss of customers/throughput. These factors encourage overcapacity in terminals (Hidalgo Gallego et al., 2015), which increase competition between terminals to fill their idle capacities in times of low demand.

Additionally, for shipping lines the key determinate for container terminal selection is based on quick turnaround times (Haralambides, 2002) i.e. productivity and efficiency, as the request from shippers is for more frequent services and faster transit times (Farrell, 1999 cited by (Acciaro, 2004). Price is a lessor factor as shippers pass this cost onto the consignee (end customer), this aspect in turn greatly contributes to the growing excess capacity in the sector (Haralambides, 2002). Terminals also create excess capacity as a form of limit pricing to discourage new competitors from entering their market (Haralambides, 2002), in order to maintain their oligopolistic or monopoly position.

2.3.3 *Revenue risks*

Container terminals operate a relatively simplistic business model. Revenue is primarily generated by container volumes handled by the terminal, the greater the throughput the greater the revenue. The secondary source of revenue which is largely dependent upon throughput volumes, is derived from storage fees charge per TEU at a daily rate and other auxiliary container services. Therefore, forecasting container throughput is the key determinate for all the other lesser revenue streams.

According to Drewry (1998) as cited by Acciaro (2004), factors that have the greatest bearing on throughput volumes are:

- The growth rate of the container trade routes which could utilise the target terminal, where a low risk terminal's trade routes typically experiences growth of above 10% per annum Drewry (1998) as cited by Acciaro (2004).
- The strategic investment plans of neighbouring ports.
- The element of competition in the market, derived from the capacity and productivity from the neighbouring terminals.
- The effect the terminal will have the traffic and congestion of the inland road and rail networks.
- The hinterland transport infrastructure's ability to aid or limit the terminal's attractiveness to cargo owners and shipping lines.

By nature of the project, the flow of revenue streams generally only start many years after the initial investment (in comparison to alternate investments), additionally container terminals are exposed to extreme volatility and the associated rapid changes occurring in the economy and industry (Wiegmans et al., 2002). All of which increases the overall risk level for the project.

The problem posed by trying to predict the future demands for long-term projects is wide-acknowledged (Brooks et al., 2014). This is further compounded for container terminal projects. The projects volume projections need to be based on the actual demand not the designed capacity of the terminal. The capacity must be dependent on the forecasted demand, adding to this, a strong opinion must be formulated regarding the efficiency of the operation, as this will determine if the designed capacity is achieved (Brooks et al., 2014).

Forecasted demand can be deduced from overall analysis of global shipping trends and regional economic development. This process would be further enhanced by disaggregating the regional and local economic development factors (Brooks et al., 2014). Local drivers of container demand can be provided with greater levels of accuracy by examining the volume demand of the overall region versus the current capacity provided, rather focusing on the capacity limits within the target port (Brooks et al., 2014).

As seen by the 2007/2008 recession, which saw record drops in global trade, many shipping lines and container terminals were severely hit, as the prior ‘bubble economy’ where globalisation was driving bullish global trade, very few focused on scenario testing for capacity building investments (Brooks et al., 2014). Now the industry is showing far more concern for the ‘what if’ scenarios but very few players are using model simulations to accurately assess this issue.

Demand forecasts need to examine alternate scenarios in order to test the effect of different overall rates of trade growth and economic development (Brooks et al., 2014). This will aid in identifying the periods in which capacity limits will become critical.

2.3.4 *Political risks*

Container terminals require vast amounts of governmental interactions, and the waiting period for government feedback and item approvals, is relatively out of the control of the private company, as the time required for political decision making generally always exceeds expectations. These formalities and delays result in major additional costs for the project (Wiegmans et al., 2002) through plan/design amendments, material price increases, cost of capital, idle man power and forex exposure.

Political risk can be created when governments change policies after the investment decision has been made (Acciaro, 2004). Changes in labour requirements have been noted in many countries, this could have a large impact of the projects variable costs and quality of labour (Irwin, 1997). Adjusting the taxes and royalties, is a major consideration as these are rarely adjusted downwards, causing major impacts into the profitability of the project as market conditions mostly do not allow for sudden adjustments in container terminal pricing. With a change in government leadership and/or the ruling party, governments may impose different government participation requirements in shareholding, which can change the strategic direction for the terminal (Acciaro, 2004), all of which will dramatically move the projects actual performance away from the investment decision’s forecasts.

2.3.5 *Operating risks*

Compared to the huge amount of capital investment required and the high portion of fixed operational costs, the relatively low level of operational (variable) costs, enact an additional increase in the risk of the project (Wiegmans et al., 2002).

Congestion is a major operational limiting factor for attaining forecasted throughput, this results from the seasonality of trade, as trade volumes are not evenly distributed throughout the year. Terminals benefit from economies of scale up to the point of 70% utilization (Brooks et al., 2014), above that point diseconomies of scale kick in. Furthermore, congestion increases the risk of cargo owners and shipping companies being incentivised to relocated their business to more efficient terminals. This adds to the projects capacity modelling dilemma, of what is the ideal fixed capacity of the terminal in order to yield the highest return on investment?

2.3.6 *Other risks*

There have been many examples of terminals which have been delayed due to opposition from the local inhabitants (Acciaro, 2004). While projects managers do consider this risk and put in place well planned strategies to mitigate this risk, the uncertainty of people and their actions can never be fully mitigated. Even a very small group of individuals can cause severe project delays even if their protest is unfounded or misplaced. But the overall attention from local communities and municipalities can also help alleviate this risk element, as the container terminal brings many positive economic factors to the area's inhabitants, which is highlighted by the fact that typically it is the local authorities that provide the majority of subsidies to promote investment , compared to the central government (Farrell, 1999).

Due to the size and location of container terminal projects, there are a multitude of environmental concerns which can stop or delay a project. These concerns can have major influence on the sustainability and the feasibility the project (Acciaro, 2004). Although these risks are mostly addressed in the design phase of the project therefore would be known prior to the final capital commitment (Drewry, 1998, as cited by Acciaro (2004)).

If the terminal is mandated by authorities to set its pricing in local currency, this exposes the terminal to exchange rate risk. As equipment is mostly imported and the majority of the investment is funded from outside the country (typically in US dollars), this creates additional risk as the revenues are collected in local currency (Acciaro, 2004). For emerging markets, where the majority of new container terminals are being developed, this exposes the project to high levels of risk as, historically emerging markets currency is infamous for high levels of volatility.

2.3.7 *Proposition 1*

Container terminal projects are prone to a variety of uncertainties and conditions which shows the extreme difficulty in selecting static cash flow input estimates, as they can never incorporate the true level of uncertainty, therefore it would be imprudent to base a decision upon only using static variable inputs.

2.4 The ability of risk analysis modelling to mitigate the limitations of NPV modelling and the pertinence of the 'planning fallacy' effect for container terminal investment decision making.

2.4.1 *Planning fallacy in large projects*

The ideology of planning fallacy was first introduced by Kahneman & Tversky in 1979, Flyvbjerg (2007) concisely explains this term as the action where project planners base their decisions, regarding project inputs, upon delusional optimism instead of applying rational logic based on probabilities and weightings of gains, where the term is interchangeable with that of optimism bias. By overestimating the benefits and underestimating the costs of the project, decisions are made upon a skewed reality where projects rarely produce the desired outcomes.

Flyvbjerg (2007) argues that while planning fallacy may be unintentional and does occur in reality, more concerning for projects is that of strategic misrepresentation.

As discussed previously, for container terminals there is a high level of uncertainty regarding the model input variables and the opportunities for new projects are fast diminishing, all of which means that these projects are very prone to the element of planning fallacy through unintentional actions and/or through the more sinister strategic misrepresentation in order to 'grow' the executive's portfolio.

2.4.2 *The limitations of NPV modelled decisions*

For capital projects it must be determined, if choosing to invest will create economic value for the company, the DCF analysis is most commonly applied theory today for large capital investments (under uncertainty) (Pietz, 2011). The value of a 'risky' project is determined by calculating the NPV of its future cash flows, which is are discounted at discount rate appropriate to the risk level of the project (Brealey & Myers, 2000) . The basic guideline for decision making is to go ahead with all positive NPV projects and reject those less than zero (Pietz, 2011).

Decisions based on deterministic DCF models have the major drawback that they are based on static point estimates for the various project input variables, which provide no information regarding the uncertainty of the resulting future cash flows and subsequent NPV outcome (Pietz, 2011).

To overcome this limitation, the NPV model can use risk analysis to help assess the robustness of the NPV outcome, these include; sensitivity analysis, scenario analysis and simulation analysis (Pietz, 2011). In Ryan and Ryan (2002) and Graham and Harvey (2001) survey's, as cited by Edner and Paulsson (2014), which showed how often companies make use of these three forms of analysis, they found that companies who always used sensitivity analysis to be 20.5% vs 51.5%, companies that always used scenario analysis to be 10.5% vs 26.6% and for simulation analysis only 3.1% vs 13.7% made use of this approach. Even though their percentages differed (due to the slightly different focus of industries and regions), their weighting's distributions still agreed, showing that simulation analysis is the most underutilised form of analysis.

While the former two can provide some insight, they are extremely limited in the ability to provide a vivid picture of the probabilities for the uncertainties and their associated impacts.

Sensitivity analysis provides a view of which variables the project is most sensitive to, and those that could be potential ‘project killers’, but it does not account for the combined effects of variables and the correlations among the input factors (Pietz, 2011). Additionally it does not provide any insight into the probability of a change in each respective variable (Gallagher, 2012).

Scenario analysis attempts to model various different events, typically in the form of three situations best, base and worst case. This form of analysis is quite rudimentary as the analyst or executive would choose the base case variable movements, either to the best or worst reasonable level and only examines a few possible situations compared to the thousands in reality. Furthermore, it provides no analysis as to the probability of each scenario and ignores interrelations between project input variables (Pietz, 2011)

2.4.3 *The application of stochastic modelling for Container Terminal projects*

Monte Carlo simulation is one form of stochastic modelling, which is the term used to describe the process of performing repeated random sampling in order to produce a probability of the output of interest (Pietz, 2011). For the purpose of this paper’s investigation, ‘Monte Carlo simulation’ is be used to describe this method.

The method involves taking the primary deterministic model, in this case the DCF model, and running the calculation thousands of times, but for each iteration, the models input variables are changed within the specified assumed range and within the variable’s respective probability (Pergler & Freeman, 2008).

The use of Monte Carlo simulation for *quantitative* risk modelling is not new, as it was presented by David Hertz in 1964. Hertz (1964) put forward the notion that typical capital budgeting techniques (DCF), are extremely inaccurate for projects with moderate to high levels of uncertainty, as each input variable’s assumed uncertainty is belittled by being forced to use a static point estimate, which could either be conservative or optimistic. This is further compounded when all the assumptions are taken together and thus could multiply into a state of complete uncertainty. Many have agreed that for projects which face uncertainty, the DCF analysis alone is inappropriate and Monte Carlo simulation is an ideal method to improve decision making accuracy (Clark, et al., (2010); Kelliher &

Mahoney (2000); French & Gabrielli (2004)) as cited by (Edner & Paulsson, 2014), especially for projects that are too complex to be simply described by rudimentary calculations (Kritzman, 1993).

Additionally decision makers have no basis other than instinct and gut feel when deciding between two project with similar NPV outcomes, Monte Carlo simulation provides the required insight by being able to present the different probability NPV distributions and thus take a more informed decision (Pietz, 2011).

Research by Bock and Trück (2011), found Monte Carlo simulation to be a key risk analysis tool which is able to expand the attributes of the static and limited DCF modelling, by being able to provide a long-term risk-return profile for large investment projects, like container terminals. Which is in line with what Kwak and Ingall (2007, p. 49) previous findings, which showed that simulation modelling is “an extremely powerful tool when trying to understand and quantify the potential effects of uncertainty of the project”. Although Monte Carlo simulation cannot deliver a clear accept or reject decision outcome, the benefit gained from the increased insight into the probability distribution of outcomes is invaluable.

As discussed previously container terminal projects are synonymous with high levels of uncertainty therefore decision makers would be naïve to base decisions solely on deterministic DCF modelling. Therefore, Monte Carlo simulation could provide the additional insight in order to avoid possible high capital exposures and due to the severe shortage in potential locations/projects, companies can better analyse those projects which their traditional deterministic models showed to be not investment worthy, in order not to miss a potential opportunity in disguise.

2.4.4 *Proposition 2*

Deterministic DCF modelling alone is not a suitable basis for decision making for container terminal investments, informed decisions which mitigate ‘planning fallacy’ needs to be made through additional insight gained from a Monte Carlo simulation which provides superior risk insight when compared to sensitivity and scenario analysis.

2.5 Conclusion of Literature Review

Container terminal projects are plagued by a multitude of uncertainties regarding the majority of the input estimates. This creates the situation where the deterministic financial model (DCF) used could in fact produce any outcome, which can be further influenced by the planning fallacy effect. This means that underlying financial decision basis for the investments accept or reject decision can very easily be vastly different to the eventual performance of the project.

This process leaves the project extremely susceptible to the specific project manager's (model builder) personal view of the project, as one would be able to sway the NPV result of the project by selecting static point estimates which one deems most appropriate. Unfortunately, when the project is in turn presented for a Board decision, due to time constraints and the limited project specific knowledge held by the board members, there is little to no vetting done on each of the models static input estimates. Therefore, a decision is made without being able to fully appreciate the level of risk associated with the NPV outcome presented.

DCF modelling alone is not enough to safe guard a project against the various uncertainties and 'planning fallacy' effect. The investment decision requires additional risk analysis to enrich the decision basis. Sensitivity and scenario analysis do somewhat identify the various risks and quantify the potential impacts, but the problem remains that both methods use static point estimates. These two methods cannot demonstrate the plethora of possible future realities, rather the realities are selected by the financial modeler, thus still being extremely susceptible to the 'planning fallacy' effect. This opens the door for Monte Carlo simulation to provide the requirement for a complete view of the projects potential (NPV) and the associated risk level included in each outcome.

2.5.1 *Proposition 1*

Container terminal projects are prone to a variety of uncertainties and conditions which shows the extreme difficulty in selecting static cash flow input estimates, as they can never incorporate the true level of uncertainty, therefore it would be imprudent to base a decision upon only using static variable inputs.

2.5.2 *Proposition 2*

Deterministic DCF modelling alone is not a suitable basis for decision making for container terminal investments, informed decisions which mitigate ‘planning fallacy’ needs to be made through additional insight gained from a Monte Carlo simulation which provides superior risk insight when compared to sensitivity and scenario analysis.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research methodology / paradigm

3.1.1 *Research paradigm*

Research papers typically adopt either *positivism* or *constructivism* as the guiding paradigm for the study (Bryman & Bell, 2015) where the underlying assumptions of each paradigm are differentiated based on their respective theoretical terms of *ontology* and *epistemology* (Edner & Paulsson, 2014). The study's assumed paradigm of research must be identified, as this allows for further enrichment of understanding from the end analysis of the paper and gives clear insight into the mode of thought as to how the findings were derived.

The positivist paradigm revolves around the notion that an objective reality is independent to ourselves (Bryman & Bell, 2015), where observed real events can be explained through logical analysis (Kaboub, 2008). This is the paradigm which most closely lends itself for the empirical studies of the various theoretical financial models through mathematical inquiry (Edner & Paulsson, 2014).

This is extremely applicable to this study, as the analysis of the various risk elements and financial decision basis, is derived from mathematical simulation not subjective inferences. As this paper focuses upon the analysis of a project through Monte Carlo simulation, the selection of *positivism* as the paradigmatic lens which this study is conducted through, is determined to be the most appropriate to this form of study.

3.1.2 *Research methodology*

In order to adequately answer or develop founded opinions regarding the research question, the researcher must select the applicable research method, which is either *quantitative* or *qualitative*.

The *positivist* paradigm is commonly associated with *quantitative* research method which uses the *deductive* form of reasoning in its application, where the aim of the research would be to revise current theories or generalizable theories based upon the studies new data which is tried against the respective hypothesis' (Edner & Paulsson, 2014).

In contrast, the *qualitative* method is commonly associated with the *inductive* reasoning approach where through empirical observations the researcher develops the theory (Bryman & Bell, 2015).

The purpose of this paper is to gain quantifiable insight and understanding of existing theories regarding the elements of uncertainty and enhancement of accurate decision making for green field container terminal projects. Monte Carlo simulation provides the ability to quantify uncertain variables impact and their respective probabilities. Therefore, considering this papers intention and it's adopted *positivist* standpoint, the *quantitative* approach is deemed the most suitable method of inquiry.

3.2 Research Design

This paper utilised a single project investigation approach in order to effectively analyse the ability of the Monte Carlo simulation tool to enhance container terminal investment decision making. The primary motivating factor behind this decision, is that by using an actual project instead of a wide sample, the reader will be able to gain a much deeper form of understanding into the subject at hand compared to rather than a handful of superficial analyses (Edner & Paulsson, 2014). For research with the aim of developing knowledge and insights regarding a single situation, case methodology is deemed to be the superior approach (Baxter & Jack, 2008). Additionally, for the purpose of a comprehensive analysis regarding the differences of a particular situation, i.e. in this case a specific container terminal investment, the single project investigation approach is also considered to be the most relevant and ideal.

By using an actual business case and its financial model, this study duly gains credibility for not only its application but also its ability to provide valuable insight into the selected project, rather than to merely creating a generic Monte Carlo model for container terminal investment decisions. As discussed previously, although Monte Carlo simulation is known by many executives very few actually make use of it for decision making, therefore by applying the simulation to a real project, executives will be now able to shift their perception that the simulation only has a place in academia.

3.3 Selected project

The project used for this research was provided by a company who is an international container terminal developer and operator. The study is based on a single container terminal business case created by the company for an actual terminal investment decision. The company asked for all data to remain confidential and the input cash flow data was changed by an appropriate factor in order to ensure confidentiality. The adjustment factor used did not skew the data, all proportions were kept true to the original input data.

3.4 Procedure for data collection

This study makes use of data which is *quantitative* in nature. The data was obtained from primary sources at the company which provided the case.

3.4.1 *Quantitative data collection*

The company provided the actual DCF valuation model which it used for its decision-making basis. The model was supplied in *Excel* format and included all the static input estimates for the deterministic model's input variables. The model's inputs were categorized into the following sections:

1. Capital investment schedule
2. Revenue
3. Fixed operating costs
4. Variable operating costs
5. Discount rate

By the nature of the deterministic model, all input data is a static estimate and provides no insight regarding the how the final input number was determined. The Monte Carlo simulation requires a viewpoint on each input estimates probability distributions and their correlation to other input variables (if any).

Therefore, in order to acquire this vital information, a discussion was conducted with the project manager of this respective case at the company. The discussion took the form of an informal interview, where each of the model's input variables were questioned as to ascertain the respective probability distribution and correlation of each input variable, as per the project's underlying source data and company's amassed intellectual property.

3.5 The research instrument

In addition to the DCF model provided by the company which included the relevant data inputs, some additional quantitative data was required. Thus, the task of the research instrument was to gain additional information which was not explicitly stated in the primary *quantitative* data provide (the actual business case).

The informal discussion only involved the respective case's project manager, as he had all the required information at his disposal and was the person in possession of the most accurate and valid information. The questions followed the same format for each input variable and were repeated until all input variables had been assessed (see Appendix A regarding the question format).

3.6 Data analysis and interpretation

After all the required data had been collected via the *quantitative* approach, the Monte Carlo simulation model was built.

Step 1: Setup Basic Model
Step 2: Defining Input Probability Distributions
Step 3: Defining Correlations
Step 4: Defining Output Variables
Step 5: Simulate Model

The model sought to generate output in NPV terms, for all iterations ran (10,000). The NPV results are presented in a probability distribution. Using the probability distribution, interpretations were made regarding the applicability of the original investment decision based on the deterministic NPV model. Here the original investment NPV was compared to the simulations expected value of sum distribution, in order to highlight the frailties of either the determined over optimistic or conservative approach when deciding on static cash flow input estimates. The analysis then sought to show either possible opportunities which were missed or raise items of concern.

3.7 Limitations of the study

- Monte Carlo simulation is heavily reliant upon the quality and accuracy of the input data, the classic notion of GIGO (garbage in, garbage out) is extremely pertinent for this method. Therefore, in order for tangible and reliable inferences to be made, the quality of input data is paramount, but due to the extremely high level of uniqueness related to each container terminal project it is almost impossible for an outsider to effectively ratify the models input estimates and assumptions.

- The researcher was unable to verify the true accuracy of the probability distribution information provided by the company project manager. Incorrect identification of probability distributions could severely skew the end NPV probability distribution, which would thus greatly skew the formulation of any inferences and opinions.

3.8 Validity and reliability

3.8.1 *External validity*

As this research used a specific DCF valuation model from one company, for one of its projects of a container terminal project, the external validity of the research is limited regarding the findings of the investigation. Although the methodology can be applied to other project investigations in the maritime terminal sector, as their base of uncertainties are very similar. Disregarding the specific uncertainties identified, the underlying model and methodology can be applied to any investment decision.

3.8.2 *Internal validity*

The research set out to determine the appropriateness of Monte Carlo simulation for container terminal investment decisions compared with traditional DCF/NPV analysis and other risk modelling. The methodology undertaken by this paper sought to result in a high level of internal validity as the Monte Carlo simulation was conducted and duly compared with the original NPV outcome and decision. Therefore, providing the basis to analyse the core purpose of the research.

3.8.3 *Reliability*

Based on the data collection procedure and the data which was required to be collected, if the study was to be conducted again, the reliability would hinge upon the consistency of data collected from the project manager. The project manager would need to be constant in the other studies. But as with all human interactions, human error may slightly modify the data which was originally provided regarding the probability distributions and respective correlations.

In order to ensure reliability, the project manager was given due notice and was advised regarding the type of information required. This gave the project manager time to go through the project data files and consult key stakeholders, in order to be duly prepared to provide accurate input, based upon the true assumptions and information used by the project team at the time of the investment model formulation.

3.9 Ethical considerations

3.9.1 *Avoidance of harm*

The outcome of the study may highlight an incorrect decision made by the company or possible incompetence of the company's project manager. All of which may lead to negative consequences for the project manager as a result of this paper.

As this paper's objective was purely to analyse a business case from an academic viewpoint rather than discovering the fault of any entity, the following measures were enacted to mitigate this unintended consequence. The company's name was kept anonymous, the project name was omitted by the company before being shared with the researcher. The results of the study will only be shared with the company's project manager only upon his request, the project manager can thereby seek to share the results further internally at his discretion.

3.9.2 *Due care of information*

The researcher is mandated to ensure due care in the storage of the company's data. Any leak of information may result in possible loss of a competitive edge and/or loss of a project bid.

The mitigation of this possible consequence was as follows. The researcher changed all company specific data to ones of anonymity. The researcher was mandated under contractual agreement to ensure the security of the company information. Furthermore, the company or project manager held the right to withdraw their data if they suitably deem that their information shared was at risk, which forms part of a direct breach of the confidentiality contract signed between the researcher and the company.

CHAPTER 4. PRESENTATION OF RESULTS

4.1 Introduction

This chapter presents the results of the investigation for an actual container terminal investment decision. In order to thoroughly determine the ability of Monte Carlo simulation to mitigate the shortcomings of NPV modelling and the element of 'planning fallacy', it describes the container terminal's original DCF model's NPV result based on its static inputs. The deterministic DCF model is then used as the base to model the sensitivity and scenario analyses.

The identified key uncertain input variables are then presented along with their respective resultant maximum, minimum, most likely value, probability distribution type and for cases of normally distributed variables, the relative standard deviation. These upper and lower limits of the key uncertainties are then used for the sensitivity and scenario analyses and these results are presented accordingly.

After which, the project is analysed using a Monte Carlo simulation, where the model output (NPV) is based upon the various probability distributions of the input variables rather than the deterministic DCF model's static input variables.

Finally, result summaries pertaining to each of the propositions proffered in chapter 2, are presented along with the respective proposition's conclusion.

4.2 Original project valuation

The container terminal's original valuation was based solely upon a deterministic DCF financial model. The basis for an acceptable project, is one which delivers a positive NPV i.e. any rate of return greater than the company's required rate of return (discount rate). The result of the deterministic NPV valuation was based upon using the original model's *most likely* static input values for all the project's uncertain variables. The subsequent NPV result is for the *most likely* future outcome in terms of the company's outlook, and is the quantifiable result which the company used for its project approval decision.

The DCF model produced a positive NPV result of USD 332,000 for the container terminal project based on the company's discount rate of 14,51%, thus the project should be approved based on the quantitative model outcome.

4.3 Key input variables

The project's key input variables' static values and the associated ranges presented below, were sourced from the company's DCF model's underlying dataset and company information. The quantitative data points were compiled using the information known to the company at the time of finalising the original DCF valuation, no new information or developments were considered to ensure the integrity of the study's result.

The following subsections will identify and explain each key input variable's composition.

4.3.1 *Civil CAPEX*

The civil CAPEX which was estimated by the company included the numerous infrastructure developments which were required by the project, these included; dredging, demolition, quay construction, buildings, road and rail.

Table 2 **Civil CAPEX**

(USD million)	**Min**	**Most likely**	**Max**	**Distribution**
Civil CAPEX	51	58,8	75	Triangular

Table 2 shows the most likely, minimum and maximum values sourced from the company's underlying project assumptions and records. The values range, accounts for the risk of material price fluctuations as well as delays resulting from environmental, human and/or political impact. The distribution is *triangular* in nature which is skewed to the right, as the upper and lower limits are defined by the company's civil contracts with its suppliers. It must be noted that the original deterministic DCF model used a static value of USD 61,5 million as the civil CAPEX estimate, this included a 4,5% contingency which was used as a buffer to account for cost overrun risk. Therefore, taking out the risk factor, the most likely cost is forecast as USD 58,8 million.

4.3.2 *Throughput (volume)*

The forecasted throughput in the terminal's first year of operation can never be guaranteed, but through customer contract commitments, the number can be identified with a certain level of confidence. The below table portrays the company's estimated first year throughput.

***Table 3* Year 1 Throughput**

	Most likely	Relative σ	Distribution
Year 1 TEU Throughput	150,000	7%	Normal

The volume estimated for the first year of operation is 150,000 TEUs, as this input is indeed uncertain and could vary equally up or down, its probability represents one of *normal* distribution with a relative standard deviation of 7%.

4.3.3 *Tariff increase and inflation*

These inputs are largely unknown variables as there are many forces at play which affect its development. Hence both are *normally* distributed and the company estimated both to have a relative standard deviation of 8%.

***Table 4* Tariff increase and inflation**

(% per year)	Most likely	Relative σ	Distribution
Tariff increase	2,5%	8%	Normal
Inflation	5%	8%	Normal

These two variables are also positively correlated, as there will not be a tariff increase in years of deflation.

4.3.4 *Volume growth multiplier*

The DCF valuation, models volume growth as a multiple of the respective GDP growth rate for each year. The deterministic DCF model estimated this to be at a constant multiple of 2 for every year throughout the project's life time. In reality this multiple will vary in line with a *normal* distribution, company information found this to be with a 10% relative standard deviation, shown in Table 5.

***Table 5* Volume growth multiplier**

	Most likely	**Relative σ**	**Distribution**
Volume growth multiplier	2	10%	Normal

4.3.5 *Other revenues*

All revenue yielded from the auxiliary container services offered, were categorised under *other revenues*. Services such as container unpacking, customs examinations, container repairs etc. Based on similar container terminals and historical data, the company used the most likely estimate of 10% of the standard container services revenue. This variable is especially difficult to forecast, with equal probability of returns being above or below the estimate, thus the relative standard deviation was determined as 15% for a *normal* distribution, seen in Table 6 below.

***Table 6* Other revenue**

(% container revenue)	**Most likely**	**Relative σ**	**Distribution**
Other revenue	10%	15%	Normal

4.3.6 *Concession fee*

The deterministic DCF model took the slightly pessimistic perspective that the opening concession fee offer of 45% of revenue would stand. However, similar projects in the same country signed for a hard-negotiated concession fee of 42,5% while best practice in the region states that the fee should not exceed 46%. Thus, a *triangular* distribution was applied for this uncertainty with a most likely value of 45%.

***Table 7* Concession fee**

	Min	**Most likely**	**Max**	**Distribution**
Concession fee	42,5%	45%	46%	Triangular

4.3.7 *GDP growth rate*

The forecasted GDP growth rate of the country is a key uncertain variable for the project, as the growth rate of the country is one of the primary factors affecting the container terminal's throughput development, each year's GDP growth rate is *normally* distributed with a relative standard deviation of 10%, showing equal probability of swings up and down. Table 8 shows the various forecasted (most likely) GDP growth rates per year of the project's life which were sourced from the World Bank's country GDP growth dataset.

***Table 8* GDP growth rate**

GDP growth rate	**Most likely**	**Relative σ**	**Distribution**
2016	7,6%	10%	Normal
2017	6,7%	10%	Normal
2018	7,7%	10%	Normal
2019	9,1%	10%	Normal
2020	8,0%	10%	Normal
2021	7,0%	10%	Normal
2022	6,5%	10%	Normal
2023	6,0%	10%	Normal
2024	6,0%	10%	Normal
2025	6,0%	10%	Normal
2026	6,0%	10%	Normal
2027	6,0%	10%	Normal
2028	6,0%	10%	Normal
2029	6,0%	10%	Normal
2030	6,0%	10%	Normal
2031	6,0%	10%	Normal
2032	6,0%	10%	Normal

4.3.8 *Repairs and maintenance*

All equipment used in the running of the container terminal requires regular repairs and maintenance. The company has predetermined limits for the annual costs per equipment type, which are expressed as a percentage of the equipment's new cost price. For the various equipment/asset types the upper and lower limits are known, but the probability of distribution varies between *triangular* and *uniform* distribution types. Table 9 below presents the various determined distributions.

***Table 9* Repairs and maintenance**

(% of CAPEX)	**Min**	**Most likely**	**Max**	**Distribution**
RTG cranes	1,8%	2,0%	2,5%	Triangular
Senneborg cranes	1,8%	2,0%	2,5%	Triangular
Existing MHCs	3,6%	4,0%	6,0%	Triangular
Reachstackers	6,3%	7,0%	8,0%	Triangular
Terminal Tractor	6,3%	7,0%	8,0%	Triangular
Computer + IT	6,0%	7,0%	9,0%	Uniform
Empty Container Handlers	4,5%	5,0%	6,0%	Triangular
Fork Lift Trucks	6,3%	7,0%	7,7%	Uniform
Trailers Single	1,8%	2,0%	2,5%	Triangular
Others	4,0%	5,0%	6,5%	Uniform
Civil infrastructure	0,18%	0,20%	0,25%	Triangular

4.3.9 *Average staff cost*

The total labour or staff cost for the container terminal is based upon an average staff cost for all employees. The most likely value is USD 1,800 per headcount but in execution this can vary within the limits of company hiring policies, hence this forms a *triangular* distribution with minimum and maximum values shown in Table 10.

***Table 10* Average staff cost**

(USD/person)	**Min**	**Most likely**	**Max**	**Distribution**
Average staff cost	1,700	1,800	2,000	Triangular

4.3.10 *Selling, General and Administrative expenses*

These expenses were estimated from similar projects, but with a relatively medium to low level of confidence. Costs are estimated per annum and show a *normal* distribution with a relative standard deviation of 10%.

***Table 11* SG&A costs**

(USD/year)	**Most likely**	**Relative σ**	**Distribution**
SG&A	750,000	10%	Normal

4.4 Sensitivity analysis

The sensitivity analysis was conducted to determine which of the previously identified uncertain variables in section 4.3 had the greatest impact on the projects NPV output value. The process followed, was to keep all variables constant, and only altering the input values for one variable at a time. The resulting NPV output value for each identified uncertain variable was calculated using its minimum and maximum values for *triangular* and *uniform* distributions, while for *normally* distributed variables, the upper and lower limit values at one standard deviation from the mean (most likely) was used. This process was performed for all uncertain variables identified in section 4.3.

The results of the sensitivity analysis are presented below in a *tornado* chart, which graphically shows the eight variables which had the largest impact on the NPV output mean value. Each variables bar, shows both the largest positive and negative effect that the variable's minimum and maximum input value had on the NPV output mean value. The variables are shown in descending order, with the variable with the greatest impact positioned at the top of the chart. All other variables have been excluded from the graphical representation due to their comparative inconsequential effect on the NPV output value.

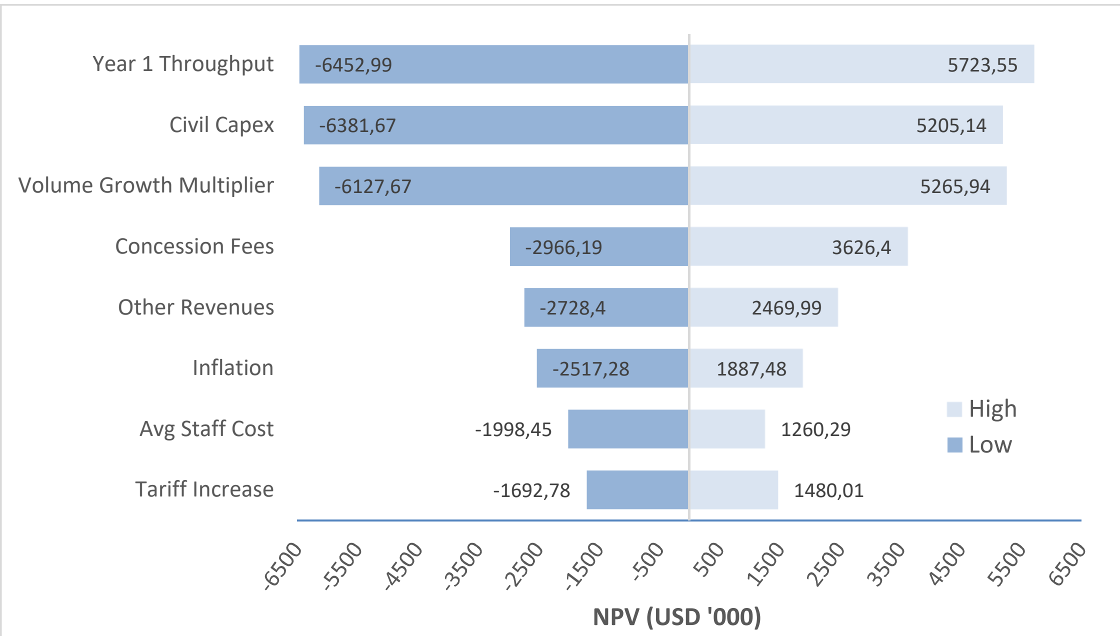

Figure 3 **Sensitivity Analysis of NPV** (Source: Own construction)

From Figure 3 it can be seen that the container terminal project is the most susceptible to deviations for the following uncertain variables; year one throughput, civil CAPEX and the volume growth multiplier, followed by concession fees, other revenues, inflation, average staff cost and tariff increase. The year one throughput variable was *normally* distributed with a relative standard deviation of 7% and the most likely volume of 150,000 TEU. Yet the 7% relative standard deviation resulted in this input variable proving the greatest risk input for the project's NPV output. Furthermore, the sensitivity analysis showed that all of the graphically illustrated variables in Figure 3 have the ability to alter the project's NPV output by a sum greater than the deterministic DCF model's output value of USD 322,000. This is only true if the conditions of the sensitivity analysis are held true for reality, as it is assumed that only the selected variable will vary, the analysis does not allow for other variables to vary in conjunction with the selected variable.

4.5 Scenario analysis

Basic scenario analysis creates three scenarios which produce a NPV output, they are the worst, base and best case scenarios. The worst and best case scenarios use the 'worst' or 'best' value for each of the identified input variables in section 4.3. From this an output NPV was calculated, while both scenarios are not likely to occur, they do produce the 'possible' extremities for the project. The base case is the original NPV output value which used the most likely values for all inputs. Table 12 shows the results of the 3 scenarios.

***Table 12* Full scenario analysis results**

	NPV (USD '000)
Worst case	-31 885
Base case	322
Best case	32 828

This form of analysis can be further refined by only adjusting certain select variables. The additional scenario analysis builds upon findings from the prior sensitivity analysis, where only the variables with the highest sensitivity are varied using the same logic as the scenario analysis above. These uncertain variables are; year one throughput, civil

CAPEX and the volume growth multiplier. The results of this scenario analysis are present in Table 13 below.

Table 13 **Select scenario analysis results**

	NPV (USD '000)
Worst case	-16 559
Base case	322
Best case	13 271

By only adjusting the largest three variables, the 'select' scenarios' NPV output value reduced by 48,1% for the worst case and 59,6% for the best case. Showing that the best case scenario is more vulnerable to changes in the selected three variables when compared to that of the worst case scenario's result.

4.6 Monte Carlo simulation

The simulation performed ran 10,000 iterations for the various uncertain variables as defined by the parameters set in section 4.3. Each iteration produced an output NPV value based upon the respective set of 'random' input variable's values. Table 14 shows the summary of the Monte Carlo simulation performed.

Table 14 **Monte Carlo simulation results summary**

	NPV (USD '000)
Minimum	-24 624
Maximum	23 897
Mean	-202
Iterations	*10 000*

The mean NPV of the simulation is USD -202,000, which is USD 524,000 less than the deterministic DCF model's output NPV of USD 322,000.

The simulation results are best presented graphically using a histogram chart, which shows the simulated outputs distributed by the probability densities. The results are illustrated in Figure 4 below.

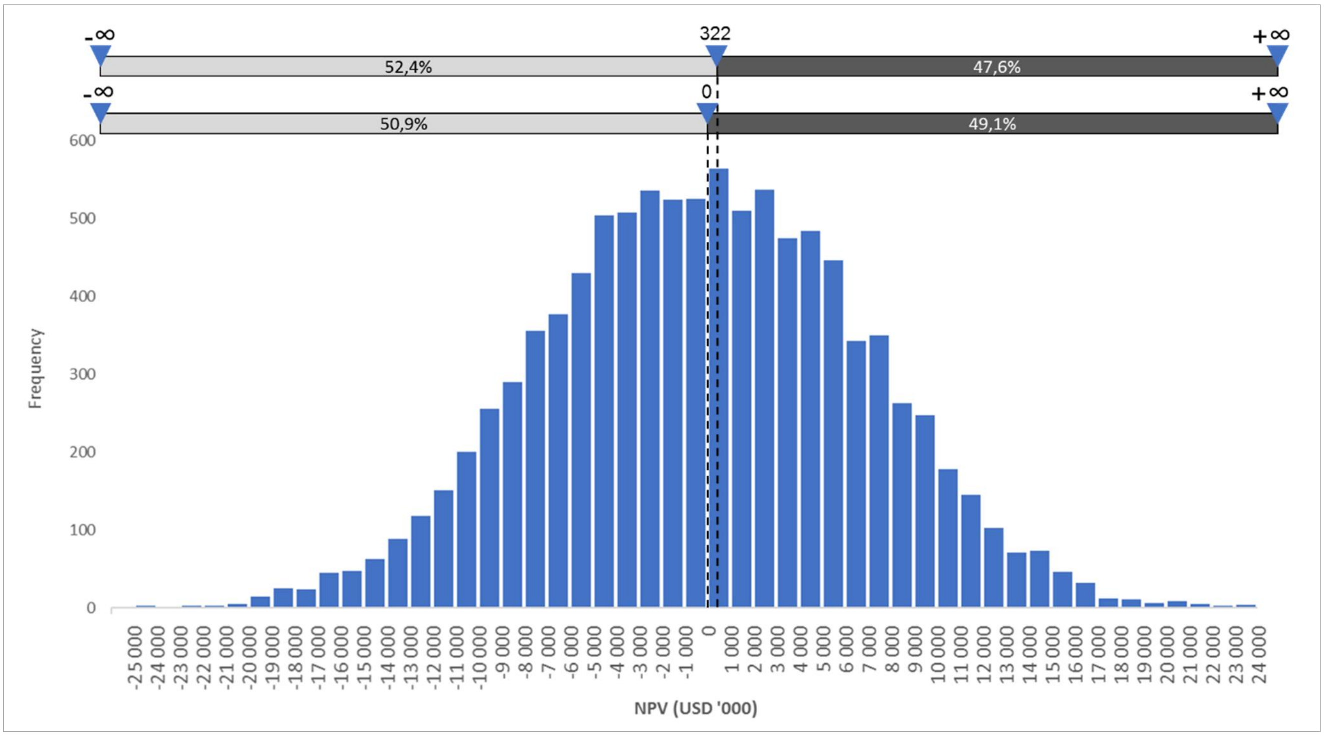

Figure 4 **Simulation NPV results**

The NPV approval criterion stipulates that only projects with a positive NPV should be approved, as these projects create economic value. The simulation showed that the project only has a probability of 49,1% that it will achieve a NPV of zero or greater. Taking the other perspective, there is a 50,9% probability that this project will destroy economic value for the company. The deterministic DCF model's NPV output of USD 322,000 has a lower probability of 47,6% that it will be achieved or better.

CHAPTER 5. DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter discusses the findings of the investigation into the container terminal project selected. By first examining the identified uncertain variables and the respective degrees of uncertainty, explanations are proffered for each variable under the subheadings of the risk categories identified in the review of literature. After which, results provided by the three modes of risk assessment are evaluated upon their respective abilities to mitigate the limitations of NPV modelling and the pertinence of the 'planning fallacy' effect for investment decision making.

5.2 Discussion pertaining to the uncertainty of the project's variables

The investigation into the source data and underlying information used to select the various static input values for each variable of the DCF model, revealed that although static values where indeed used, none were selected with complete confidence that they would come into fruition.

For the uncertain variables, the degree of influence the company has on the ultimate value varies, from some near fully within their control, to others which rely on many outside forces as identified in section 2.3 where the company has reduced influence, all of which contributed to the varying ranges and relative standard deviations of each variable.

Each of the material input variables investigated were found to have either a *triangular, normal* or *uniform* probability distribution. The nature of the probability distribution means that each possible value differs in nature for the respective distribution type. In the *triangular* distribution, when the variable approaches the minimum or maximum specified value the probability approaches zero, while for the *uniform* distribution the probability of any value within the specified range is equally possible. The *normally* distributed variables do not have a maximum or minimum value set, rather a relative standard deviation is specified. Thus, in circumstances with a probability of less than 68,27% (one standard deviation) the value may be greater than the respective maximum or minimum relative standard deviation.

The preceding analysis of literature identified six categories of uncertainty for container terminal projects, these were construction, technical, revenue, political, operating, and other risks. The following subsections will discuss the results using these six categories.

5.2.1 *Construction risks*

The deterministic DCF model's input value for the CAPEX included a contingency factor of 4,5% which already attempted to quantify and include the uncertainty of this variable. Upon further analysis of the variables elements regarding the complexities of the geographic and environmental conditions, it showed that the cost estimates provided by construction firms were not fixed, as clauses allowed for upward and downward movement in the final costing, which agrees with the findings of Wiegmans et al. (2002) that construction costs are extremely difficult to predict due to the varying underlying conditions relating to each infrastructure project.

The underlying data for this variable showed the range of possible outcomes to be within USD 51-75 million, from the most likely input of USD 58,8 million, the ultimate cost varies from 27,6% above and 13,3% below the most likely value. More concerning is that the *triangular* distribution is skewed in favour of a value higher than the most likely value. As the largest cost category, it calls for concern that the real uncertainty of this variable can be 'hidden' by a single static point estimate in the deterministic DCF valuation.

5.2.2 *Technical risks*

As referred to in section 2.3.2, container terminal's infrastructure development is 'lumpy' in nature, meaning that extra capacity can only be added in large sections due to the size of the civil works required. This is also true for equipment purchasing, especially for large costly assets such as mobile harbour cranes. Both the civil design and equipment infrastructure requirements, depend on the capacity requirement of the terminal.

The project's deterministic DCF model used a static maximum physical capacity of 750,000 TEUs per annum for the entire project life. Any additional civil capacity additions would require a separate business case and DCF model in the future. The ideal container terminal size of 750,000 TEUs was identified as the most cost effective size based on construction estimates. Therefore, this variable was fixed and certain for the purposes of analysis.

The second element of the CAPEX is that of equipment, while the civil capacity of the terminal was fixed, the equipment make up could be determined by the volume throughput per annum. The DCF model took this correlation into account in its formulae, meaning that the equipment required and purchased for year one of operations was the minimum required for the most likely year one volume estimate of 150,000 TEUs, as the projected volume grew year on year (YoY) so too did the equipment requirement, based on the company's and industry equipment/capacity productivity ratios.

The identified ability of the deterministic DCF model to somewhat account for over capacity, using correlation of equipment requirements to yearly volumes and by selecting 750,000 TEUs as the most cost effective size of terminal to initially build, provides a mitigating solution to the issue matching capacity with demand highlighted by Brooks et al. (2014).

While the capacity risk mitigating function of the deterministic model is sound, it is completely reliant upon the volume input variable.

5.2.3 *Revenue risks*

As the review of literature revealed, a container terminal's revenue is the primary function of two inputs, volumes and tariffs.

The primary input value of the projects year one forecast volumes is critical for the project's revenue development, as this is the base upon which the volumes grow YoY. The deterministic DCF model incorporated two secondary drivers which determined the development of the volume value YoY, they were the growth multiplier and the GDP growth rate. The estimated year one of operation's volume was deemed most likely to be 150,000 TEUs, which then grew YoY at by a factor which was determined by the multiplication of the growth multiplier and the forecasted GDP growth rate for the respective year, which is in line with the view proposed by Brooks et al. (2014) to focus upon local demand rather than physical capacity when forecasting volume.

A concerning notion that was discovered, is that although the volume input variable is critical for the NPV outcome, none of the three input drivers (year one volume, volume growth multiplier & GDP growth rate) are certain. All three were found to have *normal* probability distributions with 7-10% relative standard deviations. Therefore, for cases of a small positively correlated deviation in all three variables, there is a sizable exponential net effect on the project outcome.

Although the deterministic DCF model was able to incorporate further inputs to determine the ultimate volume value YoY, the volume figure remains dependent upon variables of high uncertainty. Thus, by selecting a static point estimate for each variable dramatically compromises the validity of the final NPV outcome, by essentially 'hiding' the underlying risk in these static value estimates.

Another large input to the project's revenue comes from the auxiliary services offered. The DCF model used the fixed factor of 10% of container revenue as the static input value for each year of the project. As container revenues grow so too does the other revenue value with the same fixed proportion. The value of 10% was determined from aggregated historical data of similar terminals in the company's portfolio. This premise contradicts Wiegmans et al. (2002)'s learnings, where prior projects performances are very seldom applicable for new projects as each country differs in nature. The limitation of the deterministic DCF model to not incorporate other input drivers to determine the ratio used to calculate the other revenue figure is concerning, as in reality no container terminal produces the same ratio YoY. The investigation found that the figure of 10% was the average from a historical sample of projects, thus it was used as the most likely value, but it was acknowledged that this value could easily fluctuate within the past projects range of values. Thus, a *normal* distribution was shown as most appropriate with a relative standard deviation of as high as 15% to incorporate the sizeable fluctuations YoY.

5.2.4 *Political risks*

The various political risks of the country where the project is positioned can have many material knock on effects for the project's outcome. The deterministic DCF model incorporated the variables of concession fee and GDP growth rate which took this risk factor into account.

As discussed in the preceding section, GDP growth rate is a key determinant of the volumes forecast and thus the project's revenue development. The political policies, initiatives, development and stability all play their roles in the GDP development of a country. The GDP growth is outside the control of the company and thus management's ability to ensure volumes achieved during the project lifetime is further limited. The data used in the deterministic model was sourced from the World Bank's country GDP forecast, while the source is reliable as an institution, the historical accuracy of forecasting country GDP growth rates varies considerably from country to country. By analysing the historical GDP forecasts vs. actuals, the company deemed the forecast to be uncertain and thus it was deemed a *normal* distribution with 10% relative standard deviation most applicable.

The limitation of the DCF model resulted in this possible variation being unable to be incorporated, thus the forecasted GDP per year was used as per the World Bank's estimate. This is concerning for a project with a modelled lifetime of 17 years, for there is no allowance for the effects of changes in political policies and agendas which critically contribute to a fluctuating GDP growth rate, agreeing with the notion proffered by Acciaro (2004) that political risk arises when there are changes in policy after the investment decision is made. The previous section 5.2.3 commended the deterministic DCF model's ability to incorporate secondary drivers in the determination of the volume value for each respective year, but the after analysis of the GDP growth rate driver, which shows high levels of uncertainty, the reliability of the final volume input value falls into disrepute.

5.2.5 *Operating risks*

Brooks et al. (2014) identified the main point of concern when operating a container terminal is that of congestion, where a terminal enjoys economies of scale up to the point of 70% utilisation (2014). For situations where utilisation is greater than 70%, this results in rapidly rising operational expenses without material increases in productivity. The deterministic DCF model included this risk by placing limits on the volume development to never exceed 525,000 TEUs per annum (70% of capacity). While this adheres to the point raised by Brooks et al. (2014) in concept, the execution may be more complicated. Seasonality is the point of concern, as container volumes are not constant throughout the year. For any given year, the total annual volumes might not exceed the yearly throughput capacity limit of 525,000 TEUs, but at certain times the terminal may experience containers on the ground which exceed the 70% utilisation 'limit'. This results in operational risk, as costs will exceed those forecasted even though the terminal did not exceed the annual forecasted volumes of 525,000 TEUs. This follows the logic that operational lost time comes at a high cost, i.e. if a day or week is lost, as a result of severe weather or strikes, the operation cannot then still achieve the targeted throughput without exceeding normal utilisation limits, thus exceeding projected normal operational costs. Although through proactive management, operational costs can be reduced in times of low throughput, the possible savings do not mirror that of the possible cost overruns in times of high throughput. This explains and provides insight into the data which showed that operational cost items such as; the respective repair & maintenance percentage estimates and average staff cost per annum, showed skewed distributions towards the upper cost limit for the respective probability distributions. Deeming that while the most likely values used in the DCF model are indeed possible, the static values do not incorporate the true nature of a container terminal's operation, where cost overruns are more likely than cost savings for operational expenses.

5.2.6 *Other risks*

From the review of literature, there were several risk elements that were discussed in the 'other risks' section. A common theme was that of delays, which could arise from action taken by local inhabitants or other members of society and/or through environmental issues raised. The project's deterministic DCF model somewhat incorporated this risk under the umbrella of a contingency added to the quoted civil CAPEX cost. The logic behind this was that preliminary geotechnical field studies and community engagement strategies had already been commissioned and subsequently executed. These measures were completed as a prerequisite for the project to enter the financial modelling stage and thus final submission for approval, therefore are sunk costs borne by the company and not part of the projects financial decision basis. The measures are assumed to mitigate the risk of delays over and above the portion covered by the CAPEX contingency.

The determination of the probability distribution for this risk element was unable to be accurately determined by one distribution, as the risk of delay will in itself not cause a cost increase, but rather its negative effect will be visible in many of individual cost variables. Therefore, the delay risk factor contributed to variables of civil CAPEX and asset purchase price, being skewed towards higher prices. The analysis showed that delays are near impossible to accurately account for in financial modelling, even when applying the ill effects to only those variables directly affected, one still is unable to accurately forecast its possible range of impact.

5.2.7 *Conclusion: Proposition 1*

The investigation showed that for the container terminal's input variables used in the deterministic DCF model, all had a range of possible values and static variable values could not be forecasted with unwavering confidence. Thus, while the logic and data used as the basis of selection for each static value of the DCF model was indeed comprehensive, a single point estimate cannot encapsulate the varying degrees of risk encountered for the respective variables. The use of a deterministic financial model alone will not suffice for an exhaustive green field container terminal investment decision.

5.3 Discussion pertaining to the benefits of Monte Carlo simulation

As previously discussed in section 2.4.2, DCF modelled decisions are critiqued for its sole reliance upon static single point estimates, where a variable's uncertainty behind each of the point values is in effect hidden by each point estimate. For in the final execution of the project, the ultimate figure can assume a range of varying values. The findings from section 5.2 agrees with this notion and argues that suitable risk assessment must be performed in addition to the base DCF model. To this end, risk analyses were conducted using the identified methods of sensitivity analysis, scenario analysis, and Monte Carlo simulation (stochastic modelling).

5.3.1 *Sensitivity analysis*

It was shown in section 2.4.2, that past studies found that sensitivity analysis is the most common risk assessment tool used in conjunction with an NPV valuation model. The analysis performed identified and presented the input variables whose input values had the greatest effect on the project's NPV outcome, when the input value was set at its most upper and lower limit. Critically, when calculating the resulting NPV effect of using the upper and lower value per variable, there is no consideration as to the probability of the upper or lower value occurring.

The analysis found that the project was most 'sensitive' to the variables of; year 1 throughput, civil CAPEX & the volume growth multiplier (see Figure 3). While this is indeed an 'useful' insight when taken on face value, one needs to first understand the mechanics behind these results.

The first point of contention relates to the upper and lower value used per variable in the sensitivity analysis' calculation. The investigation previously found that the project's variables had either *normal, triangular* or in only three variables, *uniform* distributions. The sensitivity analysis does not take the different types probability distributions into consideration, it assumes all variables have a *uniform* distribution. To explain, the problem is that when one approaches the upper or lower limit value of a variable with a *triangular* distribution, the probability of the value's occurrence moves towards zero. Therefore, the sensitivity analysis produces results where the input value used is known to be near impossible.

The second issue is that the analysis assumes variables vary in isolation. There is no insight into the net effect on the project if more than one variable varies in conjunction. This is a very naïve stance, as reality is very unlikely to play out in a similar fashion.

Analysing the results of the project's sensitivity analysis showed that the top three 'project killer' variables all had the individual ability to shift the project's NPV to below -USD 6 million and above USD 5 million, comparing this to the original projected NPV of

USD 322,000 it seems to belittle the analysis as the deviations border on the level of a illogical reality. No tangible insight is able to be extracted from the results, apart from the fact that changes the above three variables can either single handed sink or catapult the project's profitability forward. This agrees with the propositions put forward by Pietz (2011) and Gallagher (2012), as the analysis is empirically flawed by ignoring insights into the probability of the variable values used in the calculation.

This study notes that sensitivity analysis is able to determine and portray the key 'sensitive' variables for the project. Thus, from a board decision perspective, those big items should then attract the greatest focus. Then the respective assumptions behind each 'project killer' should be further ratified and vetted by the decision makers as they are able to see that if these big items are not accurate, then NPV is effectively unusable. But this process requires using personal logic and one's personal appraisal of the probability for each item. The question in the interested of efficiency is; is it the role of the decision makers to then take a personal assumption upon the respective risk of each identified key variable, if so, how can decision makers effectively quantify these risks for the big items?

This paper contends that a prudent decision cannot be drawn from the sensitivity analysis results alone, as decision makers are only able to view which variables present the highest individual risk to the project's outcome. Thus, decision makers can only attempt to ensure they are in agreement with static value used, but as literature showed, one cannot perfectly forecast a future point value. One's skills, insight, logic, historical evidence and knowledge can at best specify a range of possible values rather than a static point value, thus this paper reasons that the risk assessment model must address this fundamental issue.

5.3.2 *Scenario analysis*

One of the vulnerabilities of sensitivity analysis was shown to be its inability to varying the inputs of more than one variable at a time. Scenario analysis seeks to mitigate this shortcoming by altering several variables to either their best or worst 'possible' value as deemed by the respective distributions, thus creating three scenarios; the best, worst and base cases.

Although scenario analysis exhibits another point of concern, by using the best or worst possible values for all variables, the scenarios created are far removed from reality. The problem encountered for the sensitivity analysis for variables with a *triangular* distribution is now exponentially worse, as the scenario analysis used all *triangular* distributed variable's best or worst values in combination. Where it was previously shown that these values actually have near zero probability of occurring, thus the scenario analysis creates realities which are far removed from reality. Therefore, the results were only able to show the 'possible' extreme outcomes of the project. Table 12 presents the range of outcomes to have a spread of USD 64,7 million. This figure provides little comfort for a decision maker as the spread is so large that little inference can be gained from it, except for pure joy or pure fear, depending if one's outlook is delusional optimism or pessimism.

By building upon the findings of the sensitivity analysis, the scenario analysis' results can become more meaningful in nature. The results from the select scenario analysis in which only the top three variables from the sensitivity analysis were alter, provided better insight into the project's risk. The spread of was reduced to USD 29,8 million, but more meaningful was the difference in the resulting imbalance between upside vs. downside NPV results, the project was shown to be weighted towards the downside (worst case) as the result produced the greatest absolute value (see Table 13). This should raise concerns for decision makers but without any data comparing the probability of each scenario, the decision will still fall heavily upon the decision maker's perception and opinion, which Flyvbjerg (2007) warned is still very susceptible to the element of 'planning fallacy'.

As with sensitivity analysis, scenario analysis builds upon the fundamental flaw of using the projects extremity values for all value distribution types, thus assuming all variables are *uniformly* distributed, where the investigation showed that this is not the case apart from three variables. Couple this with the inability of the analysis to provide any tangible insight into the probability of each scenario occurring, it renders the analysis ineffectual for exhaustive and prudent decision making.

5.3.3 *Monte Carlo simulation*

All projects are beset with the element of uncertainty in the identification of input variable values. Previous researchers have proffered Monte Carlo simulation as the tool to mitigate the shortcomings of the two risk assessment tools previously discussed. By rather specifying the project's input variable's values as a probability distribution versus using static single values, project specific risk is thereby accounted for in the valuation. This is done without having to incorporate an input variable's risk into single point estimates, which typically means selecting conservative input values to cover any possible risk, this results in providing a stunted view of the projects true potential. Conversely the element of 'planning fallacy' means over optimism is often hidden in point estimates for input variables, leading to over estimation of a project's potential. By removing both positive and negative bias from the model, Monte Carlo simulation seeks to provide a clear impartial perspective of a project's potential.

The performed Monte Carlo simulation found that the project's mean to be USD -202,000 which was USD 524,000 less than the original NPV valuation (see Table 14). Comparing this to the original valuation which showed a NPV of USD 322,000, therefore was originally deemed a viable positive investment case which should be approved and implemented as per the NPV decision criterion. But the results of the simulation found that an 'accept' decision may not in fact be the most prudent decision.

Based on the simulation performed, the project had a 47,6% probability of achieving the initial NPV outcome of USD 322,000 or greater. This is a very powerful insight, because previously when the board would have been presented the business case which showed a positive NPV of USD 322,000, they would duly have had high confidence that this project is indeed attractive and would produce an economic profit, as they had no other basis to challenge the result. Although the board would have considered the results of the sensitivity analysis and scenario analysis, but both analyses showed extreme upsides and downsides, as is common for the majority of these analyses' results, rendering their usefulness extremely limited.

Therefore, the results of the Monte Carlo simulation introduce an interesting dynamic to the project decision, for it could now be deemed imprudent for the board to have the same opinion of the business case, as one which was solely based on the original NPV outcome and the associated sensitivity and scenario analyses. This additional insight provided by the Monte Carlo simulation brings colour to a previously black and white decision, which is key for the mitigation of ‘planning fallacy’ in project valuation.

Adding to the decision basis is the finding that the project only has a 49,1% probability of creating economic value (positive NPV), meaning that without substantial positive management intervention throughout the life of the project, there is a 50,9% probability that this project will erode monetary value for the company.

‘Planning fallacy’ is a result of input variable estimate manipulation via unintentional optimism or in more sinister cases through strategic misrepresentation. As shown basic DCF models cannot show whether the input variables used are accurate and true or have been influenced by the element of ‘planning fallacy’ and are thus extremely susceptible to this risk.

The findings from the study showed that Monte Carlo simulation was able to provide superior insight into the projects true potential. The insights found followed that of two central themes; the simulation’s ability to enhance the quality of variable input estimation and the simulation’s aptitude to effectively communicate project risk for decision making.

i) ***Variable value estimation***

Deterministic modelling only requires a single static value per uncertain variable, which are selected using a combination of historical data, quotations and company knowledge. The company expects that the actual final variable’s point estimates will vary to some extent from the estimated value. The issue here is that variation is not required to be quantified, thus providing latitude to the financial modeller and project team, as the degree of reasonable deviation is subjective in nature.

As with the deterministic model, Monte Carlo simulation is not immune the principal problem where a model’s outcome is only as good as the integrity of its input data, thus any enhancements to the vetting process of the variables inputs is critical for the project’s valuation accuracy.

For a Monte Carlo simulation, the requirement to first determine the appropriate probability distribution type, and then select the absolute limits for *triangular* and *uniform* distributed variables, puts due pressure on the project team to perform exhaustive due diligence for variable estimates, as there are clear targets which they will be measured upon after project implementation. This creates an environment of accountability, no longer can estimates be casually inserted into the model. The added benefit gained through the increased level of accountability, is to also help mitigate the risk of 'planning fallacy', as estimates can be closely scrutinised and later measured, an individual's ability to influence the outcome of a project valuation is thus further deterred.

For effective Monte Carlo simulation to be performed more resources are required in terms of the project team headcount. The process demands substantially more time to adequately determine and extensively vet variable estimates. Furthermore, project team members will need to have a firm understanding of core statistical concepts and methods, in order to duly model the variable's distributions. While the required investment of company resources is indeed greater for the proper use of Monte Carlo simulation for investment analysis, the cost becomes inconsequential when compared with the ultimate cost of a bad project implemented based on inferior input data and risk assessment.

ii) ***Project risk communication***

Without Monte Carlo simulation, a decision maker has to rely on personal reasoning and experience to determine the riskiness for a project presented. This skill varies significantly from individual to individual, and can only be ratified many months down the line. By graphically representing the projects NPV outcomes and associated probabilities as shown in Figure 4, executive's thinking regarding risk is quickly aligned, allowing for more pertinent topics of discussion relating to the investment decision, rather than arguments surrounding the NPV outcome's formulation. The project investigated showed that the inherent risk of the project was substantial, with below 50% probability of the project yielding a positive return. Based upon the company's board approved risk appetite, the investment decision would thus be allowed to be made with a consistent understanding of the projects risk among all decision makers. It is this identified ability of the simulation to quantify and simply portray the potential effects of project risk which sets it apart from deterministic modelling agreeing with the findings put forward by Kwak and Ingall (2007).

5.3.4 *Conclusion: Proposition 2*

By not being able to quantify project risk, there is inadequate evidence to show that the use of deterministic DCF modelling aided by sensitivity and scenario analysis can accurately encapsulate the project's level of risk.

The use of Monte Carlo simulation cannot mitigate all the limitations found in NPV modelling due the inherent risk regarding the quality of the input data provided and used. Nonetheless, the simulation's requirement to quantify variables value deviations into absolute probability distributions evokes accountability among the project team members upon the integrity of the inputs selected. This accountability further promotes exhaustive value estimation which aids the integrity of value inputs and in doing so limits the pertinence of 'planning fallacy' among project team members.

Furthermore, by graphically portraying the projects NPV outcomes along with the respective probabilities, decision makers cannot claim ignorance of inherent project risk when a poor project is selected and in due course fails, thus Monte Carlo simulation provides additional mitigating qualities to combat executive's overzealousness in project selection.

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

The concluding chapter of this paper presents a summary of the conclusions developed as a result of the performed investigation. The insight gained through the inquest process has afforded the development of select recommendations which are proffered for the benefit maritime infrastructure development professionals and alike. While developing this paper, several ideas for future research have been discovered, these are duly explained in the final part of the chapter.

6.2 Conclusions of the study

Container terminal projects like other large infrastructure projects are prone to a multitude of diverse risk elements. For the traditional DCF valuation model, risk is in effect embedded in each variable's input estimates, not only does this hide the underlying risks from decision makers, it potentially misrepresents a project's inherent complexities.

DCF valuation models are typically aided by the risk assessment tools of sensitivity and scenario analysis. While both have their merits where sensitivity analysis helps provide insight into the project's most significant variables and scenario analysis shows the mathematically possible extreme NPV outcomes, neither is able to provide insight into the probability of their calculated outcomes, thus essentially placing the onus of risk assessment on the decision maker's personal ability to view project risk.

While the previous research reviewed consistently agreed that a key limitation of DCF modelling was its inability to account for correlations between variable inputs, the project's DCF model analysed found this to be not entirely accurate. The DCF model used for this study was advanced and dynamic in nature, great attention had been placed to ensure that only a few variables were standalone static inputs. The financial model's formulae allowed for various correlations between variables in order to mitigate the possibility of a skewed reality being created. Monte Carlo simulation does provide the ability to correlate variables, but in the case which was investigated, the DCF model was found not to be limited in its ability to effectively account for the correlation between variable inputs.

Monte Carlo simulation is still by no means immune to the risk of ‘planning fallacy’, as its effectiveness relies upon the quality of its inputs. Under the requirements of the simulation, exhaustive due diligence is essential when determining each input variables range of values. This added focus and measurable output enhances the overall quality and accuracy of the models inputs, thus helping to mitigate the threat of ‘planning fallacy’. It is through the additional accountability created by the simulation’s requirement for well-considered and vetted inputs, the team of information providers are further dissuaded from substandard work and/or data misrepresentation. This does increase the resource requirement for the simulation’s creation, but a company would be imprudent not to approve the additional minor expense in order to circumnavigate a future exponentially costlier outcome.

The performed simulation calculated the NPV outcome based on 10,000 iterations where input variables vary as per their prescribed probability ranges. By performing Monte Carlo simulation in conjunction with the DCF valuation model, a relatively simple graphical representation of the project’s risk profile was developed. While the simulation’s output does not provide a clear ‘accept or decline’ result, it does portray the various probabilities for every NPV output calculated shown as a probability distribution. The provides the board a clear insight into the underlying risk profile of the project which the other risk assessment tools of sensitivity and scenario analysis could not effectively portray. By not having to solely rely upon NPV criterion as the decision basis, the board can assign additional probability criterions which a project must meet for approval e.g. a probability percentage that the NPV must be greater than zero.

The simulation for the project investigated showed a skewed probability distribution in favour of a negative NPV outcome which coincides with the notion put forward in section 1.2 where container terminal’s upside potential is limited by their volume throughput capacity (physical infrastructure). Additional the resulting mean NPV outcome from the simulation was below the original business case’s NPV result, which agreed with

Flyvbjerg (2007), that large infrastructure projects consistently and substantially show cost overruns versus the original estimate.

This investigation found that for effective risk assessment of a container terminal investment decision, the risk insight that Monte Carlo simulation creates, brings colour to a previously black and white decision basis.

6.3 Recommendations

Monte Carlo simulation is a well-documented underutilised tool in investment decision making, often casually passed over based an unsubstantiated prejudice. While this investigation showed that Monte Carlo simulation does required additional resources and increased statistical knowledge from the project development team to ensure its effectiveness, these 'costs' are immaterial when compared to container terminal investment projects which range from USD 50 million – 3 billion (World Bank, 2016). A container terminal elements of uncertainty are numerous and immense, thus making an investment decision with no quantifiable view of project risk is imprudent and could even be considered reckless, especially considering that performing Monte Carlo simulation is well within the abilities of all companies considering a container terminal investment.

As the viable opportunities for maritime infrastructure investment are ever dwindling, so does the potential risk of 'planning fallacy' by top management increase. Therefore, company decision makers must require Monte Carlo simulation to be included in business case appraisals, in order to alleviate any concealed overzealousness of its operational leaders.

6.4 Suggestions for further research

During the course of this paper's investigation some thought-provoking potential topics of additional research have come into the fray.

Monte Carlo simulation was found as a key factor which promotes an increased level accountability and focus when determining a project's input variable's values. It would be intriguing to study the accuracy of estimated input values, for a sample of projects with the benefit of hindsight. This could be done by comparing projects that used and did not use Monte Carlo simulation in their decision basis, which have already been implemented and in operation for more than a select number of years. This study would thus provide the quantifiable difference in investment variable estimation accuracy.

While DCF modelling together with the risk assessment tools of sensitivity analysis, scenario analysis and Monte Carlo simulation, provide the mathematical/financial data for which investment decision maker’s use to reach an approval decision, this paper’s review of literature noted that there are indeed other decision factors for maritime investments. Therefore, an interesting qualitative study would be to determine the level of focus maritime investment decision maker’s place upon the identified financial models and to determine the other predominant intangible factors which sway investment decisions.

As discussed in section 2.4.3, literature shows that Monte Carlo simulation’s application to DCF modelling is not a new concept as it was introduced in 1964 (Hertz, 1964), yet numerous other studies have found that it ranks as one of the least utilised risk assessment tool by companies. These findings seemingly contradict the findings of this paper’s investigation, which contends that Monte Carlo simulation become a compulsory requirement for infrastructure investment appraisal, as it was found to offer a superior ability in project risk assessment to other tools analysed. Thus, an intriguing area for future research would be to investigate the underlying reasons for company’s low level of adoption of Monte Carlo simulation as a key risk assessment tool in investment appraisal, within the select industry of maritime infrastructure. This study would be best suited to that of a qualitative inquiry.

Closely linked to the above paragraph, would be future research which seeks to determine the adoption level of Monte Carlo simulation for DCF based investment appraisal, across the various industries. The quantitative element of the study could best be performed by leveraging upon Monte Carlo simulation software company’s databases, such as *Palisade* who developed the @*Risk* simulation software *Excel* plug-in. Subsequently the predominant focus of the research would be to determine the key underlying qualitative reasons for the differing adoption rates between industries. By gaining this understanding, companies such as *Palisade* and alike would be able to better address those industries with low adoption rates through improved understanding of how to address their needs and/or creating alternate software to better suit these industries requirements. Furthermore, Monte Carlo practitioners and educators, would also benefit from this study by gaining insight into those industries that require Monte Carlo simulation services and/or training. Overall if more companies are making business and investment decisions based upon all the possible insights and information available to them (gained through the use of Monte Carlo simulation), then an assumption is that this should lead to improved accuracy of decision making, which would help to evade bad decisions which could have been avoided if they were exhaustively considered. Thus, improving the sum economic value of global business at a higher growth rate than of today.

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