Adaptive agribulk terminal planning in light of an uncertain future

Terminal Design Optimization

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Preface

This research has been conducted as part of my masters graduation from the Hydraulic Engineering faculty, at the TU Delft. The academic procedure leading up to this point has come with its challenges and I would like to use this opportunity to sincerely express my thanks to the many people that have provided me with their support and guidance throughout the process.

The research has been performed in collaboration with Martine & Transport Business Solutions (MTBS), a port consultancy firm based in Rotterdam, that has provided me with an excellent environment to conduct my work. Being able to brainstorm with colleagues that are very much into the day to day business of assessing terminals investments, ensures the research is in line with actual projects found throughout the world.

To start off, I would like to thank my professor, Mark van Koningsveld, for finding time within a busy schedule to sit together for extensive brainstorm sessions revolving around the development of the computer model used within this study. The sessions helped me to convert ideas into programmable concepts, while encouraging me to continuously scrutinize model results in order to ensure they were correct.

Furthermore, I would like to thank my co-supervisor, Cornelis van Dorsser for his unwavering support throughout my entire graduation process. Cornelis and I have sat together and thought about the concept of bringing finance and engineering together for quite some time before I started with this research. His extensive expertise in forecasting and his background in port masterplanning during his time at Royal HaskoningDHV has helped me to stay on track all these months.

In addition, I would like to express my thanks to my other co-supervisor, Dingena Schott. Dingena has helped me to ensure that the focus of this research builds on previous findings within our research field. With her research into dry bulk terminals and her expertise regarding terminal superstructure she has helped to finetune the findings within this research.

Finally, I would like to thank Ryan Cornelisse, my colleague and supervisor at MTBS, for guiding me through this extensive process. Ryan has helped me to formulate my goals and was always willing to reserve time to evaluate my progress. His experience with dry bulk terminals gave me the chance to bring academic literature and empirical business logic together, which I have always deemed an important component of this research.

Wijnand IJzermans

Rotterdam, February 2019

Executive Summary

Keywords

Dry bulk, traffic forecasting, grain terminals, marine terminal design, terminal design rules, construction costs, operational costs, demurrage costs, terminal investment strategy, project feasibility, terminal risk reduction

Summary

With agribulk trade trends pointing towards burgeoning global crop consumption, the expected volume of crops that are shipped all over the globe is expected to grow. This increase in maritime trade will have to be met with a wave of terminal development. This holds especially true in regions that can expect a strong hike in consumption in the near-term, driven by high population growth accompanied by an increase in welfare, such as sub-Saharan Africa. However, before such terminals can be developed, the underlying project will have to be proven to be feasible. This process consists of translating traffic projections into a terminal design, which is subsequently converted into a set of expected cashflows used to assess project feasibility.

This study focusses on modelling this translation from traffic projection to terminal design, which is referred to as a *work method*, and has analyzed the financial impact of various terminal design guidelines. Furthermore, as the timeline of such projects is in the order of decades, the terminal project will inevitably face many uncertainties. One of the uncertain factors that is of major influence on the project's feasibility is the traffic volume that will flow through the terminal. Both aspects have been investigated using a purposely developed computer model.

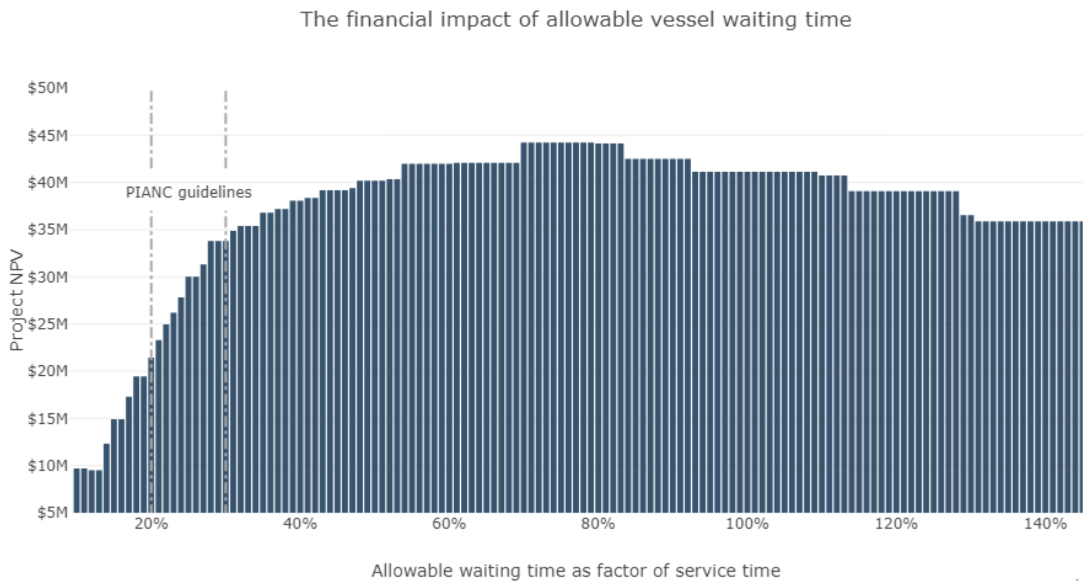
The computer model can translate traffic projections into terminal design in an automated fashion, allowing the user to analyse the financial impact of the individual, underlying design assumptions. It is important to note that this study makes a clear distinction between two aspects that make up a single design assumption; the first being the performance threshold which triggers an investment, e.g. '*if the average waiting time of vessels exceeds 30% of service time, expand unloading capacity at the quay*'. The second aspect is the temporal nature of this trigger; do we gauge the waiting time at this moment in time or do we base the trigger on a future, *expected* waiting time, allowing us to invest now so that the new asset is up and running once we need the extra capacity.

Literature provides high-level guidelines for what performance thresholds, referred to as *performance triggers* within this research, should be used to design a terminal. Despite their generalist nature, high-level design guidelines are an essential component in terminal feasibility planning. This is because stakeholders are often deprived of extensive and complete technical and economic data at early project stages. Using the developed computer model, an analysis was conducted to see if such performance triggers could be further optimized. All in all, the financial impact of investment triggers related to the development of the quay, the unloading equipment, the storage- and the loading facilities have been individually assessed.

This assessment was done by designing numerous terminals based on identical economic boundary conditions, while changing the underlying design assumptions ever so slightly after each model run. The resulting terminal designs were subsequently converted to a cashflow statement and compounded into a net present value, assumed to represent a terminal's project value. Cross-referencing the design assumption configuration with the resulting project value quantified the financial performance of individual design assumptions.

When examining the terminal's receiving operations at the quay, the average waiting time of vessels at the terminal has been identified as the key performance indicator on which investment decisions can be based. By monetizing the negative consequences of low-quality service at the terminal (i.e. long waiting times) using demurrage rates, the average allowable vessel waiting time has been optimized. Existing guidelines, published by PIANC, state that terminal investments are typically based on maintaining an average ratio of waiting time to service time between 20% and 30% for bulk terminals. However, results from the

computer model have shown that, if a terminal were to incorporate the notion of demurrage rates into its business model, waiting times could be allowed to rise to 70% of berth service time, unlocking significant project value. Allowing higher waiting times is especially beneficial in markets that show signs of high volatility.



When examining the design assumptions related to a terminal's storage facilities, it is clear that terminal operator will always want to minimize commodity dwell time in order to increase project value. Furthermore, results have shown that terminals boasting dwell times shorter than 10 days start to be bounded by the fact that they have to be able to accommodate the entire cargo of the largest vessel calling to port. In such cases, bypass systems which enable hinterland transport being loaded directly from the vessel may prove beneficial.

The final performance trigger which was analyzed was related to the loading bays for trains. But in absence of reliable daily train freight rates, this analysis remains inconclusive. However, results have shown that investments regarding the train loading bay do not weigh as heavily as investments related to quay or storage operations in respect to project feasibility. In the end, based on reference projects in eastern Europe, the loading bay was modelled using queuing theory and an assumed allowable train waiting time equal to 50% of service time.

Once the analysis regarding performance triggers was completed, the computer model was used to analyze the temporal nature of performance triggers. When modelling a terminal, should investment decisions be based on a terminal's *current* performance, or should investments be based on a terminal's *expected* performance given a certain traffic forecast? The financial performance of three work methods were compared, with each method having a different temporal setup for their performance triggers.

1) The first work method that was evaluated models investment decisions based on the notion of *perfect foresight,* a presumption that the traffic projections on which investments are based will always come true. This technique is currently seen as common practice, making it a good benchmark against which other work methods can be compared. By designing a terminal using a work method and then simulating how it would have performed financially, had it been built, allows us to assess the modelling method's accuracy regarding the estimation of project value.

2) The second work method that was evaluated bases its investment decisions on the performance of the terminal, gauged at the same moment at which an investment decision is considered. This method is therefore referred to as the *current performance method*. Whether this method addresses the impact of uncertain traffic developments will be evaluated by comparing the method's estimating accuracy to that of the method based on perfect foresight.

3) The final work method that is analyzed bases its investment decisions on yearly traffic forecasts in a bid to expand terminal capacity in an effective manner. This work method will postpone terminal expansion until an asset's *forecasted* performance degrades past a certain acceptable threshold and is therefore referred to as the *forecast method*.

All three work methods were used to model terminal development in order to assess a project's feasibility. The capability of producing a terminal with a high project value was tested together with the work method's estimating accuracy. The results of the various assessments are summarized in the table below.

	Common practice	Current performance method	Forecast method
Estimated project value	\$45.510.781	\$39.831.371	\$43.789.820
Project value after simulation	\$44.042.366	\$39.861.159	\$43.356.637
Standard deviation	\$5.204.568	\$2.629.872	\$3.662.902
Accuracy	Overestimates by 3.3%	Estimates ± <1%	Estimates ± <1%

The results show that the work method based on perfect foresight overestimates a project's value. Depending on the size of the project and the market's volatility, this over-estimation is in the range of 3% (steady market growth) to 20% (volatile markets). This can be explained as follows: modelling investment decisions based on the assumption of perfect foresight presumes projected traffic volumes to always come true. This is a distortion of the actual decision-making process that takes place in the real world. Decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decision. Therefore, in overperforming markets, lagging terminal investments will lead to capacity saturation (i.e. unmet demand) and in underperforming markets overinvestment will lead to excess expenditures. Models that simulate investment decisions based on perfect foresight ignore such negative consequences and the fact that this leads to sub-optimal terminal development strategies.

The results of this analysis show us that although the accuracy of project valuation has gone up by using the work method based on perfect foresight, it has done so at the expense of project value. However, by postponing investments until materialized traffic volumes have made them necessary has led to a reduced project risk, signaled by the smaller standard deviation in possible project values. This positive development carries financial significance and could be fed back into the model by lowering the weighted average cost of capital for instance. However, such developments fall outside the scope of this study.

The method based on yearly forecasts has proven it is capable of slightly increasing the estimating accuracy of a project's value when assessing a project's feasibility. The real added value of such an approach, however, is the fact that it has automated the translation process from traffic projections into terminal designs. This will allow a terminal developer to run countless traffic projections in contrast to a couple of plausible scenarios, which is currently seen as common practice. This in turn allows the developer to quantify the range of project values which are to be expected, given the uncertainty of traffic developments over a project's lifetime.

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Annex

1 Introduction

1.1 Background

Global demand for agricultural commodities such as maize, wheat and soybeans has soared in the past decades (USDA 2018). This trend is set to continue, driven by global population growth accompanied by a substantial increase in welfare. In the 19th century, the German statistician Engel observed a positive correlation between per capita food demand and income, ultimately levelling out at high incomes (Bodirsky et al. 2015). The impact of higher living standards on food consumption can be dissected into three components; increased daily consumption, increased food waste and a dietary shift towards animal products.

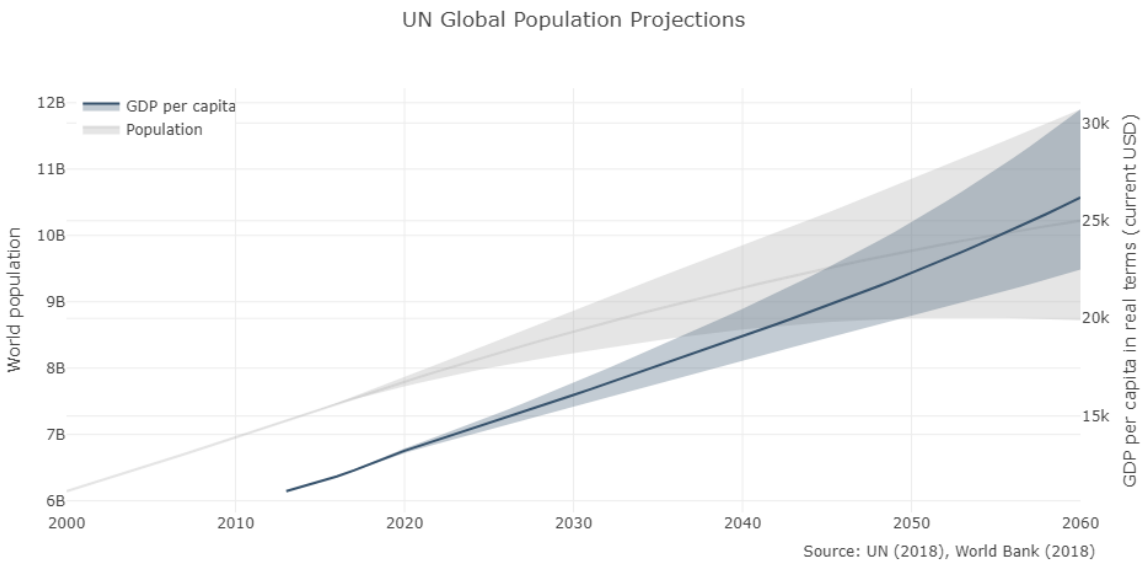

Figure 1-1: Population growth and corresponding GDP per capita figures (OECD 2018; The World Bank 2018a).

The impact of a global dietary shift to animal products should not be underestimated. Currently, 36% of the world's yielded grains and up to 68% of the grains used by developed countries are being fed to livestock (Elferink, Nonhebel, and Moll 2008; FAO 2012b). This portion is set to increase, as the past 50 years have seen the global demand for animal products and the amount of crop production used for feed approximately triple (330% and 300% respectively) (Food and Agriculture Organization of the United Nations 2014). The increase in food demand will be met with limitations on local production due to regional climates, boosting the global maritime trade in agricultural commodities.

The three agricultural commodities that fall within the scope of this research are maize, soybeans and wheat, as they all share the fact they are currently traded in substantial volumes and they all show signs of large growth potential. So much so, that grains are one of the major bulk commodity volumes shipped in the world in terms of weight, third only to iron ore and coal (PIANC 2014). Analysis published by shipping agencies such as Clarksons, shown in Figure 1-2, confirm such trends (Clarksons 2018b). Further analysis regarding the various commodity trends can be found in the chapter on *Trade trends*, located in this report's annex.

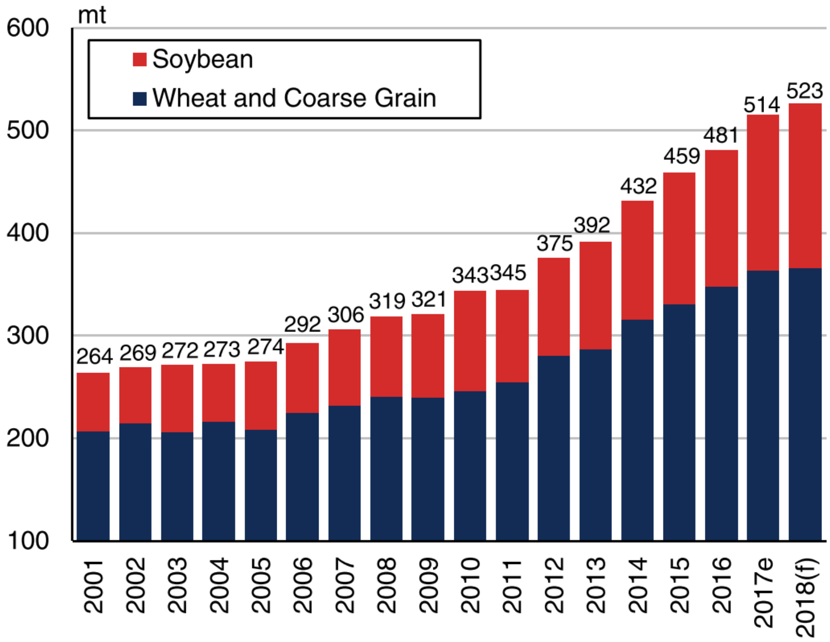

Figure 1-2: Maritime global grain trade volumes (Clarksons 2018b)

1.2 Problem statement

This climb in maritime agricultural trade is facilitated through the extensive development of agribulk terminals, which form the interface between long distance maritime trade and different forms of transport found within a terminal's hinterland. Various guidelines and design rules have been published that aid terminal developers and port engineers within the strategic planning phase of a project, i.e. the feasibility phase. However, as these guidelines are based on a wide array of empirical studies, they inevitable leave quite a spectrum within their recommended dimensioning methods.

Furthermore, it is important to note that stakeholders have a relatively high influence on a terminal's overall design strategy during these early project phases (see Figure 1-3). As they base the terminal's design strategy on the beforementioned guidelines, the impact of the variability found within these guidelines is amplified. This research will therefore set out to assess the financial implications of such design assumptions and whenever possible, optimize the design assumptions from an agribulk perspective.

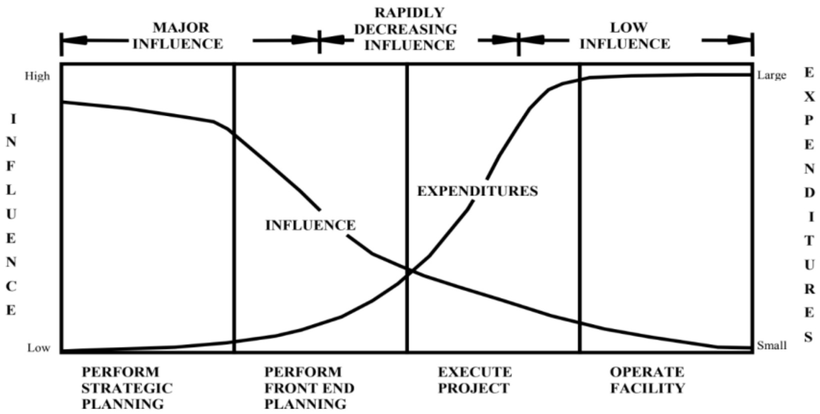

Figure 1-3: Cost of influence over the various project phases (Yussef et al. 2017)

Despite their generalist nature, high-level design guidelines are an essential component in terminal feasibility planning. This is because stakeholders are often deprived of extensive and complete technical and economic data at this early project stage. Furthermore, feasibility design is often a rather segregated process; economists make traffic projections, after which port engineers translate that projection into a terminal plan, before having an economist re-evaluate the terminal plan and analyze its feasibility. This results in a very coarse feedback mechanism in which the final economic analysis may require the port engineers to redo their initial design, leading to an increase in design costs. This impasse is often overcome by designing a terminal using various economic and technical scenario's.

Although such scenarios are often based on expert judgement, underperforming or overperforming traffic developments will inevitably lead to a deviation from the project's expected value. In both cases the resulting development strategy is sub-optimal; in overperforming markets lagging terminal investments will lead to capacity saturation (i.e. unmet demand) and in underperforming markets overinvestment will lead to excess expenditures.

Incorporating unforeseen traffic developments into the design process has been subject to prior research (Taneja 2013). Such unforeseen developments can be absorbed by adding flexibility to a terminal's design for instance, a process referred to as *adaptive port planning*. A flexible design is a design that postpones capacity expansion and contraction measures, together with the accompanying investments, until the extra measure is needed. The delaying of such costs is often financially attractive, increasing overall project value. Although research on adaptive port planning conducted by Taneja focusses on projects conducted at an aggregated port-scale, the given definition of *design flexibility* is also applicable at a terminal-scale. Taneja categorizes flexibility in three ways (Wiegmans and Schott 2017):

No flexibility	A design which is not ready for unexpected events.
Just in time flexibly	The design is adaptable to changes in the requirements and adjusts to the markets. This type of design results in a staged and phased construction approach.
Just in case flexibility	This design type has been over dimensioned with fixed specifications. This type of design is initially more expensive, but if unexpected events fall within the designs robustness the extra costs associated with capacity alterations are substantially lower.

Current project feasibility evaluations generally assume a work method that produces designs that can be categorized as '*just in time flexibility'.* However, such evaluations are often based on the assumption of *perfect foresight*, i.e. investment decisions are based on traffic projections that are presumed to always come true. This is a distortion of the actual decision-making process that takes place during a terminal's lifetime, in which decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decision. Models that simulate investment decisions based on perfect foresight therefore ignore the negative consequences of over- or underperforming traffic developments and the fact that this leads to sub-optimal terminal development strategies. This research will evaluate the impact of basing work methods on the notion of perfect foresight and will set out to provide an alternative work method that incorporates, and therefore reduces, the impact of uncertain traffic developments.

1.3 Research questions

Deciding whether to initiate the development of an agribulk terminal is done based on a project's financial feasibility. This financial feasibility is evaluated using a defined work method. However, as the timeline of such projects is in the order of decades, the project will inevitably face many uncertainties. One of the uncertain factors that are of major influence on the project's feasibility is the cargo volume that will flow through the terminal. The findings presented by Taneja, Wiegmans and Schott highlight the fact that current work methods do not sufficiently incorporate such uncertainties.

This research will therefore investigate to what extent future uncertain traffic developments can be incorporated in a terminal's work method. This will, in turn, improve the technique used to evaluate the expected value of a terminal project. The objective of this research can therefore be summarized by asking the question:

"How can the financial performance of an agribulk terminal be optimized, incorporating all investment decisions over the project's lifecycle, while taking into account uncertain throughput development."

To get to the answer to this question, we will have to answer five sub questions on the way. The first sub question revolves around the purposely developed computer model used within this research to evaluate the *financial performance* of a *work method*. A work method forms the basis for the translation of traffic projections into a terminal design and can be seen as a set of design assumptions, each focused on a specific element within the terminal (quays, cranes, etc.). The *financial performance* of a work method refers to its capacity to produce terminal designs that boast a high project value. The accompanying research question is defined as:

How can the financial performance of a work method be evaluated?

It is important to note that this study makes a clear distinction between two aspects that make up a single design assumption; the first being the performance threshold which triggers an investment, e.g. '*if the average waiting time of vessels exceeds 30% of service time, expand unloading capacity at the quay*'. Such triggers are referred to as *performance triggers*. The second aspect is the temporal nature of this trigger; do we gauge the waiting time at this moment in time or do we base the trigger on a future, *expected* waiting time, allowing us to invest now and ensure that the new asset is up and running once we need the extra capacity.

Literature provides high-level guidelines for what performance thresholds, or *performance triggers*, should be used to design a terminal. Despite their generalist nature, high-level design guidelines are an essential component in terminal feasibility planning. This is because stakeholders are often deprived of extensive and complete technical and economic data at early project stages. Using the developed computer model, an analysis was conducted to see if such triggers could be further optimized. All in all, the financial impact of investment triggers related to the development of the quay, the unloading equipment, the storage- and the loading facilities have been individually assessed. The second research question therefore reads:

"How can the performance triggers used within terminal planning be altered in order to optimize an agribulk terminal's financial performance?"

Once the analysis regarding performance triggers is completed, the computer model will be used to analyze the temporal nature of the performance triggers. When modelling a terminal, should investment decisions be based on a terminal's *current* performance, or should investments be based on a terminal's *expected* performance given a certain traffic forecast? The financial performance of three work methods were compared, with each method having a different temporal setup for their performance triggers. By designing a terminal using the various work methods and then simulating how it would have performed financially, had it been built, allows us to assess the modelling method's accuracy regarding the estimation of project value.

The first work method that will be evaluated is the method based on *perfect foresight.* This method bases terminal designs on the presumption that the identified traffic projections will always come true. It is current common practice to assess terminal feasibility using this work method, making it a good benchmark against which other work methods can be compared. This has been brought together in the following research question:

"How accurately can project value be estimated using a work method based on the assumption of perfect foresight?"

The second work method that will be evaluated bases its investment decisions on the performance of the terminal, gauged at the same moment at which an investment decision is considered. This method is therefore referred to as the *current performance method*. Whether this method addresses the impact of uncertain traffic developments will be evaluated by comparing the method's estimating accuracy to that of the method based on perfect foresight. The fourth research question reads:

"How does the estimating accuracy of the current performance method compare to current common practice regarding the financial evaluation of terminals?"

The final work method that is analyzed bases its investment decisions on yearly traffic forecasts in a bid to expand terminal capacity in an effective manner. This work method will postpone terminal expansion until an asset's *forecasted* performance degrades past a certain acceptable threshold and is therefore referred to as the *forecast method*. The final research question therefore reads:

"How does the estimating accuracy of the forecast method compare to established common practice regarding the financial evaluation of terminals?"

1.4 Research approach

The objective of this research is to improve the work method used to evaluate terminal project feasibility. This is done by assessing the two components that make up a work method; its performance triggers and the underlying temporal nature of those triggers. In order to do so, a computer model was developed that could automate the translation of traffic projections into terminal designs. This section will start off by briefly addressing the conceptual outline of the computer model, before elaborating what data was required to build the model and how this data was gathered.

1.4.1 Modelling approach

The developed model, written using the Python programming language, is capable of translating traffic projections into a terminal design based on a specific work method. A work method is a set of performance triggers, with each performance trigger dictating when a capacity expanding investment is deemed necessary for a certain terminal element. Once programmed, the computer model can translate a traffic projection into a set of investment decisions that will be taken over the project's lifecycle. The set of investments related to all the various terminal assets, taken over the entire project, is referred to as a *terminal design* (see Figure 1-4).

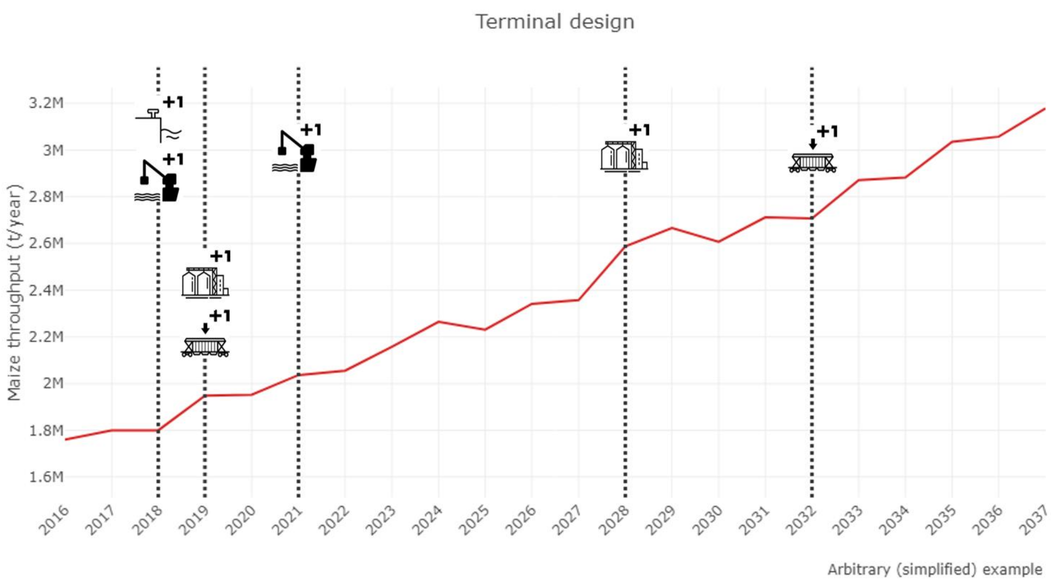

Figure 1-4: A (simplified) example of a terminal design

The financial performance of a work method can be evaluated by assessing the project value of the designs it produces. This is done by translating the various investments that make up a terminal design into a set of yearly cashflows (see Figure 1-5). Because project financing and tax operations fall outside the scope of this study, project value is determined by aggregating the *pre-tax free cashflow to the firm*, taken over the project's entire lifecycle, and translated to present value terms. The free cash flow for the firm (FCFF) represents the amount of cash flow from operations available for distribution after depreciation expenses, working capital, and investments are paid. FCFF is essentially a measurement of a company's profitability after all expenses and reinvestments (MTBS 2018). The aggregated, present value of the pre-tax FCFF is denoted in real terms (i.e. adjusted for inflation) and is defined as the project's Net Present Value (NPV). All in all, it is assumed that the NPV represents a project's value. For more information on the method used to compute a terminal's NPV, please consult the chapter on *The Financial Evaluation of Terminals*, located within this report's annex.

Evaluating a work method's accuracy regarding the estimation of project value is done through simulation. The first step in this process is to design a terminal using a specific work method. The design is then converted into a set of cashflows, which is used to estimate the project's value. The second step is to simulate how it would have performed financially, had it been built. This is done by exposing the design to a new set of traffic simulations. Each simulation will lead to a new set of yearly cashflows, which are subsequently converted into an NPV. This NPV constitutes the design's *simulated* value. Comparing the *estimated* NPV with the *simulated* NPV tells us how accurate the work method can estimate a project's value and quantifies if it is capable of taking into account the effect of uncertain throughput developments.

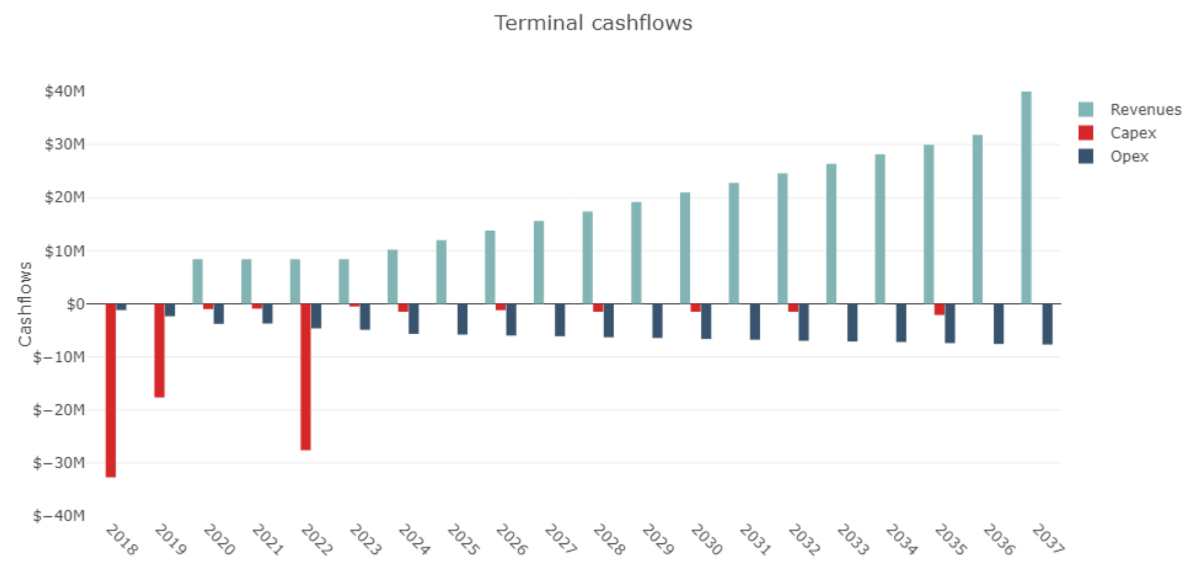

Figure 1-5: Set of yearly cashflows

Finally, the project evaluations depicted in this report illustrate an arbitrary business case for an agribulk import terminal in South Africa. South Africa was chosen because it lies within sub-Saharan Africa, a region which is expected to witness a strong rise in crop demand. Furthermore, the quality of data regarding historical commodity consumption, production and trade is substantially better than that of any other sub-Saharan African country. The applied financial project parameters are based on figures used in recent projects in the region (MTBS 2018). It is assumed that the project has a *gearing* of 60%, implying that 60% of the required funds are provided through a loan from a bank (in this case the World Bank) and 40% of the required funds are provided in the form of equity. The resulting annual discount rate is set at 11.14% (Damodaran 2018; MTBS 2018; The World Bank 2018b). For more information regarding the financial project parameters, please consult *The Financial Evaluation of Terminals* located in this report's annex.

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1.4.2 Data collection

The data required to construct a model, capable of translating traffic projections into terminal designs, can be subdivided into three categories. The first category is related to the various financial elements that play a role in the financial evaluation of a terminal. Identifying what aspects have to be included in the evaluation of a terminal's business case has been largely based on MTBS transaction reports regarding terminal acquisitions. Furthermore, other project finance parameters such as the weighted average cost of capital, are based on recently developed terminals.

The second data category is related to the various existing work methods and assumptions. A literature review will form the basis for this category. Findings will be cross referenced using interviews with various terminal operators in the Benelux and with international site visits conducted by experts within MTBS.

The third and final category revolves around the technical and financial characteristics of individual terminal elements. These include production capacities, asset lifespans, purchasing rates, maintenance schemes, etc. Such data will be gathered through terminal transaction documents, through interviews with terminal operators and correspondence with equipment manufacturers.

1.5 Research scope

This section will set out to specify the technical and financial aspects of a terminal that fall within the scope of this research. When referring to a *terminal design,* for instance, reference is made to the terminal's infrastructure and equipment configuration used in the five discrete handling phases within an agribulk import terminal; *receiving*, *initial transport*, *storage*, *secondary transport* and *loading,* see figure 1-6 (Dafnomilis et al. 2018). Table 1-1 stipulates the various infrastructure and equipment elements that fall within the scope of each handling phase.

Receiving	Initial transport	Storage	Secondary transport	Loading
Quay wall	Belt conveyors	Silos	Belt conveyors	Train loaders
Gantry cranes		Warehouses		
Harbour cranes				
Mobile cranes				
Screw unloaders				

Table 1-1: Scope regarding terminal elements

Figure 1-6: An import grain terminal

It is important to note that the design assumptions used to determine the required equipment configuration are based on a level of detail which is conventionally applicable in the feasibility phase of a project. This implies that traffic volumes are aggregated into annual averages and investment decisions are assumed to be taken once a year, at the start of each year (MTBS 2018). Furthermore, the model's scope is confined to a terminal level and will not incorporate port infrastructure such as access channels, breakwaters and harbor basins.

The commodity scope within this research is limited to maize, soybeans and wheat. These commodities were identified as suitable candidates as they are shipped in substantial volumes (PIANC 2014) and their respective supply chains have not been as vertically integrated as the supply chains of other major bulk commodities such as iron ore and coal (MTBS 2018). Not being linked to other major components in a supply chain, such as mines and powerplants, is important when simulating terminal development with the objective to maximize project value, as is the case in this report. This is because when terminals *are* part of a vertically integrated supply chain, terminal investment decisions are often overruled by the investment decisions of the underlying supply chain components. Electricity demand may, for instance, dictate the consumption of a coal power plant, which in turn will dictate the phasing strategy of a dedicated import coal terminal.

It is important to note that in the evaluations presented in this report, the assumption has been made that the terminal in question does not focus on soybeans or wheat and solely imports maize. This is done in order to isolate and clarify the impact of various design assumptions found within a work method. Furthermore, each terminal element is assumed to carry a value identical to its purchasing cost, which is linearly depreciated over its lifespan. Once an asset reaches the end of its lifespan, it is assumed that a full reinvestment is required. At the end of the project's lifecycle, the value of all remaining assets is compounded into a single virtual positive cashflow in the last year, thus contributing to a project's NPV.

The cashflows that fall within the scope of this study are shown in table 1-2. Furthermore, each cashflows is assumed to be coupled to a single 'virtual stakeholder'. In other words, it is presumed that the stakeholder that will construct a terminal's infrastructure, will also purchase its equipment and is fully entitled to its revenues. This implies that every terminal element is deemed susceptive to an equal project risk and thus subject to an identical discount rate (for further elaboration regarding discount rates please consult the chapter Discount rates*,* which can be found in the annex).

Scale	Sporadic cashflows	Yearly cashflows
Asset scale	Procurement costs	Maintenance costs
Asset scale	Mobilization costs	Insurance costs
Asset scale	Reinvestments at the end of an asset's lifespan	Labour costs
Asset scale		Energy costs
Terminal scale	Remaining asset value added as cashflow in the final year of a project	

Table 1-2: Scope regarding terminal cashflows

1.6 Thesis Outline

The global outline of this thesis is depicted in Figure 1-7, in which the various research questions all have a dedicated chapter. The annex comprises of three chapters. The first, *Trade trends,* elaborates on current commodity trade trends and how this can be used to make traffic projections. The second chapter within the annex, *The Financial Evaluation of Terminals*, describes what financial parameters and key performance indicators play a role in the model and how they are determined. The final chapter, *Agribulk Terminal* Characteristics, includes the technical and financial data related to the various terminal elements.

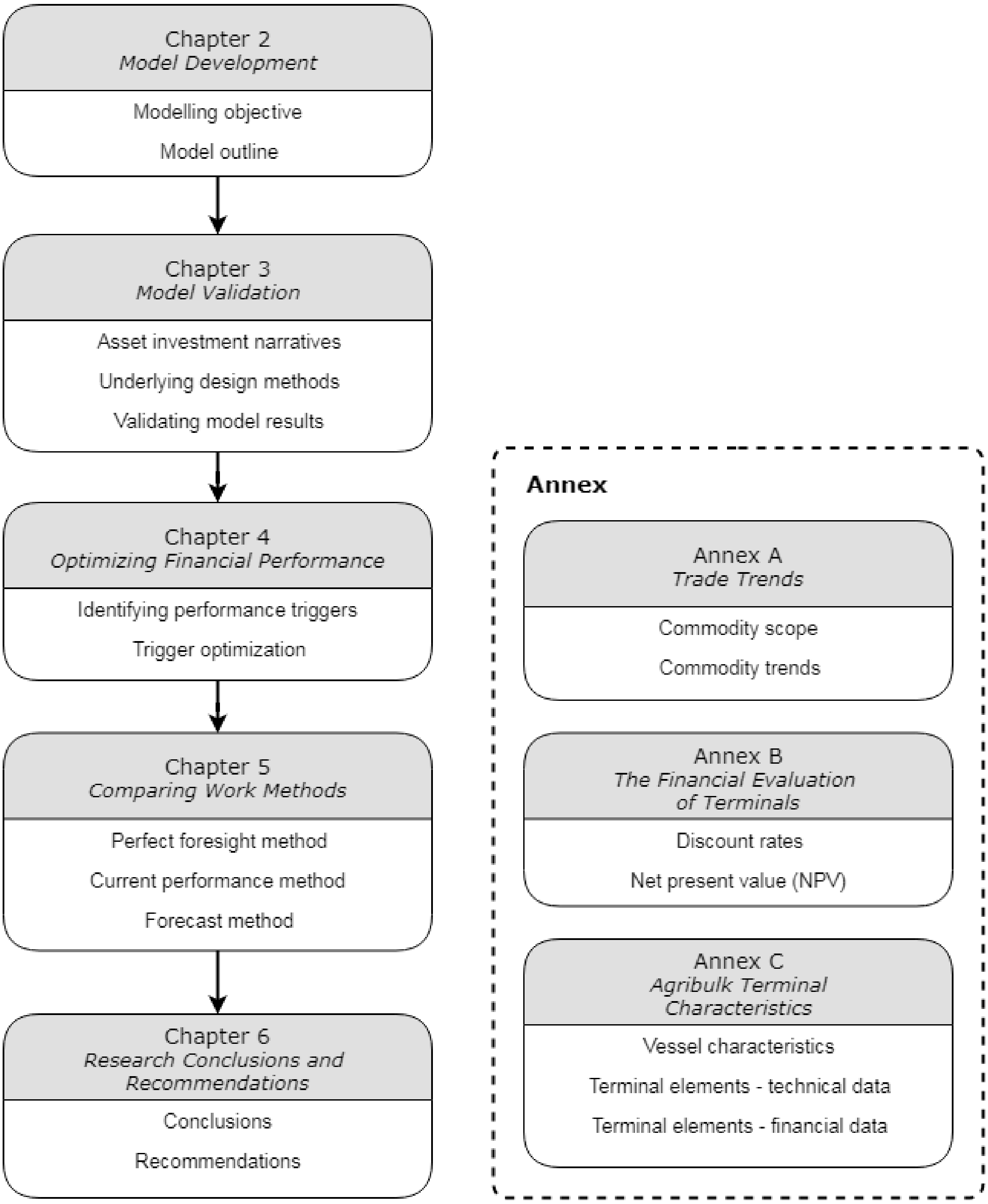


Figure 1-7: Thesis outline

2 Model Development

Several existing terminal models were analyzed as part of the literature study into terminal optimization. Many such models adopted a mixed integer linear programming (MILP) approach, which is suitable to identify the optimal selection and utilization of equipment in terms of total annual costs. Figure 2-1 gives an overview of the various models that have been consulted for this study, together with a breakdown of the various aspects that were covered in each research.

While the MILP models are useful tools to compute optimal equipment setups for a specific terminal throughput, they are fairly static in nature and do not address traffic fluctuations over time. In contrast, this study has set out to identify the impact of design assumptions taken over a terminal project's entire lifecycle. This was done in order to include the temporal nature of investment decisions, which are a large factor in terminal optimization due to the financial implications of delaying or expatriating cashflows (i.e. the time value of money). That being said, the models shown in Figure 2-1 do provide an extensive analysis regarding the technical and operational representation of terminal elements within a computer model and have therefore formed a valuable basis on which this research could be built.

	Harris et al. (2008)	Brinkman (2011)	Wu (2012)	Van Vianen (2015)	Kox (2016)	Dragović, Tzannatos, and Park (2017)	Van den Brand (2017)	Dafnomilis et al. (2018)	This study
Dry bulk terminal	✓		✓	✓	✓		✓	✓	✓
Yearly throughput	✓		✓	✓	✓	✓	✓	✓	✓
Berth allocation	✓	✓		✓		✓	✓	✓	
Business Case									✓
Commodity characteristics			✓	✓	✓			✓	✓
Dwell time		✓		✓	✓	✓	✓		✓
Downtime			✓	✓			✓		
Equipment characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
Equipment cost			✓	✓	✓		✓	✓	✓
Geographic limitations									
Health and safety aspects			✓	✓	✓		✓	✓	
Hinterland connections			✓	✓				✓	✓
Modal split			✓						
Peak volume				✓	✓		✓	✓	
Storage volume			✓	✓	✓		✓	✓	✓
Silo sizes			✓		✓				✓
Terminal area		✓			✓				
Terminal bypass				✓	✓		✓		
Vessel characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual traffic variation									✓
Maintenance costs									✓
Energy costs									✓
Insurance costs									✓
Time value of money									✓

Figure 2-1: Existing modelling approaches that have been consulted for the development of the computer model (van den Brand 2017; Brinkmann 2011; Dafnomilis et al. 2018; Dragović, Tzannatos, and Park 2017; Harris et al. 2008; Kox 2016; van Vianen 2015; Wu 2012)

Furthermore, it should be noted that in the final week of this research, Dafnomilis has published his dissertation, *Green Bulk Terminals - A Strategic Level Approach to Solid Biomass Terminal Design*, revolving around the optimization of biomass terminals. Within his research Dafnomilis *has* incorporated non-static throughput developments using a multiperiod model. Such a model is capable of identifying an optimal investment pathway given a specific development timeline (i.e. predefined stages of varying throughput). This can be seen as a hybrid approach in which discrete MILP modelling is used to optimize multi-stage terminal planning (Dafnomilis 2018).

The output produced by such a multi-stage terminal model is similar to that of the computer model developed within this research; an overview of yearly cashflows which can be used to assess a project's potential. However, whereas Dafnomilis' work has focused on optimizing the terminal's equipment configuration, the focus of this study is to assess the financial impact (i.e. financial performance) of individual design assumption used within terminal planning.

2.1 Modelling objective

In order to evaluate the financial impact of individual design assumptions, a purposely built model was developed, capable of translating a traffic projection into a terminal design. This translation is done based on a predefined *work method.* A work method is a set of design assumptions, each focused on a specific element within the terminal. As traffic increases over the years, utilization rates of the various terminal assets will rise, reducing an asset's performance. A design assumption dictates what performance levels are deemed acceptable. Thus, whenever asset performance degrades past the performance level specified by the design assumption, an investment in that asset is triggered. Design assumptions linked to individual asset performances are therefore referred to as *performance triggers.* The set of investments decisions related to the various terminal assets, taken over the entire project lifecycle, is referred to as a *terminal design* (see Figure 2-2).

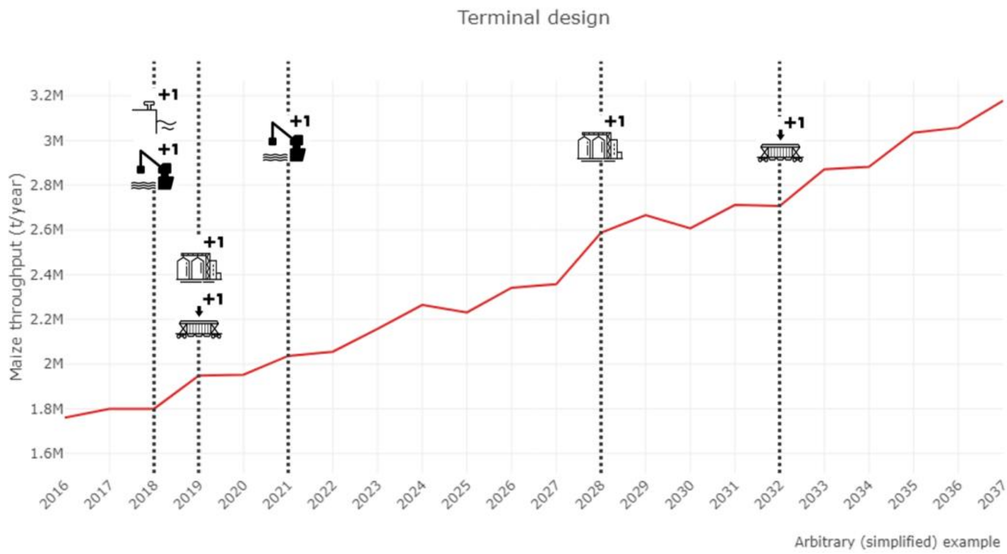


Figure 2-2: A (simplified) example of a terminal design

This translation can be seen as a parametric operation, which translates yearly throughput volumes into corresponding equipment configurations. In other words, the model simulates how a terminal expands following fluctuations in traffic volume. This chapter will elaborate on how the model comes to such a design, explain what aspects are fed into the model and how this can be used to evaluate the *financial performance* of a work method.

When referring to the financial performance of a work method, reference is made to the method's capacity to design terminals that result in a high project value. The financial performance of a work method can be evaluated by financially evaluating the designs it produces. This is done by translating the various investments that make up a terminal design into a set of yearly cashflows (see Figure 2-3).

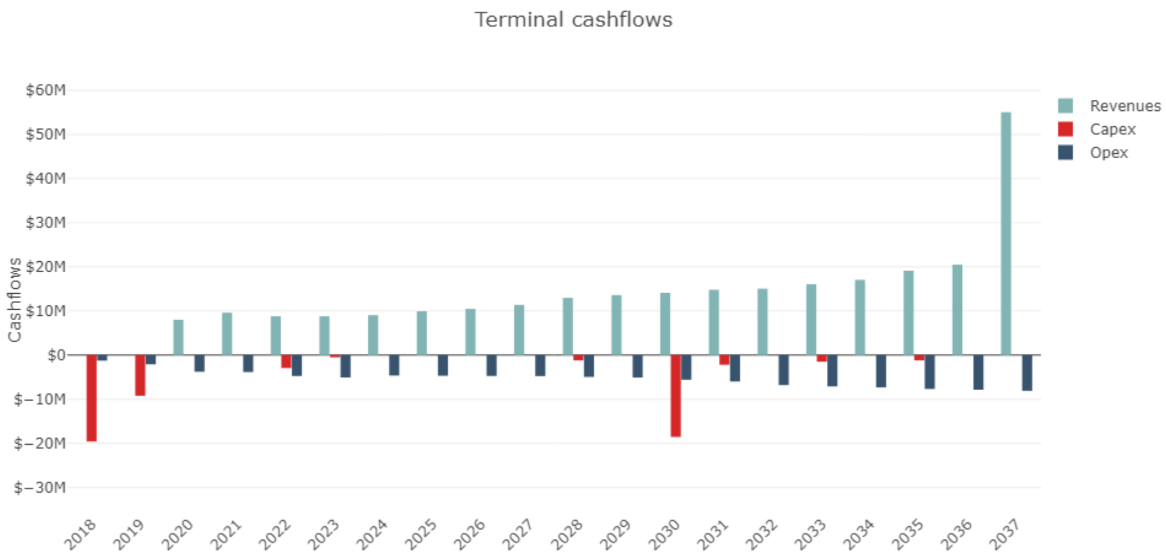


Figure 2-3: Translating a terminal design into cashflows

The cashflows have been grouped into three categories, the first of which represents the revenues generated by terminal activities. The second category are capital expenditures, also known as CAPEX. This category refers to cashflows related to the acquisition and reinvestment of terminal assets. The final category is referred to as operational expenditures, or OPEX. This category represents yearly expenditures related to a terminal's running costs, such as maintenance and labor for instance. Once all costs have been identified, they are discounted and aggregated over the project's entire lifecycle and translated into a single net present value (NPV). This process is described in greater detail in the chapter on *The Financial Evaluation of Terminals*, located in this report's annex. It is this NPV which forms the key performance indicator for a work method's financial performance. All in all, the objective of the model is to evaluate the financial performance of a work method, providing the answer to the first research question:

How can the financial performance of a work method be evaluated?

2.2 Model outline

This section will cover how the computer model creates terminal designs, explain what aspects are fed into the model and how this can be used to evaluate various work methods. Each aspect will be explained in separate subsections, with Figure 2-4 giving an overview of all the processes and how they are interlinked.

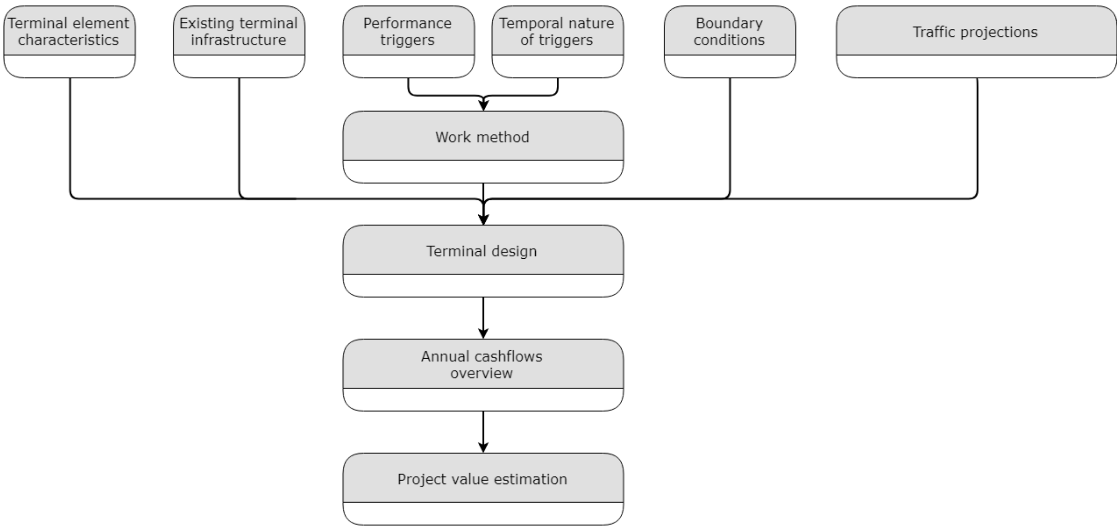


Figure 2-4: Modelling processes

2.2.1 Terminal element characteristics

Before being able to automate the process of making a terminal design, it was important to clearly define how the various terminal elements interacted with each other to form a terminal's equipment configuration. Modelling the terminal's equipment configuration was done using the process-interaction approach, which can be summarized in the following three steps (van Vianen 2015; Zeigler, Praehofer, and Kim 2000):

1) Decompose the system into relevent element classes, preferably patterned on the real-world elements
2) Identify the attributes of each element class
3) Provide the element classes process description that govern the dynamic behavior of these elements, including the interactions with other elements.

When referring to a terminal design, reference is made to the terminal's infrastructure and equipment configuration used in the five discrete handling phases within an agribulk import terminal; *receiving*, *initial transport*, *storage*, *secondary transport* and *loading* (Dafnomilis et al. 2018). This section will provide an overview of the various terminal elements that fall within the scope of this study, which is visualized in Figure 2-5. However, the attributes and applied modelling approach regarding the various terminal elements will not be discussed in this section and for further information reference is made to chapter D, *Agribulk Terminal* Characteristics, located in this report's annex.

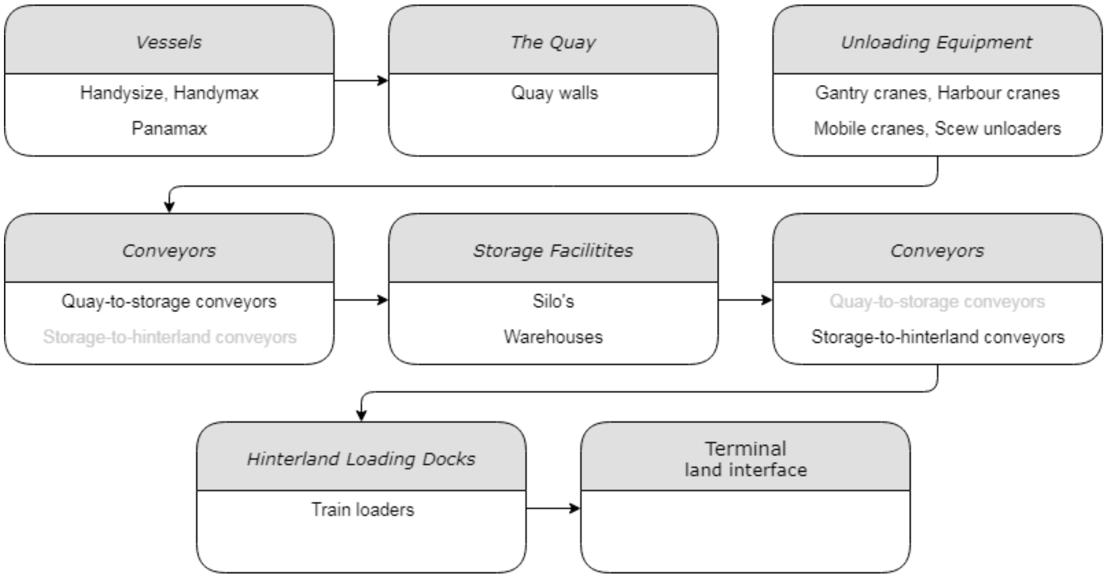


Figure 2-5: Terminal elements

Once the system is dissected into elements, the attributes of each element are defined. Figure 2-6 depicts the attributes connected to the quay wall, one of the terminal's elements, as an example. The attributes are divided into two groups, the first group is listed as *Element inputs* and represents static attributes that are defined by the user prior to simulation. These include production capacities, asset lifespans, purchasing rates, maintenance schemes, etc. The default values for these input variables are based on data gathered through terminal transaction documents, interviews with terminal operators and correspondence with equipment manufacturers. (Claes 2018; Corbeau 2018; Daas 2018; Juha 2018; Kranendonk 2018; Schutz 2018; Schuurmans 2018; Verstegen 2018).

The second group of element attributes is a result of interaction with other elements within the model. In the case of the quay wall, the length is determined by the length and number of berths for instance. The purchase date of the asset on the other hand, is dictated by the year in which there is need for an addition berth. The need for an additional berth is in turn based on its corresponding performance trigger (i.e. allowable vessel waiting time), which is linked to the terminal's throughput demand and the type of unloading equipment present at the berth. Etc.

Element: Quay wall		
Element inputs	**Value**	**Description**
t0 length	0m	Existing quay length prior to project
delivery_time	2 years	Years between aquisition and launch of asset
lifespan	50 years	Number of years before reinvestment is needed
mobilization_min	$2.500.000	Minimum mobilization costs
mobilization_perc	2%	Mobilization costs as percentage of aquisition cost
maintenance_perc	1%	Maintenance costs as percentage of aquisition cost
insurance_perc	1%	Insurance costs as percentage of aquisition cost
freeboard	4m	The vertical clearance between MSL and the apron
Gijt_constant	757.2	Constant used to determine aquisition costs
Gijt_coefficient	1.2878	Coefficient used to determine aquisition costs
Element interaction with other terminal elements		
length		The length of newly aquisitioned quay wall
depth		The berth depth in front of the quay wall
delta		Meters of quay wall aquisitioned in current year
purchase date		Year on which asset is purchased
online date		Year on which asset will come online

Figure 2-6: Asset characteristics

2.2.2 Existing terminal infrastructure

In some cases, the evaluated project concerns a development of an existing terminal, which already features certain terminal assets at the start of development. The age of such assets within the initial terminal setup is taken into consideration when defining in what year assets reach the end of their lifespan and require a reinvestment.

2.2.3 Performance triggers

As traffic increases over the years, utilization rates of the various terminal assets will rise, reducing an asset's performance. A design assumption dictates what performance levels are deemed acceptable. Thus, whenever asset performance degrades past the performance level specified by a design assumption, an investment in that asset is triggered. Design assumptions linked to individual asset performance are therefore referred to as *performance triggers* within this research.

Such performance triggers dictate the investment strategy of a terminal and directly influence a terminal's project value. Allowing performance to substantially degrade before initiating a capacity-expanding investment, for instance, will lead to a delay in investment. Postponing investments is financially attractive in light of the financial concept of discounting future cashflows. For more information on the concept of discounting please consult the chapter on *The Financial Evaluation of Terminals*, located in this report's annex. Although postponing investments may be attractive, poor asset performance may lead to bottlenecks within the terminal. This will ultimately result in the terminal's capacity trailing demand, suppressing revenues (see Figure 2-7). In other words, the extent to which terminal asset investments are delayed is dictated by the performance triggers. Optimizing the balance between delaying investments and maximizing project value will be discussed in chapter 4. Figure 2-8 shows an example of such an optimization; in this case the financial impact of the allowable waiting time of vessels calling to port has been analyzed.

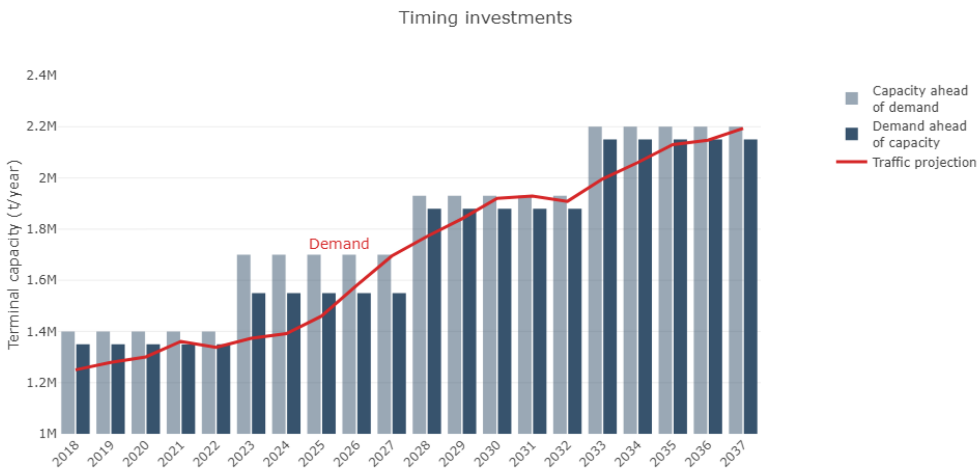


Figure 2-7: The timing of investments

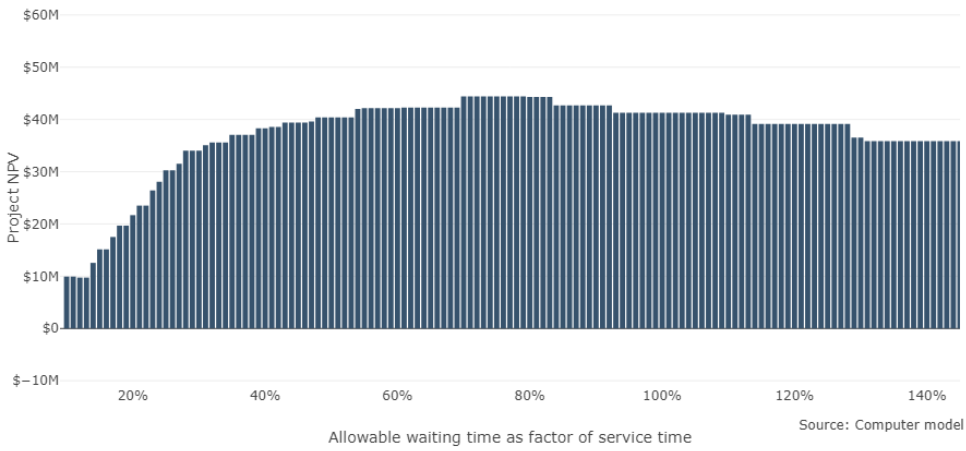


Figure 2-8: Assessing the financial impact of a performance trigger

2.2.4 Temporal nature of triggers

As mentioned before, there are two aspects that make up a single design assumption; the *performance triggers* and the temporal nature of this trigger; do we gauge the waiting time at this moment in time or do we base the trigger on a future, *expected* waiting time, allowing us to invest now and ensure that the new asset is up and running once we need the extra capacity. The three types of temporal trigger natures are discussed in the following sections:

Perfect foresight

The type of trigger is used in the work method based on perfect foresight and resembles established common practice. This implies that triggers are based on future traffic volumes expected to take place at the time an asset would come online, if the capacity expansion would be initiated at that specific moment in time. The decision to lengthen a quay wall for example, is based on traffic volumes that will take place two years from now, the time it is expected to take to construct a quay wall.

Current performance method

The second type of performance triggers are pegged to asset performance at the time of making an investment decision. Such triggers can be seen as reactive, as they will first require demand to materialize before initiating a capacity-expanding investment decision.

Forecast based method

The final type of performance trigger tested within this research will be based on forecasted traffic volumes. Such triggers differ from the triggers used in perfect foresight method in the sense that they are based on forecasted volumes, not guaranteed future volumes. These forecasts will be based on materialized traffic volumes leading up to the time of making an investment decision. The triggers will be based on forecasted volumes in the year an asset is expected to come online, if the decision to invest would be taken at that point in time. In other words, the performance trigger for quays will be based on forecasted throughput volumes two years from now, as it takes two years to construct a quay wall.

Figure 2-9: Temporal nature of triggers

2.2.5 Work methods

Once the set of performance triggers and their temporal nature is set, the work method is defined, and the computer model is ready to make its terminal designs. Within this research, the three evaluated work methods will be referred to as the *perfect foresight method*, the *current performance method* and the *forecast method*, corresponding to the temporal nature of their performance triggers.

2.2.6 Boundary conditions

In order to be able to compare the performance of the various work methods, it is important to ensure that each work method adheres to the same set of boundary conditions. The following set of boundary conditions have been applied to each work method:

1) Identical traffic projections are used for each run (see Figure 2-10).
2) Every work method must guarantee that at least 85% of traffic demand is met at all times. This condition implies that the terminal is allowed to let terminal capacity trail demand to some extent. This is always a balance for terminal operators; it is financially attractive as it allows the terminal operator to postpone investments but may damage attractiveness of the terminal (and ultimately demand). For this study the 85% threshold was based on expert judgement (MTBS 2018).
3) The incurred handling fees per commodity have been set to $9.80 per tonne in real terms (i.e. adjusted for inflation). This value has been chosen as it is the average handling fee in Sub-Saharan grain terminals, based on a tariff benchmarking study conducted by MTBS focusing on 25 Sub-Saharan grain terminals.
4) Identical project risk has been assumed, resulting in a universal real WACC of 9.23% (see *Discount rates*).
5) Each terminal operates 5840 hours a year, resembling a port that is open for 16 hours a day for 365 days a year.

2.2.7 Traffic projections

Traffic projections form the basis for every terminal design and dictate the terminal's dimensions and equipment configuration. Traffic projections are conventionally based on three complementary economic assessments (MTBS 2018). The first is a top-down macro analysis, which bases its projection on economic, demographic and social variables such as a nation's population and *gross domestic product*, or GDP. The second is a bottom-up micro-analysis, focused on market position and stakeholder expectations. This includes business strategies of local importers/exporters, terminal operators and shipping lines. The third assessment is based on a meso approach, in which the market is seen as a set of interrelated elements that influences a commodity's trade potential (i.e. a dietary shift towards animal products leads to a strong increase in maize and soybean demand).

For this report, traffic projections were solely based on the macro-analysis of maize trade trends. In order to be able to assess the various work methods, one thousand traffic projections were created that will form the basis for a financial evaluation of a theoretical terminal (see Figure 2-10). It should be noted that although the traffic projections are deemed sufficiently accurate for the scope of this research, they remain an oversimplification of reality. Extensive calibration and validation of traffic projections, based on actual trade data, fell outside the scope of this study.

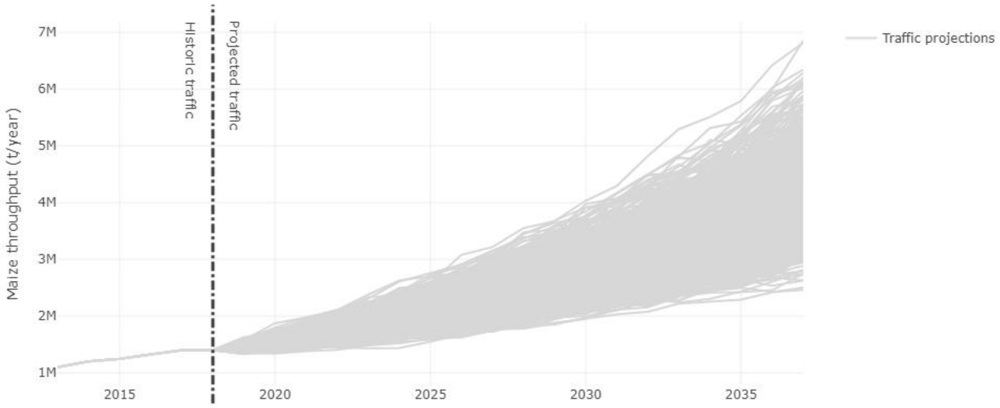


Figure 2-10: Traffic projections

2.2.8 Terminal designs

The traffic projection is now translated to a terminal design using a specified work method. The design stipulates a year-by-year equipment configuration, adhering to a specific set of boundary conditions mentioned in section 2.2.6. As an example, Figure 2-11 illustrates how the model registers the equipment configuration on the quay over a project's lifecycle. By doing this for all the handling processes on the terminal, the overall development of terminal capacity is recorded. This is visualized in Figure 2-12.

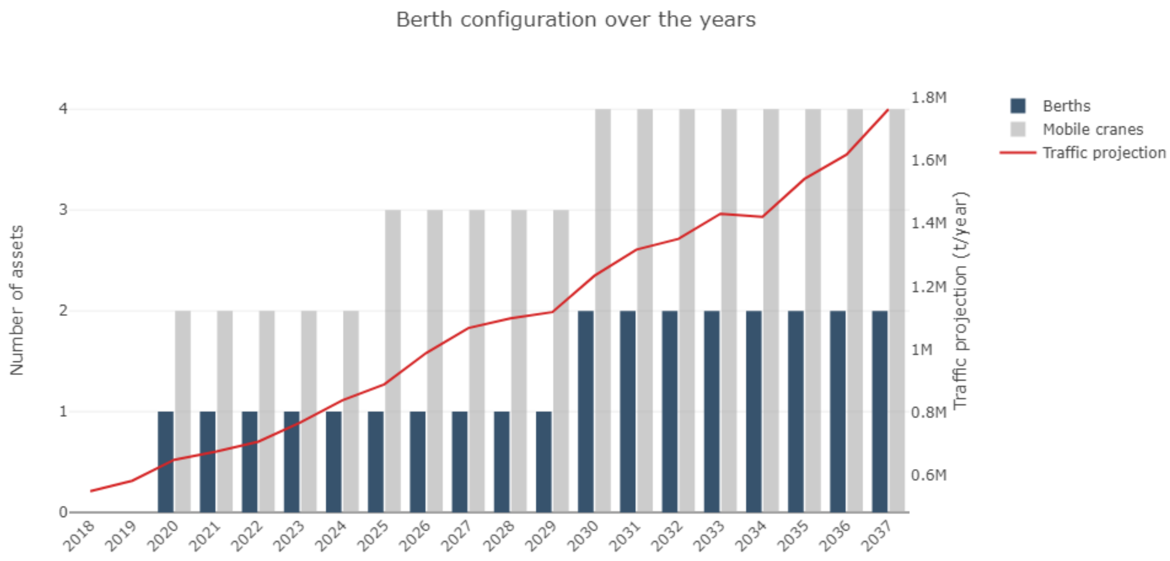


Figure 2-11: Berth configuration

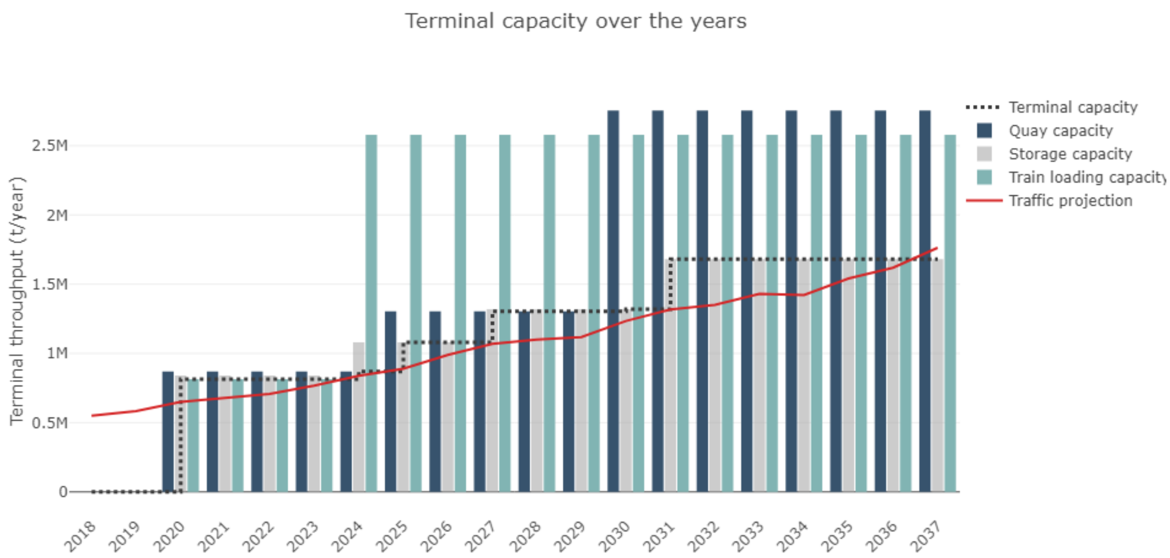


Figure 2-12: Terminal capacity development

2.2.9 Annual cashflow overview

Once the terminal design has been created, the financial characteristics of individual terminal elements can be used to convert a terminal design into a set of annual cashflows, depicted in Figure 2-13. The cashflows have been grouped into three categories, the first of which represents the revenues generated by terminal activities. The second category are capital expenditures, also known as CAPEX. This category refers to cashflows related to the acquisition and reinvestment of terminal assets. The final category is referred to as operational expenditures, or OPEX. This category represents yearly expenditures related to a terminal's running costs, such as maintenance and labor for instance. The free cash flow to the firm (FCFF) is subsequently computed by subtracting the yearly CAPEX and OPEX cashflows form the terminal's revenues.

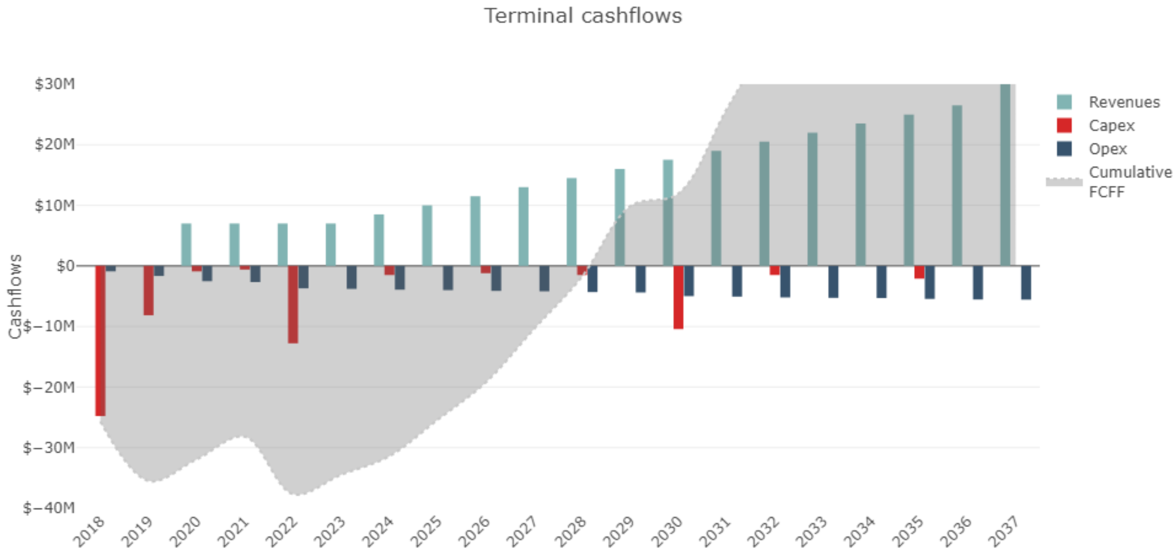


Figure 2-13: Annual cashflows

2.2.10 Project value estimation

Once the annual cashflow overview has been established, the cashflows are translated into present value terms using the project's weighted average cost of capital, or WACC (see Figure 2-14). The yearly free cash flow for the firm is subsequently aggregated and compounded into a single value, referred to as the design's *net present value*, or *NPV*. This NPV can be seen as the estimated value of a project.

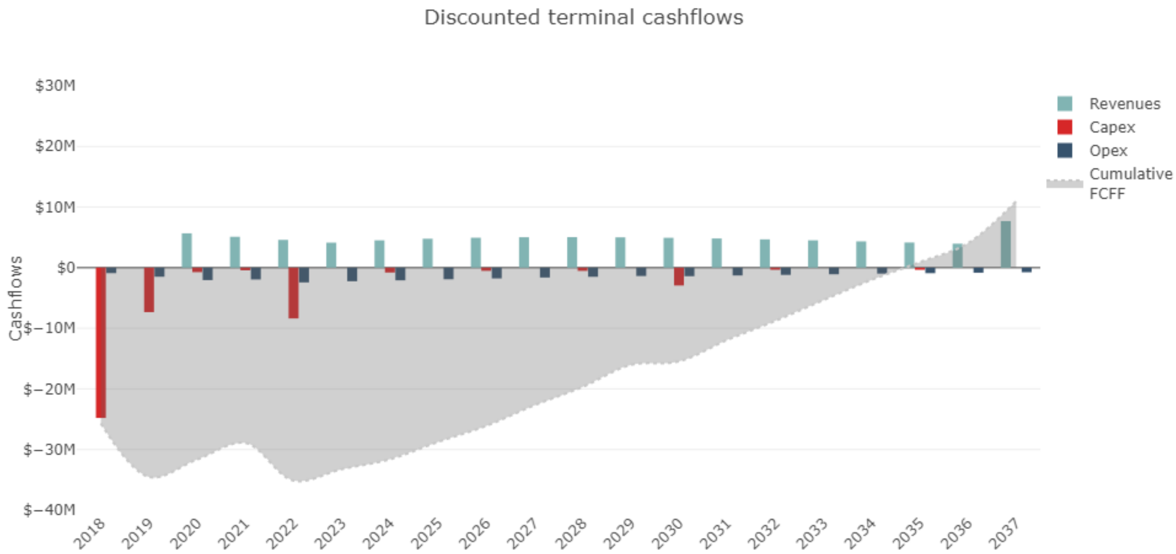


Figure 2-14: Discounted terminal cashflows

2.3 Conclusions

This chapter has shown how, through the use of a computer model, the process of translating traffic projections into a terminal design has been automated. This automation allows us to execute numerous runs, while changing the underlying design assumptions ever so slightly, enabling the user to investigate the financial impact of the various assumptions that make up a work method. This answers the chapter's sub question; *how can the financial performance of a work method be evaluated?*

A clear distinction has been made between the two aspects that make up a single design assumption; the first being the performance threshold which triggers an investment, e.g. '*if the average waiting time of vessels exceeds 30% of service time, expand unloading capacity at the quay*'. The second aspect is the temporal nature of this trigger; do we gauge the waiting time at this moment in time or do we base the trigger on a future, *expected* waiting time, allowing us to invest now and ensure that the new asset is up and running once we need the extra capacity.

An assessment regarding the performance thresholds of various terminal elements will be discussed in greater detail in chapter 4. How far do you let a terminal element's performance degrade before initiating a capacity-expanding investment? Literature provides an answer to this question, but can these triggers be further optimized?

After the performance triggers have been discussed, the temporal nature of triggers will be discussed in chapter 5. Should investment decisions be based on a terminal's current performance, or should we base our considerations on a terminal's expected performance given a certain traffic projection? What are the financial repercussions of current common practice, which bases its project value estimation on the notion of perfect foresight, in effect assuming that traffic volumes will always develop exactly as projected?

3 Model Validation

Before being able to assess various work methods through the use of the developed computer model, it is essential to validate that the model works properly. This is done by running conceptual scenarios, after which model results are cross-referenced with outcomes that are based on the approaches stated within terminal planning literature. The outline of this chapter coincides with the five discrete handling phases within an agribulk import terminal:

Receiving operations *Chapter 3.1*	The process of expanding the unloading capacity at the quay in order to live up to demand, while keeping vessel waiting times at acceptable levels. This includes the acquisition of unloading equipment, the allocation of berths and the lengthening of the quay wall.
Quay - Storage transport *Chapter 3.2*	The process of maintaining transport capacity between the terminal's quay and the storage facilities. This is done by gearing the capacity of horizontal conveyors to the unloading capacity of the unloading equipment situated at the quay.
Storage *Chapter 3.3*	The process of guaranteeing sufficient storage capacity at the terminal to accommodate yearly throughput volumes, given the commodity's expected dwell time.
Storage – Loading transport *Chapter 3.4*	The process of maintaining transport capacity between the terminal's storage and train loading facilities. This is done by gearing the capacity of horizontal conveyors to the loading capacity of the terminal's train loading stations.
Loading operations *Chapter 3.5*	The process of expanding the train loading capacity at the terminal in order to keep the waiting time of trains at acceptable levels.

3.1 Receiving operations

This first section will validate the various decisions made within the model related to the terminal's receiving operations. For this case we will assume a quasi-static traffic development, i.e. traffic volumes will remain constant with a single jump in demand halfway the project (see Figure 3-1). Furthermore, we assume that all traffic arrives onboard Handysize class vessels.

There are three stages to this exemplary scenario; the first stage represents the operations between 2020 and 2022 in which a single berth with two cranes suffices to handle cargo volume. After the increase in demand, waiting times peak due to a strong surge in number of vessel calls. So much so, that they rise above what is deemed allowable, triggering a capacity-expanding investment. The sudden jump in demand requires the acquisition of two extra pieces of unloading equipment. It is assumed that cranes can be delivered within a year (MTBS 2018), leading to an increase in unloading capacity in 2023. However, as Handysize vessels can only accommodate up to three unloading cranes at once, an extra berth is required for the fourth crane. This extra berth requires a quay extension, which takes two years to construct and denotes the second stage in which capacity lags behind demand. The third stage is initiated when the fourth crane come online, suppressing waiting times below acceptable levels once again (see Figure 3-2). The entire decision tree regarding quay-investments is visualized in Figure 3-3.

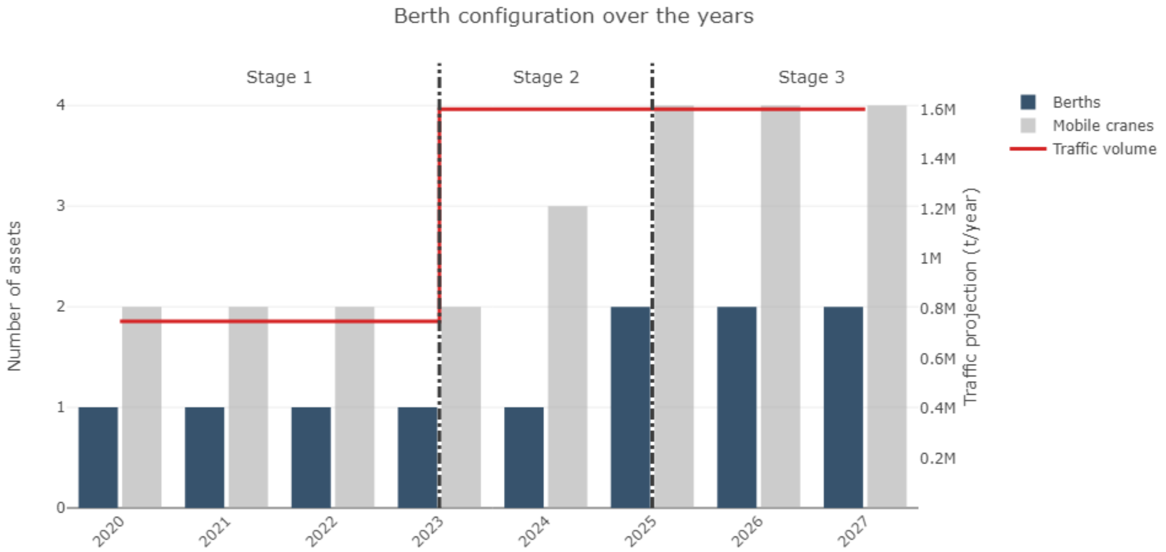


Figure 3-1: Berth configuration

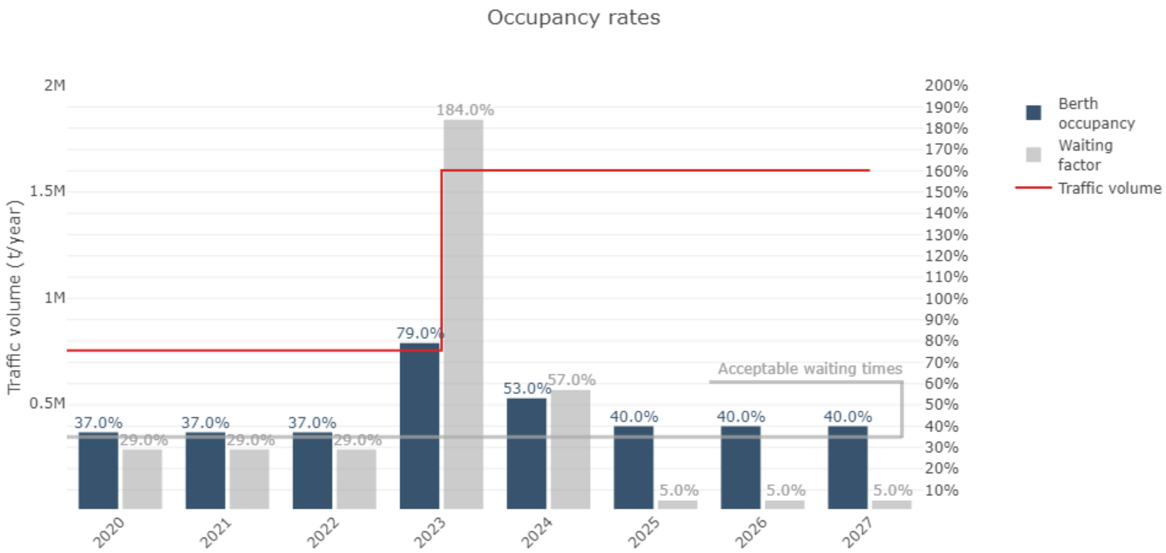


Figure 3-2: Berth occupancy and waiting time development

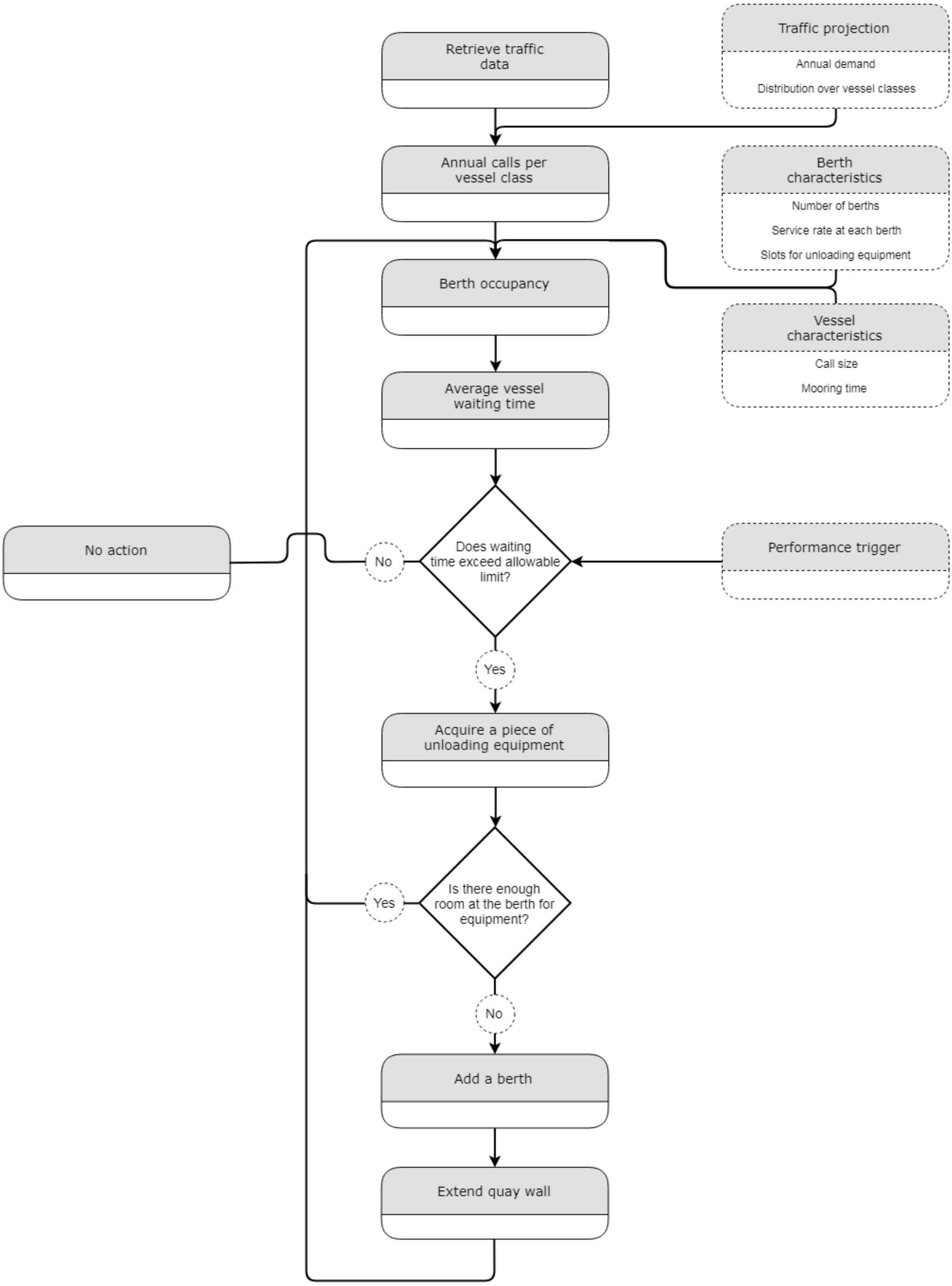


Figure 3-3: The decision tree related to the terminal's receiving operations

In order to validate if the decision making within the model is based on reliable assumptions, the results are cross-referenced with queuing theory found within literature. For this validation procedure we will compare the berth occupancy and waiting times presented by the model with results gathered by applying queuing theory.

3.1.1 Application of theory

According to the queueing theory, the arrival rate, denoted by λ, is expressed using the following expression:

$$\lambda = \frac{\text{number of calls}}{\text{operational hours}}$$

The average service rate, denoted by μ, is computed using the following relation:

$$\mu = \frac{1}{\frac{\text{call size}}{\text{unloading rate}} + \text{mooring time}}$$

The berth occupancy, denoted as ρ, can now be calculated:

$$\rho = \frac{\lambda}{\mu}$$

Once the berth occupancy has been calculated for each berth, queuing theory allows us to compute the average waiting time of vessels that call to the terminal. This waiting time is expressed as a factor of service time, which has been visualized in Figure 3-4. Extensive research into applicable distributions has been conducted by van Vianen (van Vianen 2015). In his research, real-world data was gathered at five unnamed coal and iron ore import terminals, after which the various stochastic distributions were compared to the terminal's empirical data in order to find the best fit. Building on his findings, this research assumes that both the vessel arrival and service rate is best represented by an Erlang-2 distribution. For further analysis into the stochastic representation of quay activities, please consult chapter 0, *The quay wall*, located in this report's annex.

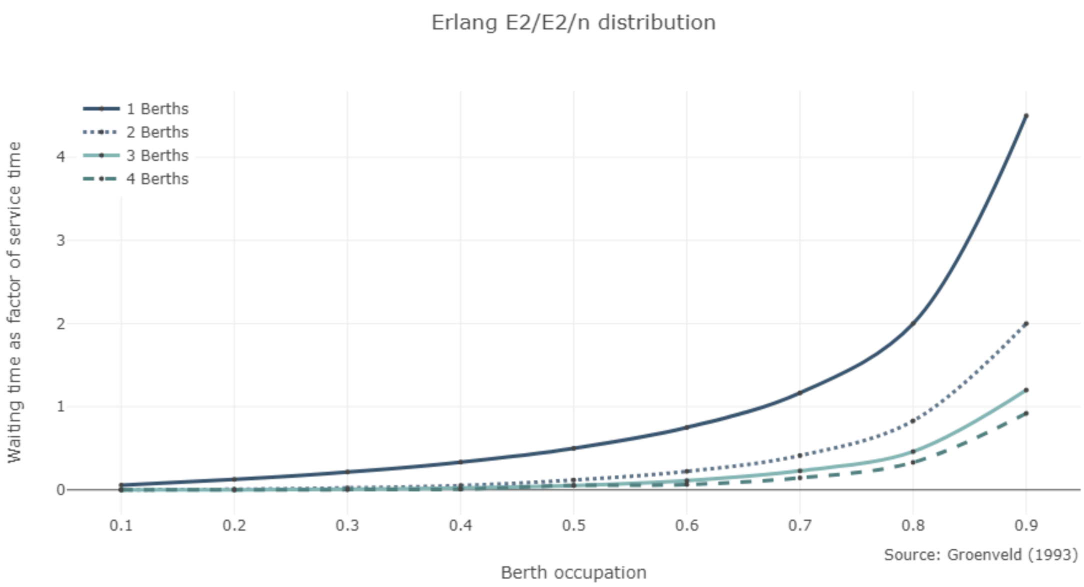


Figure 3-4: Waiting time correlated to berth occupation

3.1.2 Validating model results

The theory is now applied and compared to the model's results. The table below displays the relevant parameters in all three stages within this test scenario. The results achieved when applying the queuing theory can be found in the table's last two rows.

	2022	**2023**	***2024***	***2025 1st berth***
Traffic volume	750.000t	750.000t	1.200.000t	400.000t
Operational hours	5840 hours	5840 hours	5840 hours	5840 hours
Vessel call size	55.000t	55.000t	55.000t	55.000t
Number of calls per year	14 calls	30 calls	30 calls	22.5 calls
Mooring time per vessel	3 hours	3 hours	3 hours	3 hours
Effective unloading rate	366 t/h	366 t/h	549 t/h	549 t/h
Berth occupancy (model result)	37%	79%	53%	40%
Waiting factor (model results)	29%	188%	57%	5%
Berth occupancy (based on theory)	**37%**	**79%**	**53%**	**40%**
Waiting factor (based on theory)	**29%**	**188%**	**57%**	**5%**

3.2 Transport operations: quay – storage

This second section will validate the decisions made within the model related to the transport operations between the terminal's quay and storage facilities. Furthermore, it is important to note that within this study, conveying capacity is assumed to be installed in steps of 400 t/h (e.g. 800 t/h, 1200 t/h … 2400 t/h etc.). For this test case we will assume the same scenario as is specified in the previous section (see Figure 3-1). The decision-making process is schematically represented in Figure 3-6.

The horizontal transport between the quay and the storage facilitates in facilitated using horizontal conveyor belts. Based on interviews with terminal operators, it is current common practice to adopt a conveying capacity equal to the peak unloading capacity of equipment stationed at the quay (Daas 2018; Schuurmans 2018). In other words, an increase in unloading capacity at the quay in the forthcoming year will trigger a capacity-expanding investment related to the conveyors between the quay and storage facilities. The results have been visualized in Figure 3-5.

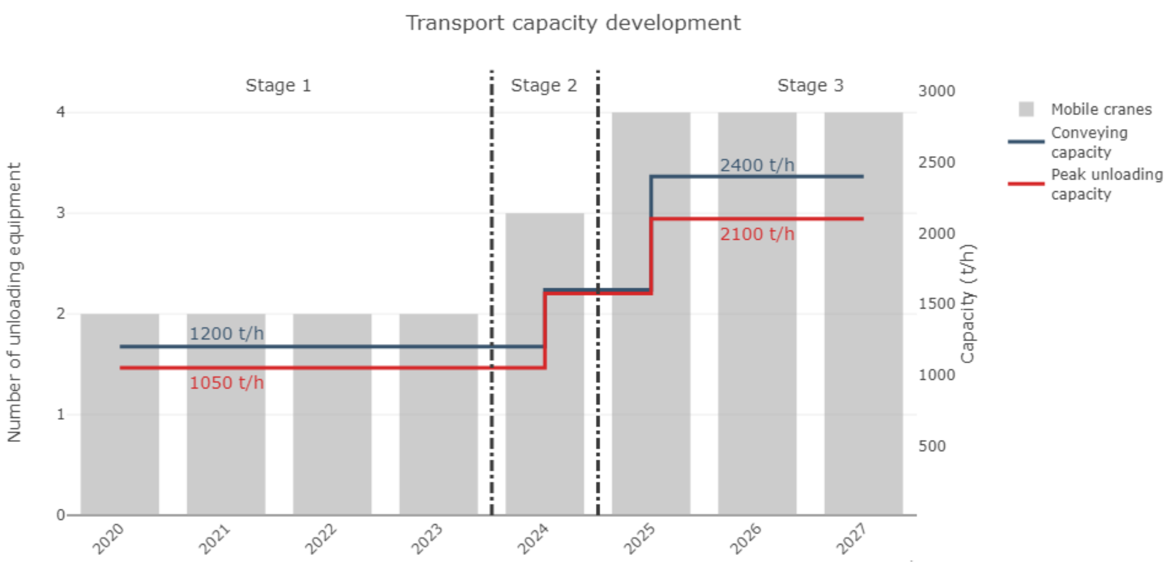


Figure 3-5: Development in transport capacity

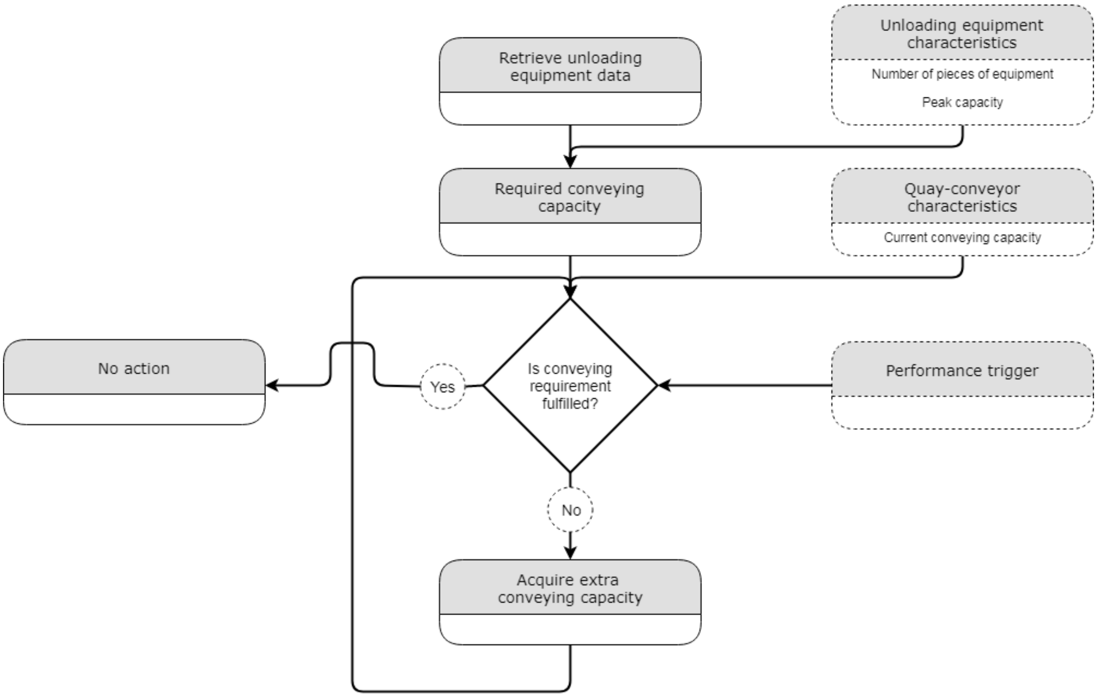


Figure 3-6: Decision tree related to conveyor investments between the quay and storage facilities

3.3 Storage operations

The investment decisions revolving around the storage facilities located at the terminal will be validated in this section. Two types of storage types fall within the scope of this study; storage in the form of silos and storing cargo through the use of warehouses. The investment decision-making process is identical in both approaches. However, when using silo's, storage capacity expansion is done in delimited steps in accordance with the capacity of a single silo. In this study, the default capacity of a single silo has been set at 5000 tonnes (Daas 2018).

The expected dwell time of cargo is a model input parameter and is to be provided by the user. It has a major influence on a terminal's required storage-related investments and will be subject to further analysis in chapter 4. Literature prescribes that storage facilities will always have to be capable of storing a single call of the largest vessels that are expected to port. Furthermore, in efficient, single-user terminals, a working guide is that the inventory is turned over 20 times a year. This implies that storage facilities are expected to be able to store roughly 5% of annual throughput (PIANC 2014). Once an investment is triggered, besides adhering to the new requirements as a result of an increase in demand, an extra storage buffer is added to meet demand in the years to come. By default, this buffer is set to 10%. The accompanying decision tree is visualized

For this test case, we will assume that all cargo arrives aboard Handysize class vessels, which have a call size of 55.000t. Furthermore, traffic volumes are expected to be quasi-static, i.e. traffic volumes will initially remain constant at 1.000.000 t/year and will jump to 2.000.000 t/year halfway along the project (see Figure 3-7). The terminal is assumed to be open 24 hours a day, 360 days a year. In line with the guidelines set out in literature, average commodity dwell times are presumed to be 18 days (1/20th of 360 days).

Figure 3-7 visualizes the resulting development in storage capacity. In the first stage, storage requirements are dictated by the guideline that stipulates that storage facilities should always be capable of storing the call size of the largest vessel that is expected to call at the terminal. This explains the 55.000t storage capacity up until 2022. In the second stage, the capacity-expanding investment is triggered. However, as it is roughly takes a year to construct storage facilities (Kranendonk 2018), capacity will temporarily trail demand. During the third stage, storage capacity adheres to the 5% guideline (100.000t) and adds an extra 10% buffer (10.000t), resulting in a total storage capacity of 110.000t.

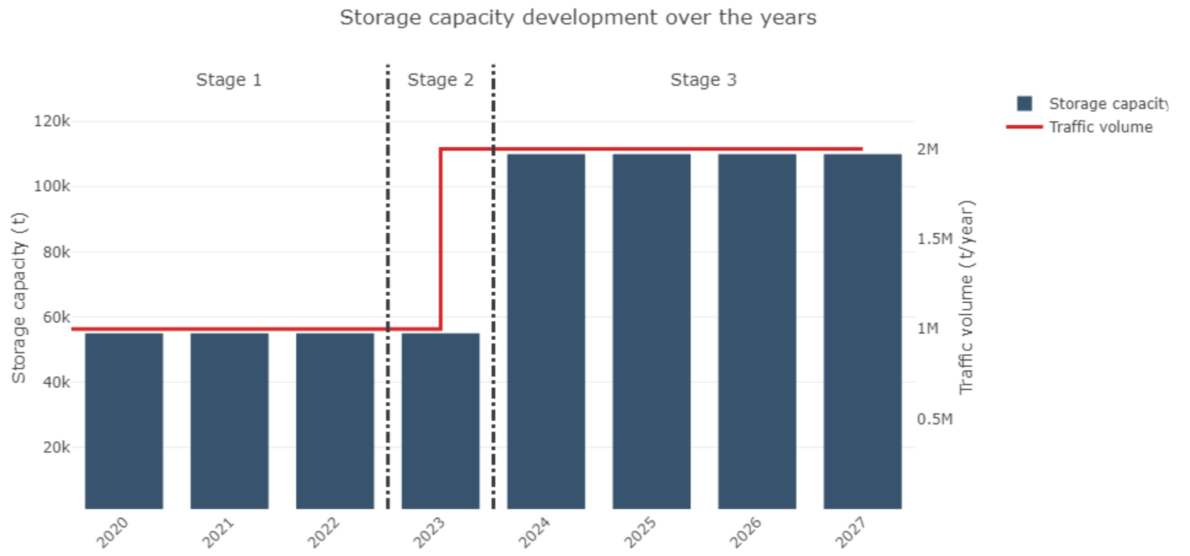


Figure 3-7: Storage capacity development

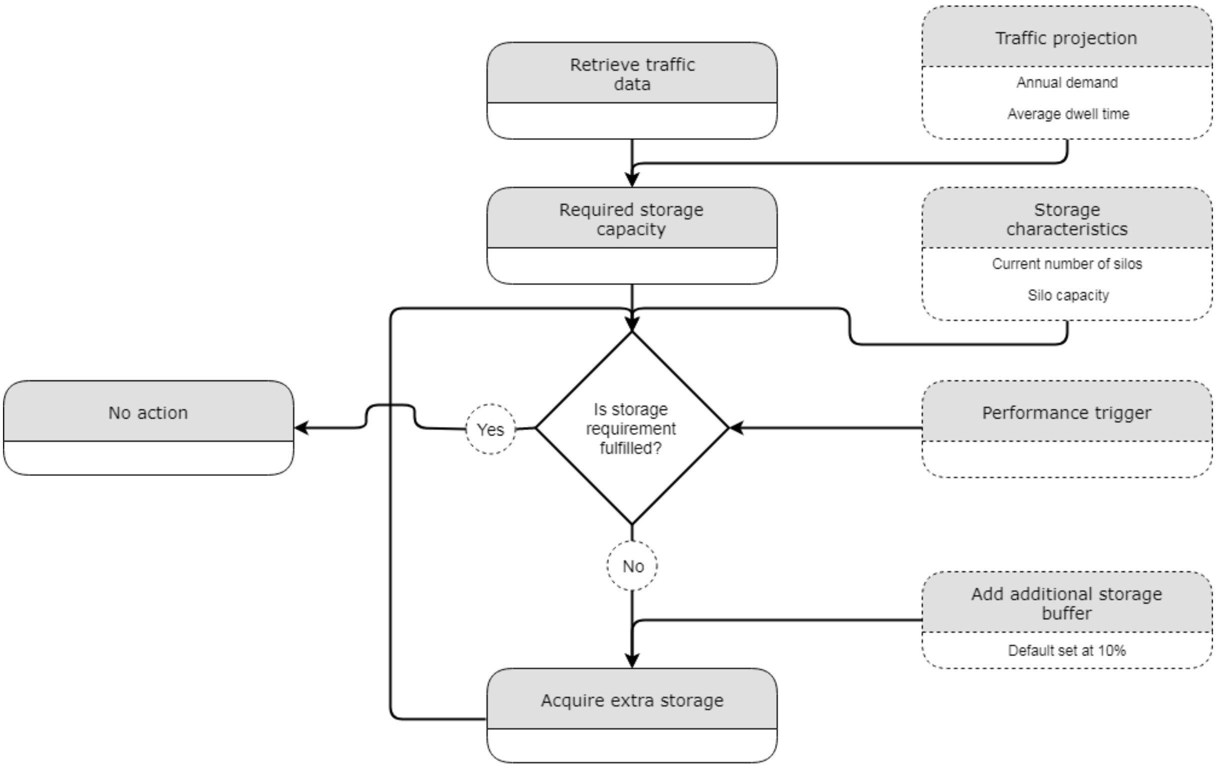


Figure 3-8: Decision tree related to storage investments

3.4 Transport operations: storage – loading dock

The forth handling phase revolves around the transport of cargo between the storage facilities and the train loading stations, located at the hinterland-side of the terminal. The transport is done using horizontal belt conveyors. The decision-making process is schematically represented in Figure 3-10.

The conveying capacity of the conveyors have been geared to the cumulative loading capacity of the train loading stations. Similar to the conveyors used on the quay, it has been assumed that conveyors are installed in capacity steps of 400 t/h (e.g. 800 t/h, 1200 t/h ... 2400 t/h etc.). For this test case we will assume the same traffic scenario as is specified in the section 3.5 (see Figure 3-9).

The train loading stations that have been applied in reference projects have a peak loading capacity of 800 t/h (MTBS 2018). As this is a multitude of the conveyor capacity steps of 400 t/h, conveying capacity will always neatly follow the terminal's loading capacity.

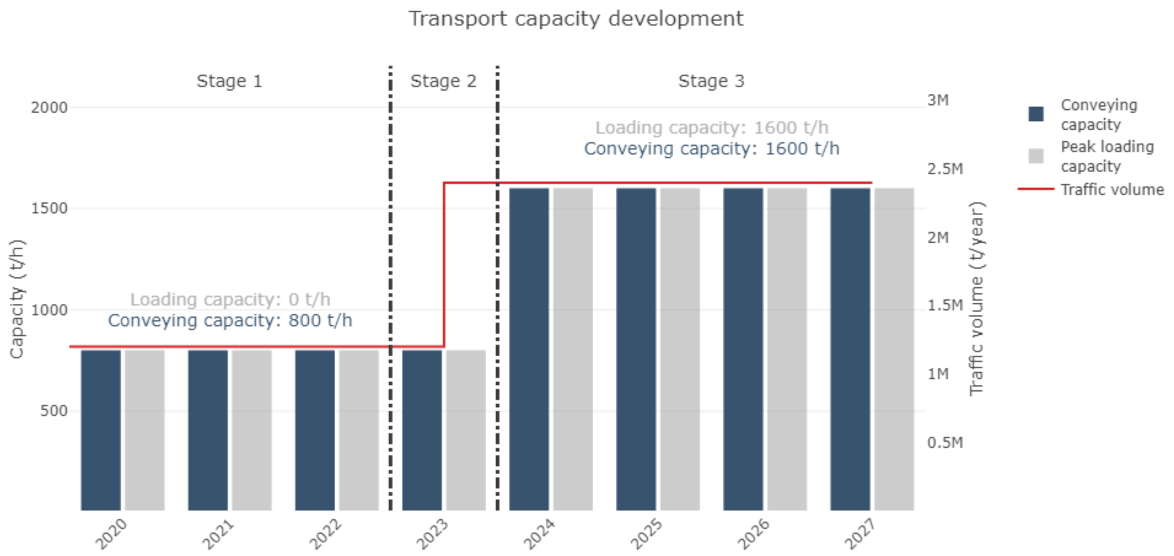


Figure 3-9: Development in transport capacity

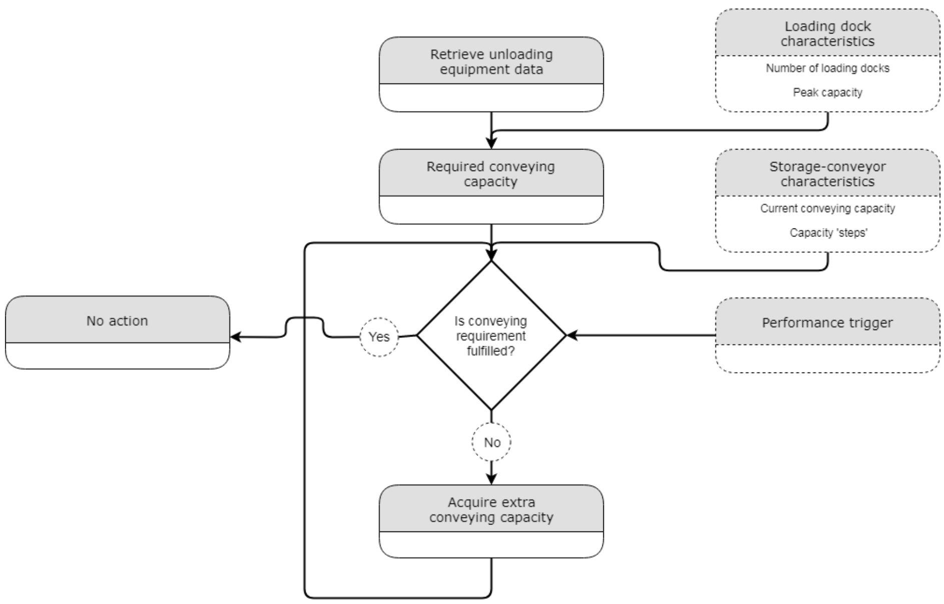


Figure 3-10: Decisions tree related to conveyor investments between the storage facilities and loading stations

3.5 Loading operations

This final section will validate the various investment decisions made within the model related to the terminal's loading operations. As with previous test cases, we will assume a quasi-static traffic development, in which traffic volumes jump from 1.200.000 t/year to 2.400.000 t/year halfway along the project (see Figure 3-11).

There are three stages to this scenario; the first stage represents the operations between 2020 and 2022 in which a single loading station suffices to handle the annual cargo throughput. After the increase in demand, waiting times peak due to a strong surge in number of trains required to bring the cargo further inland. So much so, that they rise above what is deemed allowable, triggering a capacity-expanding investment. The sudden jump in demand requires the acquisition of an extra loading station. This extra loading station will take a year to construct and denotes the second stage, in which capacity lags behind demand. The third stage is initiated when the new assets come online, suppressing waiting times once again (Figure 3-12). The entire decision tree regarding loading station-investments is visualized in Figure 3-13.

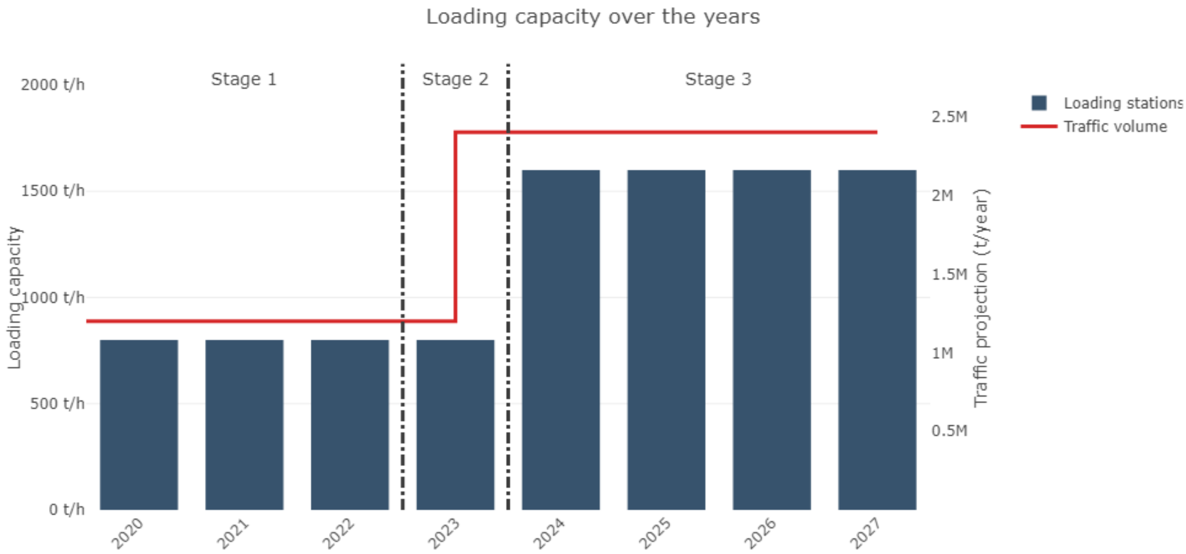


Figure 3-11: Loading station configuration

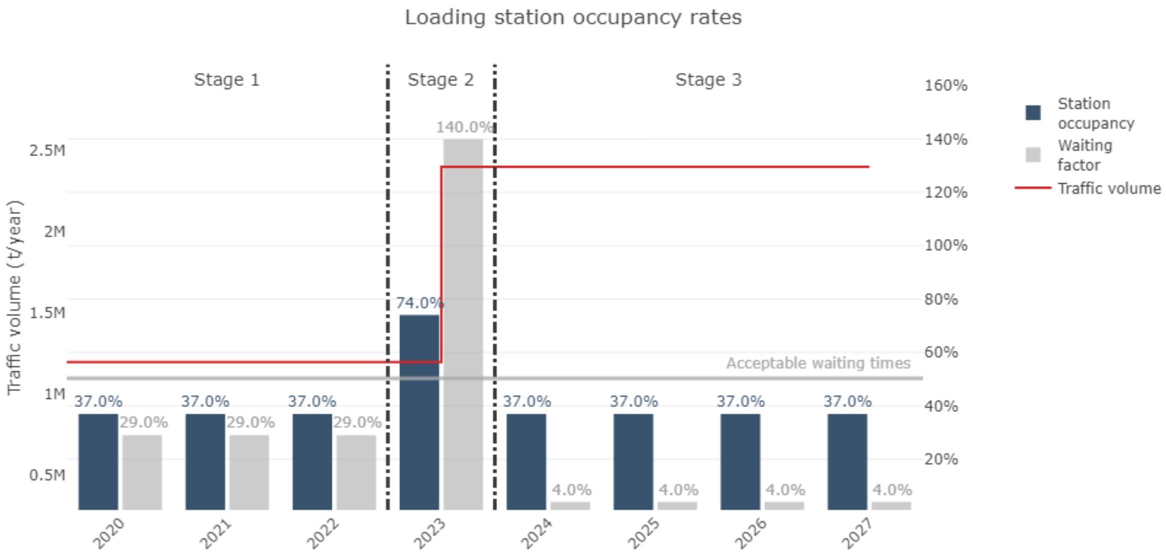


Figure 3-12: Loading station occupancy developments

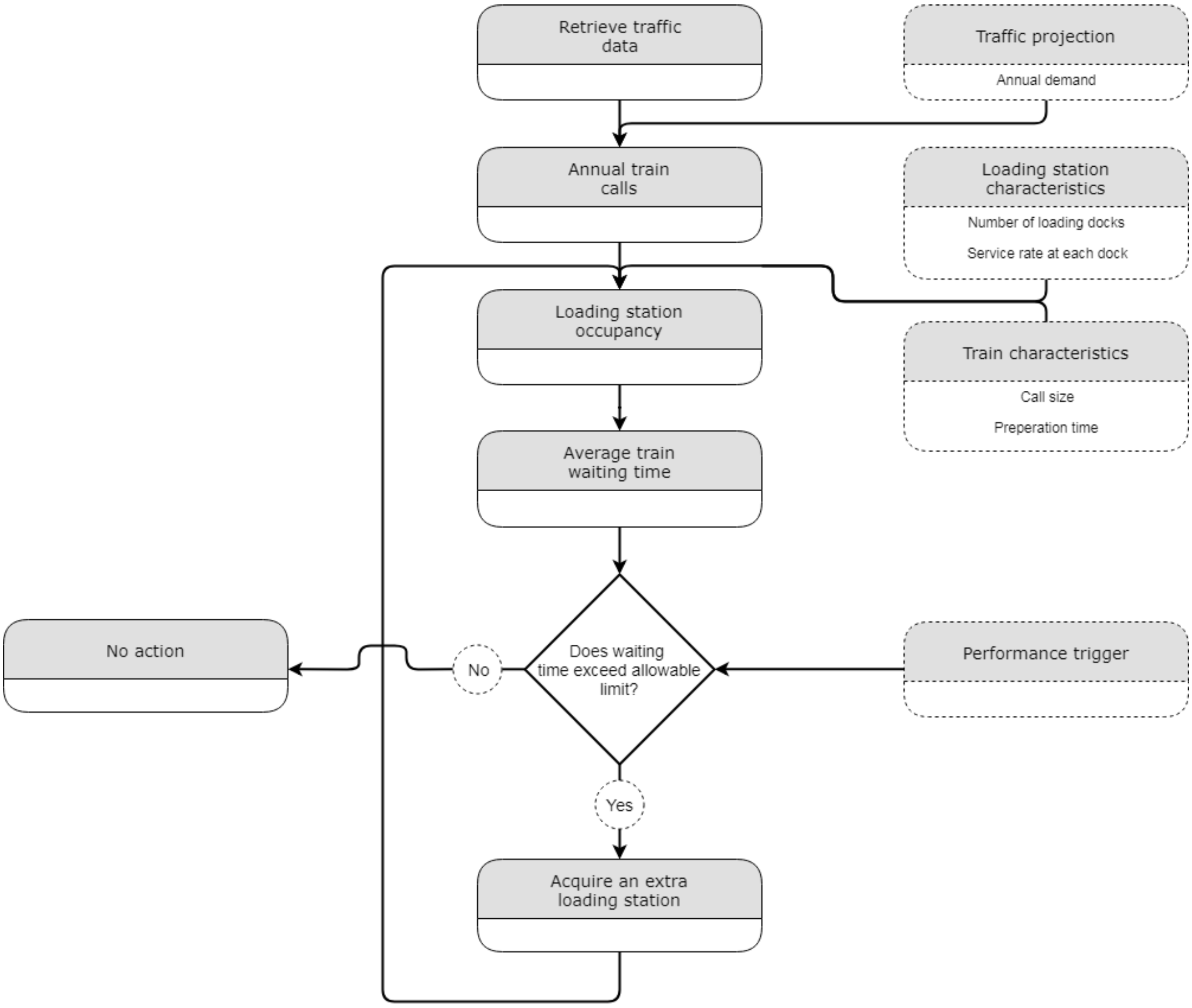


Figure 3-13: The decision tree related to the terminal's loading operations

In order to validate that the decision-making within the model is based on reliable assumptions, the results are cross-referenced with same method used to estimate queue forming at the berths. For this validation procedure we will compare the loading station occupancy and waiting times presented by the model with results gathered by applying queuing theory.

3.5.1 Application of theory

According to the queueing theory, the arrival rate of trains is, denoted by λ, is expressed using the following expression:

$$\lambda = \frac{\text{number of trains}}{\text{operational hours}}$$

The average service rate, denoted by μ, is computed using the following relation:

$$\mu = \frac{1}{\frac{\text{train call size}}{\text{loading rate}} + \text{preparation time}}$$

The station occupancy, denoted as ρ, can now be calculated:

$$\rho = \frac{\lambda}{\mu}$$

As all loading stations have the same loading rate, the average occupancy rate at each station will be identical. Once the occupancy rates are known, we can apply queuing theory to compute the average waiting time of trains arriving at the terminal. This waiting time is expressed as a factor of service time and the corresponding correlation is identical to one applied when assessing the waiting times of vessels (see Figure 3-4).

3.5.2 Validating model results

The theory is now compared with the model's results. The table below displays the relevant parameters in all three stages within this test scenario. The results achieved when applying the queuing theory can be found in the table's last two rows.

	Stage 1	Stage 2	Stage 3	
			1st station	*2nd station*
Traffic volume	1.200.000t	2.400.000t	1.200.000t	1.200.000t
Operational hours	5840 hours	5840 hours	5840 hours	5840 hours
Train call size	3.600t	3.600t	3.600t	3.600t
Number of train arrivals per year	334 arrivals	667 arrivals	333.5 arrivals	333.5 arrivals
Prep time per train	2 hours	2 hours	2 hours	2 hours
Loading rate	800 t/h	800 t/h	800 t/h	800 t/h
Berth occupancy (model result)	37%	74%	37%	37%
Waiting factor (model results)	29%	140%	4%	4%
Berth occupancy (based on theory)	**37%**	**74%**	**37%**	**37%**
Waiting factor (based on theory)	**29%**	**140%**	**4%**	**4%**

4 Optimizing Financial Performance

The process of translating traffic projections into a terminal design has been automated using the computer model discussed in chapters 2 and 3. This translation is done using a set of design assumptions, referred to as a work method, with each design assumption focusing on a specific element within the terminal. Chapter 2 explains how such work methods can be subdivided into two components; the first revolving around the method's performance triggers and the second refers to the temporal nature of those triggers. This chapter will focus a method's performance triggers.

Defining what performance levels are deemed acceptable for each asset can be seen as a trade-off; stricter performance criteria will ensure that a terminal will provide high quality service but will inevitably lead to more costs. Figure 4-1 visualizes such an example, in which stricter performance criteria (i.e. lowering of the acceptable waiting times) leads to an increase in capital expenditures.

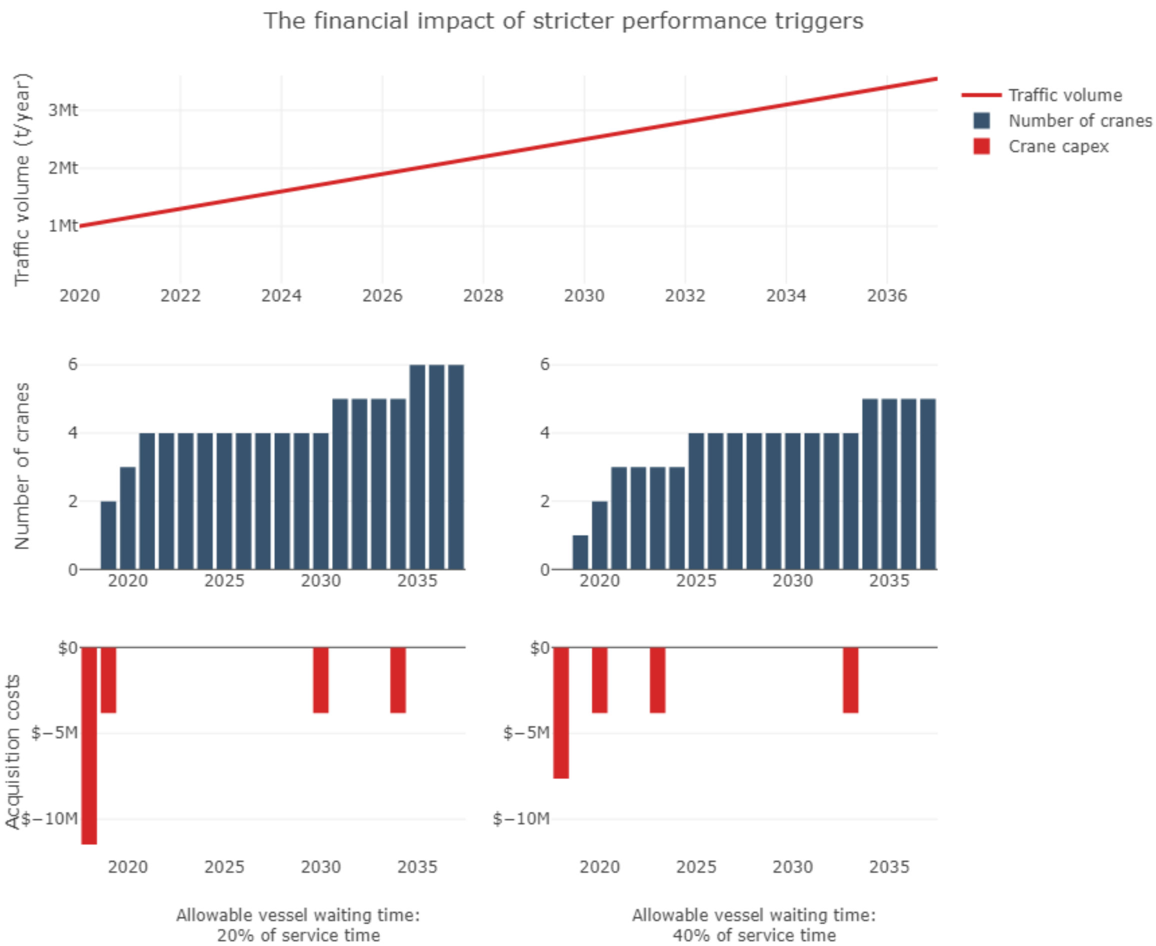


Figure 4-1: The financial impact of stricter performance triggers

This chapter will discuss how far a terminal element's performance can degrade before initiating a capacity-expanding investment. Literature provides an initial answer to this question, but can these triggers be further optimized? Through the following assessment we will find the answer to our last research question: *"How can the performance triggers used within terminal planning be altered in order to optimize an agribulk terminal's financial performance?"*

In order to be able to answer this question, the developed computer model is used to evaluate the financial impact of individual performance triggers based on the traffic scenario shown in red in Figure 4-2. This is done by designing numerous terminals using the same, identical traffic scenario, while slightly altering the underlying performance triggers in each run. After each design is converted into a set of cashflows and compounded into an NPV, the financial implications of the various performance triggers become clear.

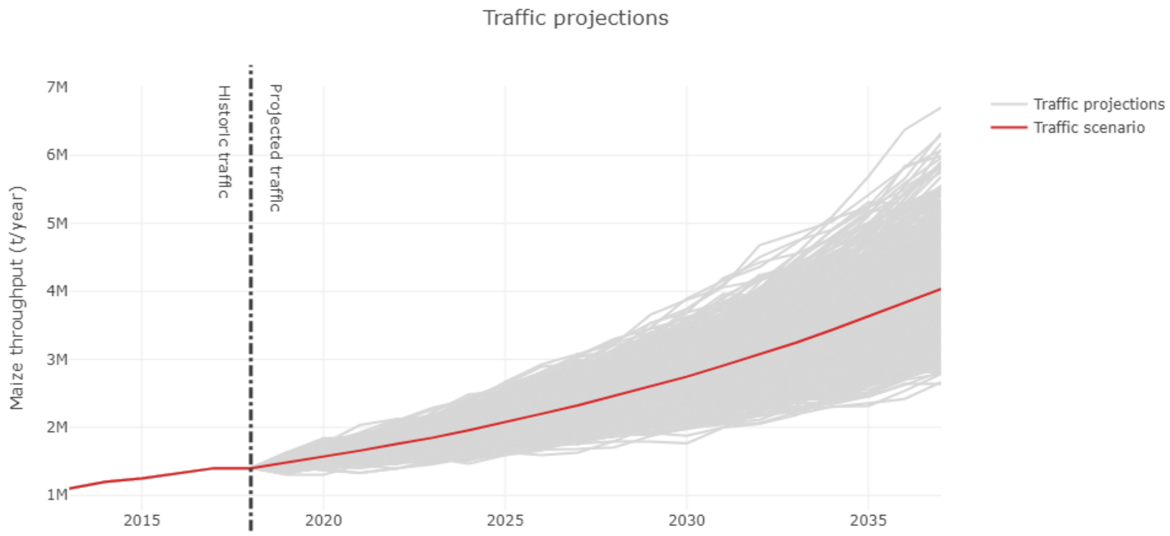


Figure 4-2: Traffic scenario used for the assessment of performance triggers

When translating a traffic projection into a high-level terminal design, results have showed that there are three main performance triggers that influence a project's viability. Each performance trigger will be discussed separately in dedicated sections within this chapter. The first is the *allowable vessel waiting time*, which drives the investments related to the receiving operations on the terminal such as quay wall extensions and crane acquisitions. The second trigger that forms an important component in terminal feasibility is the *dwell time* of the cargo unloaded from the vessels. The final performance trigger that will be evaluated in this chapter is the *allowable train waiting time*, which dictates the investment strategy of the terminal's train loading operations.

It is important to note that the investment triggers related to the terminal's internal transport operations, i.e. the belt conveyors used between the quay, storage facilities and loading stations, are not subject to individual optimization. This is because that, within this study, the investments in conveyor expansion have been geared to the assets the conveyors are coupled to. In other words, conveyor expansion is dictated by the number of cranes on the quay and the number of stations at the train loading bay.

4.1 Allowable vessel waiting times

This first section will inspect the design assumptions related to the terminal's receiving operations. Within the model, the average waiting time of vessels at the terminal has been identified as the key performance indicator for the operations at the quay. As traffic volumes increase over the years, the number of calls at the terminal increases. This increase in calls leads to a rise in berth occupancy, which ultimately leads to an increase in vessel waiting times. For more information regarding the computation of vessel waiting times please consult the dedicated section within the chapter on model validation (section 3.1).

Stricter performance criteria, in this case a lowering of the allowable waiting time of vessels, will lead to higher unloading capacity requirements at the quay. This ultimately raises and expatriating acquisition costs, i.e. more cranes are required earlier on in the project. Both aspects negatively influence the project's viability, keeping in mind the time value of money (i.e. discount rates). All in all, if we would ignore the negative consequences of an increase in waiting times at the terminal (i.e. shipping lines may start to use alternative terminals), a loosening of the performance criteria will always lead to an increase in project viability (see Figure 4-4a).

However, in reality, a terminal developer copes with the following trade-off: on the one hand allowing longer waiting times will reduce costs affiliated to the quay and unloading equipment, increasing project viability. On the other hand, this will lead to poor terminal performance, reducing the terminal's attractiveness and possibly suppressing demand. Therefore, this negative consequence should be financially quantified before being able to optimize such an investment trigger.

Monetizing the increase in average vessel waiting time was done by integrating vessel *demurrage rates* into the computer model. A demurrage rate is a fee that is paid by the terminal operator to the shipping line which operates a vessel that experiences excessive waiting times at the terminal (Daas 2018; MTBS 2018; Schuurmans 2018). Within the model, this demurrage rate is calculated as follows: each vessel class is assumed to have a time window in which it expects to be unloaded at the terminal. The default duration of the time window is based on interviews with terminal operators (Daas 2018; Kranendonk 2018). Once the total time at the terminal exceeds this time window, the terminal operator starts to experience hourly demurrage costs. Such demurrage rates are based on current daily charter rates (Clarksons 2018a) and are class-specific (see Figure 4-3). Based on the current market, the demurrage rates for Handysize, Handymax and Panamax are assumed to be \$333, \$375 and \$460, respectively. Now, as waiting times increase due to the relaxation of performance criteria, demurrage rates will act as a negative feedback, suppressing project value once vessel waiting times get too high (see Figure 4-4b).

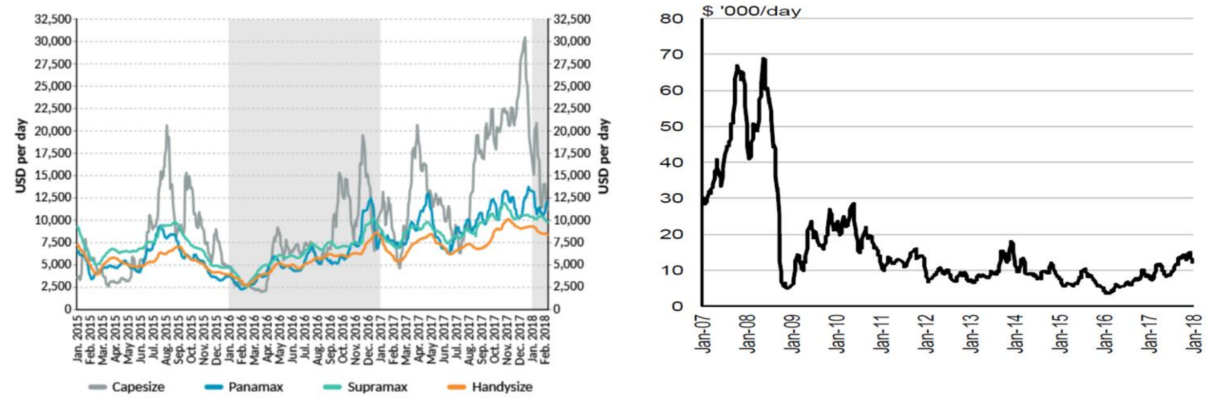


Figure 4-3: Current (left) and historic (right) bulk charter rates (Clarksons 2018a; Sand 2018)

However, as demurrage rates are coupled to market fluctuations in this approach, the optimum value of a performance trigger will remain pegged to real-time charter rates. This has been tested by applying excessive charter rates, coming close to resembling the days leading up to the financial crash in 2008, during which charter rates were around \$70.000 a day (see Figure 4-3).

The result of such excessive demurrage rates (1300 \$/hour) are shown in Figure 4-4c and tell us two things; the first is that high charter rates have the potential to suppress project value. However, it is highly unlikely that terminal operators would be willing to fully compensate shipping lines based on such high, somewhat opportunistic, charter rates (MTBS 2018). The second aspect that becomes clear is that the optimal allowable waiting time is inversely correlated to demurrage cost. In times of low charter rates, it is financially attractive to allow longer waiting times at a terminal before initiating a capacity-expanding investment.

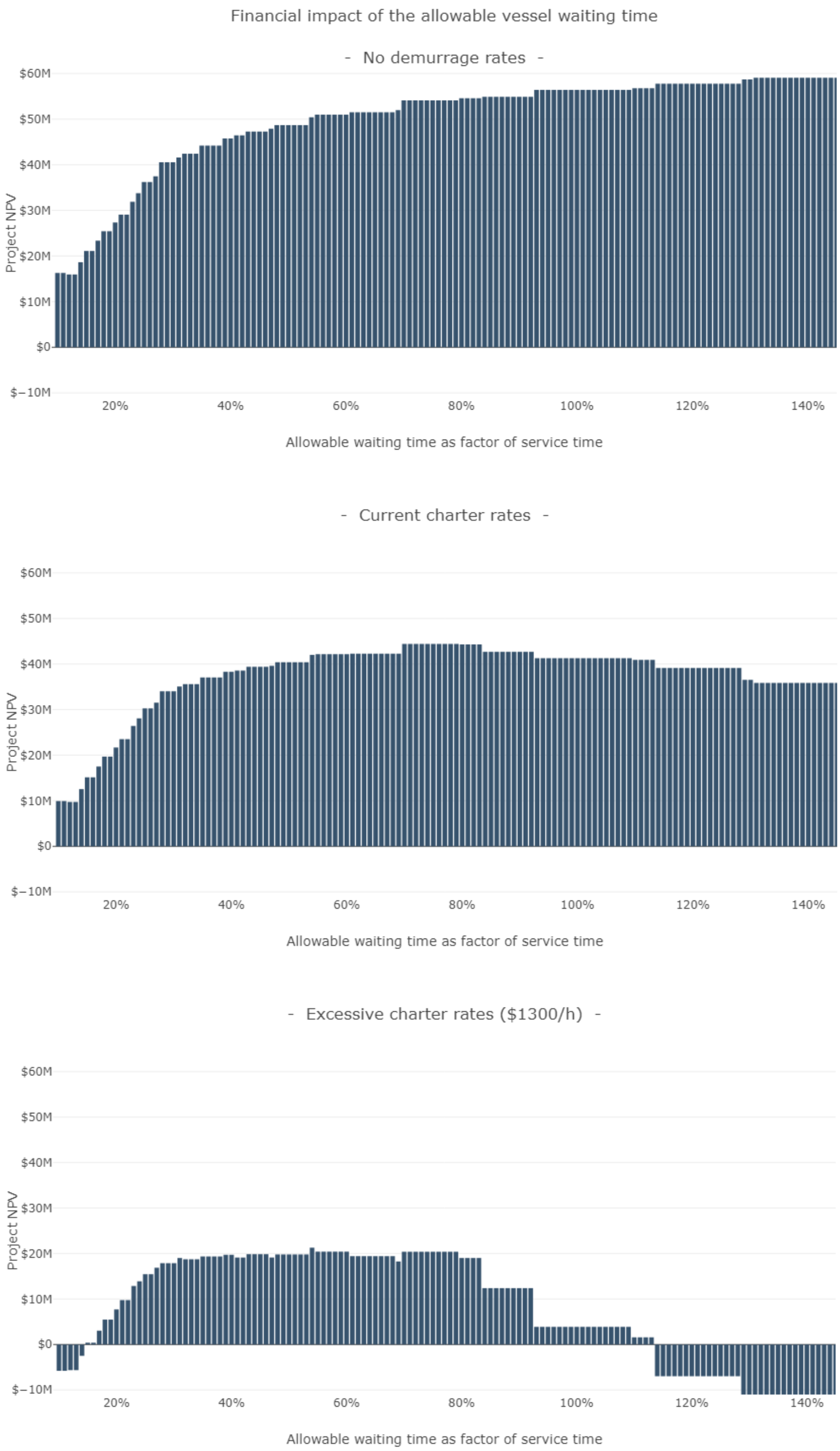


Figure 4-4: The influence of charter rates

It is expected that demand and supply on the shipping market has reached an equilibrium and will remain stable for the foreseeable future (Sand 2018). Data gathered by Bimco, a shipping consultant, regarding the supply and demand trends within the global bulk fleet confirm this (see stable utilization rates at around 70% in Figure 4-5). This implies that using current charter rates as a basis for the optimization of acceptable vessel waiting times seems reasonable.

Figure 4-5: Supply and demand on the global bulk shipping market

Existing guidelines, published by PIANC, state that terminal investments are typically based on maintaining an average ratio of waiting time to service time between 20% and 30% for bulk terminals (PIANC 2014). However, the financial impact of such a guideline has been analyzed using the computer model (see Figure 4-6), in which the guidelines have been added as a comparison. The model was run using the traffic scenario shown in Figure 4-2 and results show that if such a terminal were to incorporate the notion of demurrage rates into its business model, waiting times could be allowed to rise to 70% of berth service time, unlocking substantial project value.

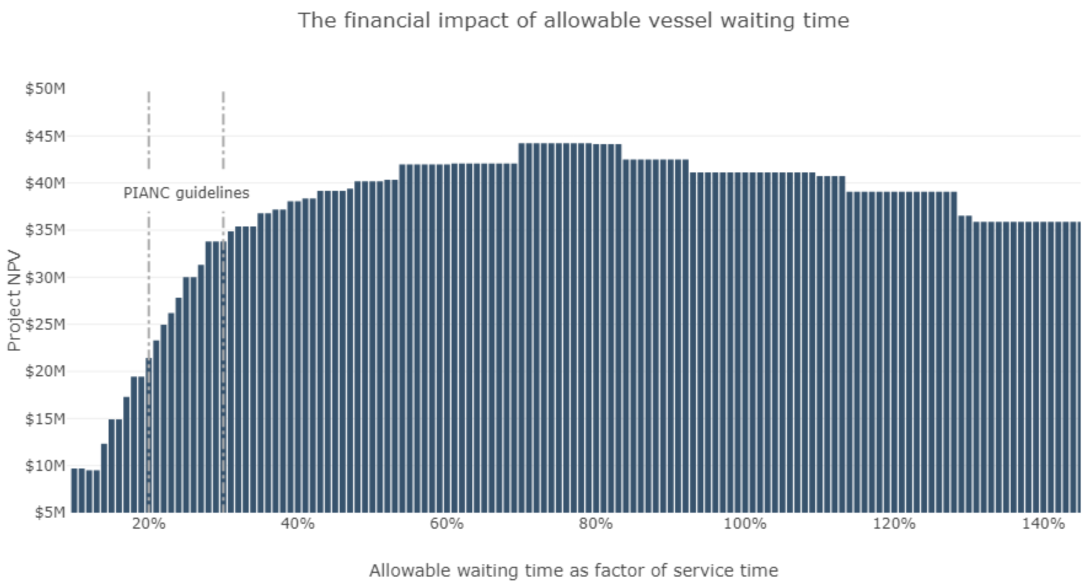


Figure 4-6: The financial impact of the allowable vessel waiting time

Furthermore, three economic scenarios were developed in order to assess how the performance trigger behaved under various market conditions. The first scenario resembles a steady, predictable growth of traffic volumes. The second scenario feature an erratic traffic growth and the final scenario simulates a sudden three-year shock to traffic volumes due to a crisis for instance. The results are shown in Figure 4-7.

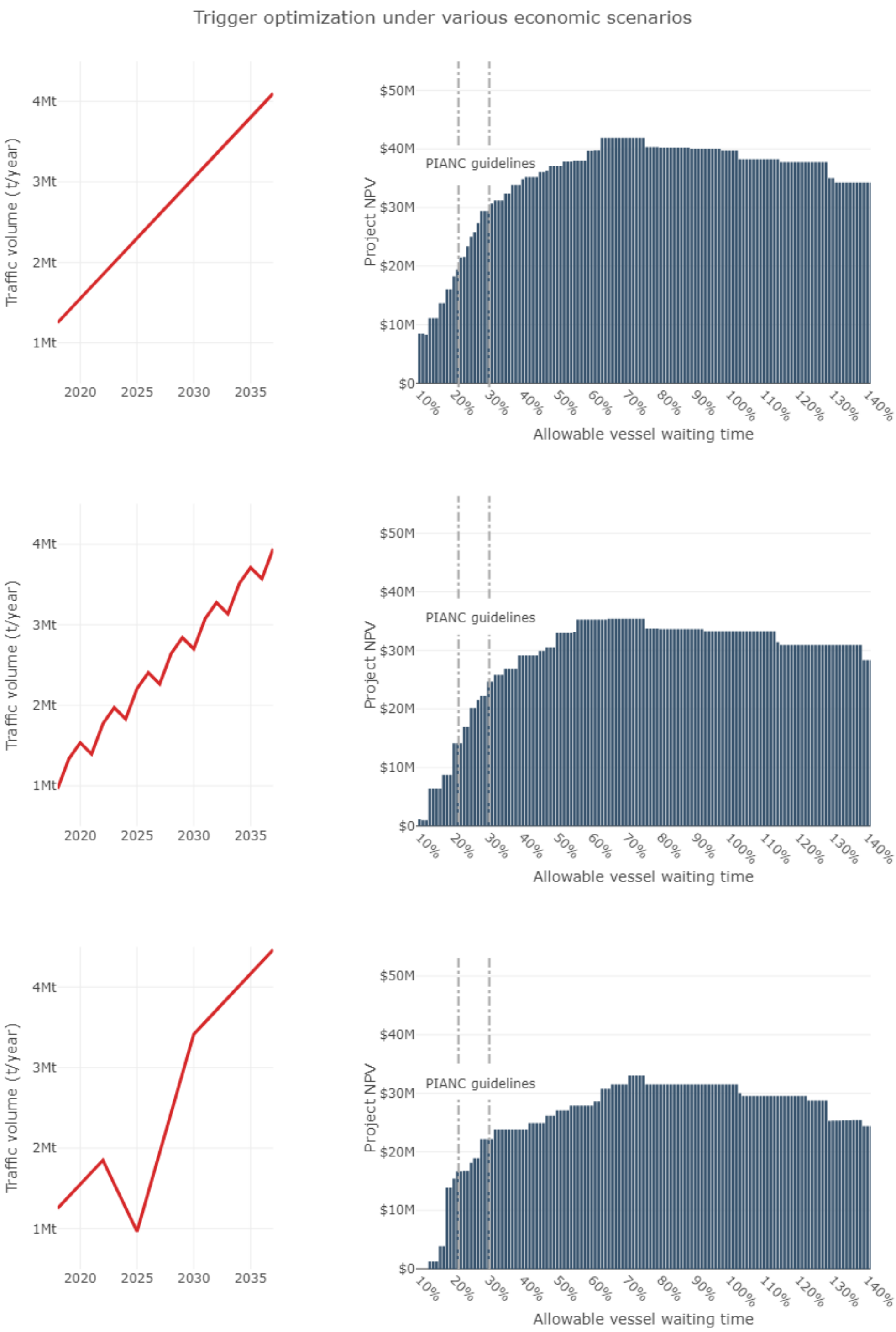


Figure 4-7: Sensitivity to market volatility

These results show that conventional guidelines for vessel waiting times at import grain terminals are quite conservative from a financial point of view. Accepting longer waiting times could offer a substantial capex reduction for terminal operators but would require them to integrate the concept of demurrage rates into their business model. Within the Netherlands, certain terminals have already integrated demurrage rates into their business model. One such example is the iron ore and coal import terminal of TATA Steel in IJmuiden.

This study will not be able to give a single optimal value for the allowable waiting time for vessels, as the optimum is influenced by the fluctuation of bulk charter rates and, to a lesser extent, traffic volume. However, it is safe to conclude that the PIANC guidelines are sub-optimal from a financial perspective. Results show that, if a terminal were to incorporate the notion of demurrage rates, waiting times could be allowed to rise to 70% of berth service time in order to improve project viability. Allowing higher waiting times is especially beneficial in markets that show signs of high volatility.

4.2 Storage dwell time

This second section will inspect the design assumptions related to the terminal's storage operations. The design of a terminal's storage has two major contributing factors; the first is the nature of the imported material flow, does the cargo arrive in Handysize vessels or large Panamax vessels? The second aspect is the expected *dwell time* the cargo. How long will the cargo have to be stored on the terminal before it is loaded into a form of hinterland transport (in this case trains)?

Guidelines state that storage capacity should always be sufficiently large to be able to store a single load of the largest vessel that is expected to call to port. Regarding the dwell time of cargo, literature states that efficient single user stockyard operations will roughly turn over inventory 20 times a year (PIANC 2014). This implies that that for a terminal operating 365 days a year, it can be assumed that the average dwell time is about 18 days.

The financial impact of commodity dwell time has been analyzed and the results are shown in Figure 4-8. It is clear from the results that terminal operator will always want to minimize commodity dwell time in order to increase project value. Furthermore, terminals boasting low dwell times are bounded by the fact that they have to be able to accommodate the entire cargo of the largest vessel calling to port. In such cases, bypass systems in which hinterland transport is loaded directly from the vessel may prove beneficial. Lastly, results show that although commodity dwell times severely impact a grain import terminal's project feasibility, the impact of a volatile market on storage costs is minimal.

In some cases, strategic storage of large volumes of grain is deemed favorable. In countries with severe seasons for instance, crop supply heavily outweighs demand in the harvesting season, resulting in a slump in price. Strategic storage can help suppress price volatility by storing excess supply in such a case. In other countries, strategic storage may also form a part of a country's policy regarding food security, in which the strategic storage forms a mitigating measure against natural disasters such as droughts (Olajide and Oyelade 2002). However, the results from the computer model show that such strategic measures, which require large storage facilities due to extremely high commodity dwell times, cannot be expected to be taken by terminal operators without requiring compensating financial measures (higher handling rate, daily storage rates etc.).

Figure 4-8: Assessing the financial impact of storage dwell times

4.2.1 Allowable train waiting times

The final performance trigger that will be subject to optimization will be linked to the design assumption revolving around the loading operations on the terminal. Similar to the approach used to analyze vessel waiting times, the average waiting time of trains arriving at the terminal has been identified as the key performance indicator for a terminal's loading operations. As traffic volumes increase over the years, the number of train calls at the terminal will increase. This increase in calls leads to a rise in occupancy rates at the loading stations, which ultimately leads to an increase in train waiting times. In this study, it has been assumed that all train traffic is in the form of so-called block trains, operating between the terminal and a single inland destination on a regular, i.e. daily or weekly basis. The wagons are kept together, and the combination is only split up for repair or maintenance works. Such trains are typically only used for the transport of just one commodity, maize in this case, and significantly brings down the cost of shunting operations (default preparation time of trains has been set to two hours in the model) (PIANC 2014). For more information regarding the computation of train waiting times please consult the dedicated section within the chapter on model validation (section 3.5).

Applying stricter performance criteria, in this case lowering the allowable waiting time of trains at the terminal, will lead to higher loading capacity requirements. This will result in more loading stations earlier on the project, increasing the project's capital expenditures.

However, in contrast to the shipping market, it has proven difficult to gather charter rates for freight trains, making it difficult to monetize the negative impact of increased train waiting times. Allowing trains to wait longer before being loaded always positively influences a project's feasibility in absence of the negative financial feedback related to the train waiting costs (see Figure 4-10). Therefore, for this study, the acceptable waiting time for trains arriving the terminal has been set at 50% of service time, based on reference projects in Eastern Europe (MTBS 2018).

Furthermore, it has become clear that the design assumptions regarding train loading stations do not impact project viability as much as the design assumption related to quay operations. This has two reasons; the first is that train loading stations are a lot cheaper than quays. The second reason is that import grain terminals tend to require multiple train loading stations. This is due to the fact that trains have a relatively small call size compared to that of a vessel, requiring more loading stations than unloading berths. When following the notion of queueing theory, the impact of an increase in traffic on average waiting time decreases exponentially with the number of service stations present at the terminal. In other words, actual loading capacity tends to be the bottleneck at import grain terminals as waiting times (i.e. performance) will remain at acceptable levels even in cases with high occupation rates (see Figure 4-9).

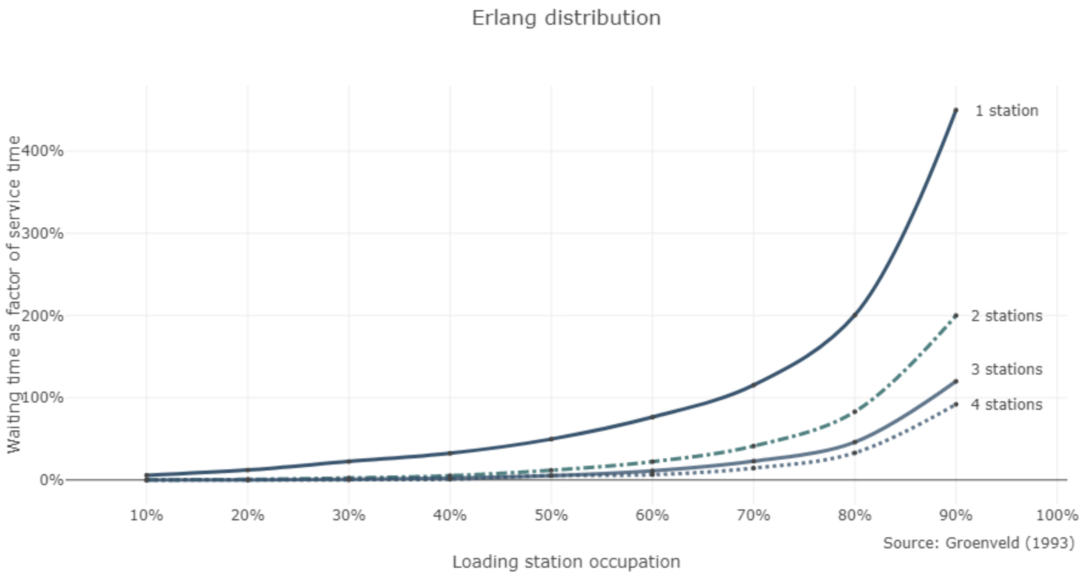


Figure 4-9: Suppressed impact of high occupation rates at the loading stations due to the number of service points

Figure 4-10: Assessing the financial impact of train waiting times

4.3 Conclusions

This chapter has shown how, through the use of a computer model, performance triggers related to various terminal assets have been analysed and compared to guidelines stated within literature. In doing so, this section has answered the following research question: "*how can the performance triggers used within terminal planning be altered in order to optimize an agribulk terminal's financial performance?"*

When examining the terminal's receiving operations at the quay, the average waiting time of vessels at the terminal has been identified as the key performance indicator on which investment decisions can be based. Defining what performance level is deemed acceptable can be seen as a trade-off; stricter performance criteria will ensure that the terminal provides a high-quality service (low waiting times) but will inevitably lead to an increase in expenditures.

By monetizing the negative consequences of low-quality service at the terminal using demurrage rates, the performance trigger related to quay operations (i.e. allowable vessel waiting time) has been optimized. Existing guidelines, published by PIANC, state that terminal investments are typically based on maintaining an average ratio of waiting time to service time between 20% and 30% for bulk terminals (PIANC 2014). However, results from the computer model have shown that, if a terminal were to incorporate the notion of demurrage rates into its business model, waiting times could be allowed to rise to 70% of berth service time, adding substantial value. Allowing higher waiting times is especially beneficial in markets that show signs of high volatility.

It is important to note that such a design guideline will remain pegged to real-time charter rates. However, according to shipping forecasts presented by experts at Bimco, supply and demand on the shipping market has reached an equilibrium, with utilization rates hovering at 70%, and will remain stable for the foreseeable future. This implies that using current charter rates as a basis for the optimization of acceptable vessel waiting times is reasonable.

When examining the design assumptions related to a terminal's storage facilities, it is clear that terminal operator will always want to minimize commodity dwell time in order to increase project value. Furthermore, results have shown that terminals boasting dwell times shorter than 10 days start to be bounded by the fact that they have to be able to accommodate the entire cargo of the largest vessel calling to port. In such cases, bypass systems which enable hinterland transport being loaded directly from the vessel may prove beneficial. Lastly, results show that although commodity dwell times severely impact a grain import terminal's project feasibility, the impact of a volatile market on storage costs is minimal.

To conclude, in absence of reliable daily train freight rates, the analysis of the performance trigger related to the loading of trains is inconclusive. However, results have shown that investments regarding the train loading bay do not weigh as heavily as investments related to quay or storage operations in respect to project feasibility. Therefore, this study has relied on the assumptions made in reference projects in eastern Europe, in which waiting time for trains equal to 50% of service time have been deemed allowable.

5 Comparing Work Methods

The process of translating traffic projections into a terminal design has been automated using the computer model discussed in chapter 2 and 3. Now that the model has been validated, we can use it as a tool to compare various work methods. A work method is a set of design assumptions, each focused on a specific element within the terminal and forms the basis for the translation of traffic projections into a terminal design. Such underlying design assumptions have been subdivided into two components; the component that will be discussed in this chapter is the temporal nature of the method's performance triggers.

Designing a terminal in the feasibility phase of a project is done to make a high-level assessment of the project's viability. All the revenues and expenditures over a project's lifecycle are estimated and brought together in order to estimate a project's value. It is the accuracy of this estimation that will be evaluated in this chapter. This will be done by comparing the estimating accuracy of three work methods. Each work method has a dedicated section within this chapter in which the process of establishing the method's accuracy is explained. The chapter will conclude by comparing the results of each work method and present the relevant conclusions. All in all, the answer to the following research questions will be provided in this chapter:

"How accurately can project value be estimated using a work method based on the assumption of perfect foresight?".

"How does the estimating accuracy of the current performance method compare to current common practice regarding the financial evaluation of terminals?"

"How does the estimating accuracy of the forecast method compare to established common practice regarding the financial evaluation of terminals?"

5.1 Input

In order to be able to compare the estimating accuracy of various work methods, it is important to ensure that each work method adheres to the same set of boundary conditions. The following set of boundary conditions have been applied to each work method:

- Identical traffic projections have been used to estimate a project's value
- Every work method must guarentee that at least 85% of traffic demand is met at all times
- The incurred handling fees per commodity have been kept at $9.80 per tonne in real terms (i.e adjusted for inflation)
- Identical project risk has been asumed, resulting in an universal real WACC of 9.23% (see *Discount rates*)
- Each terminal operates 5840 hours a year, resembling a port that is open for 16 hours a day for 365 days a year
- Vessel waiting times should stay below 30% of service time
- The terminal is assumed to turn over its inventory 20 times a year, resulting in a commodity dwell time of 18 days
- Train waiting time should be below 50% of service time

Note that the performance triggers are identical for each work method. For this report, traffic projections were solely based on the macro-analysis of maize trade trends. In order to be able to assess the various work methods, one thousand traffic projections were created that will form the basis for the comparison made within this chapter (Figure 5-1).

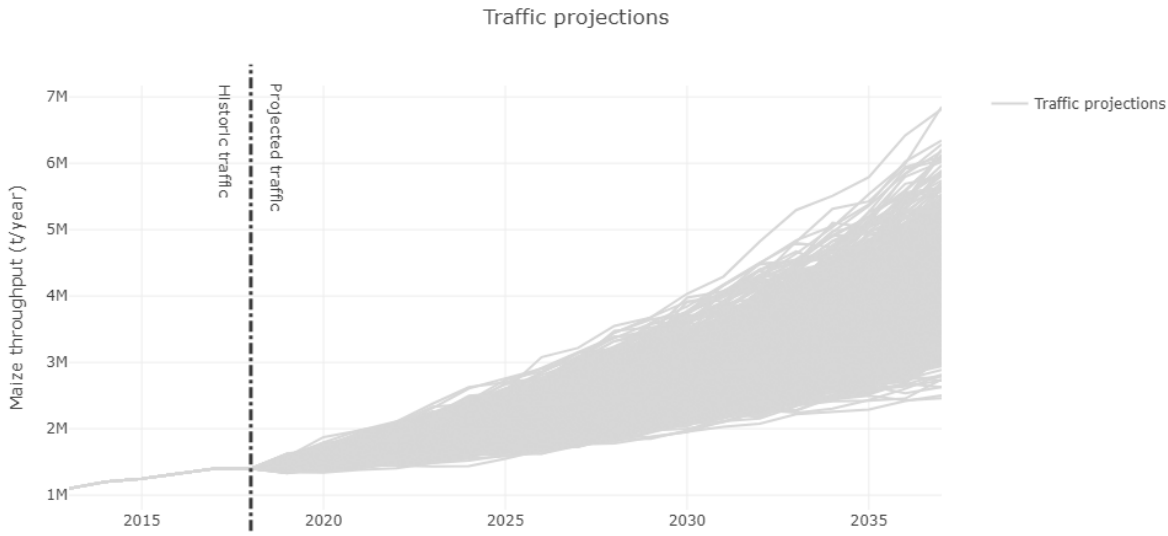


Figure 5-1: Traffic projections

5.2 Established common practice

The first work method that will be evaluated is the method based on *perfect foresight*, i.e. investment decisions are based on traffic projections that are presumed to always come true. However, this can be seen as a distortion of the actual decision-making process that takes place during a terminal's lifetime, in which decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decisions. Models that simulate investment decisions based on perfect foresight therefore ignore the negative consequences of over- or underperforming traffic developments and the fact that this leads to sub-optimal terminal development strategies. Nonetheless, this work method is currently seen as common practice and therefore forms a good benchmark against which other work methods can be compared. This approach has been summarized in the following research question: *"How accurately can project value be estimated using a work method based on the assumption of perfect foresight?".*

The various processes initiated by the computer model, when translating traffic projections into a terminal design using the work method based on perfect foresight, are visualized in Figure 5-2. Each process will briefly be discussed in the following sub sections.

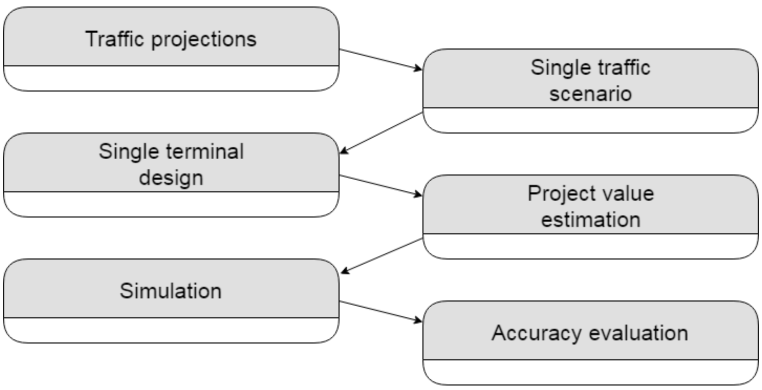


Figure 5-2: The design process using the perfect foresight method

5.2.1 Single traffic scenario

Irrespective of the type of work method used to design a terminal, the design process always starts off by analyzing the expected volumes of traffic that will flow through the terminal. In this chapter, the terminal designs are based on a wide array of traffic projections (see Figure 5-1). These projections can be seen as balanced, each having an equal probability of occurring and covering the entire future space.

However, if the translation of these projections into a terminal design is not automated, as is the case when adhering to current common practice, it is far too costly to translate each individual projection into an individual terminal design. Conventionally, in order to reduce the number of terminal design alternatives, this wide array of projections is consolidated into plausible traffic scenarios based on expert judgement. In this study the consolidation into a traffic scenario has been done numerically. Identifying which traffic projection is representative for such an array of projections is defined as the mean throughput, gauged at each year within the simulation and taken over the entire set of traffic projections. This median traffic projection is deemed a representative projection and is identified as a plausible traffic scenario. This scenario is shown in red in Figure 5-3.

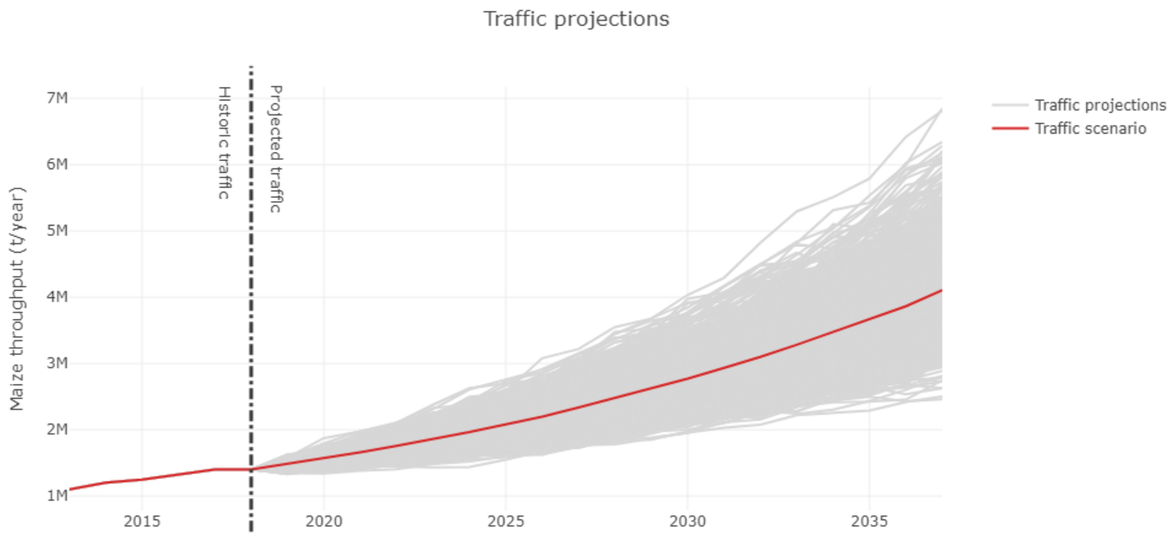


Figure 5-3: Identifying a traffic scenario

5.2.2 Single terminal design

Once the representative traffic scenario is identified, it is translated into a terminal design, adhering to the set of performance triggers that dictate what asset performance is deemed acceptable. This process is discussed in further detail in chapter 4. As the established common practice is based on the assumption of perfect foresight, investment decisions are based on future traffic volumes expected to take place at the time an asset would come online. The decision to lengthen a quay wall for example, is based on traffic volumes that will take place two years from now, the time it takes to construct a quay wall (see Figure 5-4). For more information regarding the temporal nature of triggers please consult section 2.2.4, *Temporal nature of triggers*.

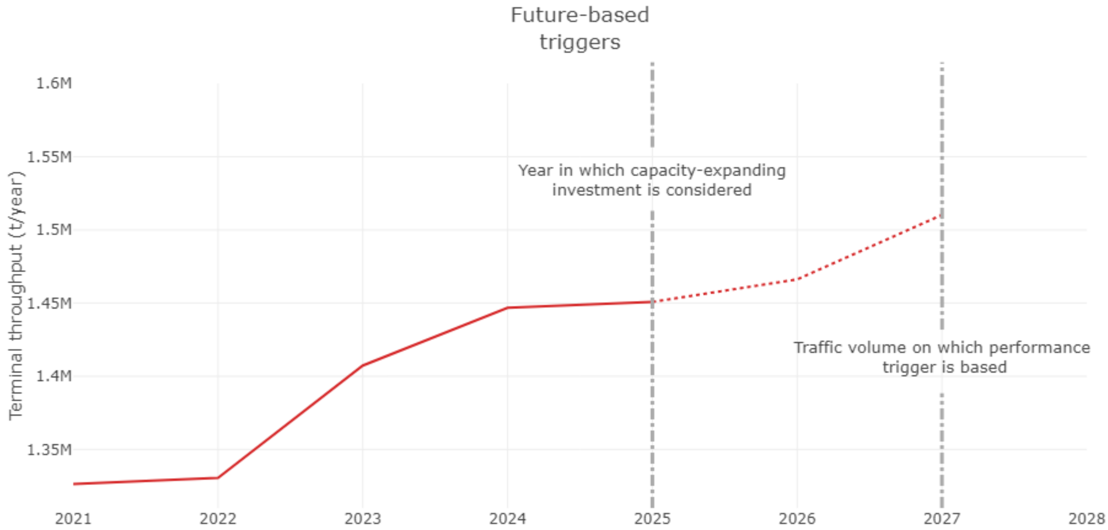


Figure 5-4: Future-based performance triggers

5.2.3 Project value estimation

Once the terminal design has been created, the financial characteristics of individual terminal elements are used to convert a terminal design into a set of annual cashflows. They are subsequently translated into present value terms using the project's weighted average cost of capital, or WACC. The yearly *pre-tax free cashflows to the firm* are subsequently aggregated and compounded into a cumulative value, referred to as the design's net present value, or NPV. This NPV can be seen as the estimated value of a project (Figure 5-5). This process is described in greater detail in section 2.2.10.

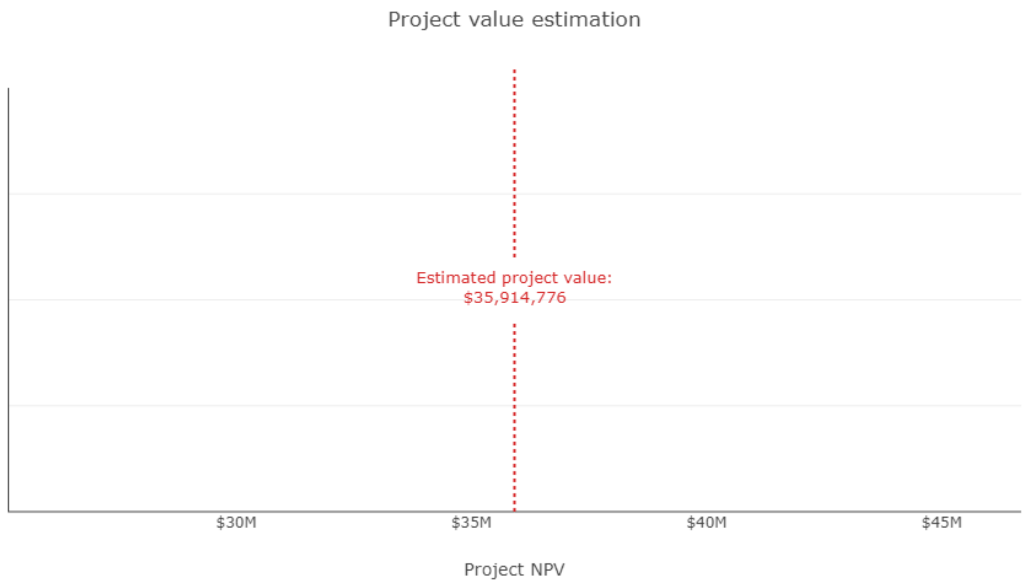


Figure 5-5: Project value estimation using the work method based on perfect foresight

5.2.4 Traffic simulations

Once the project value of the terminal has been estimated, the resulting terminal design is subject to a *new* set of traffic projections. This process simulates how a terminal design would have performed financially, had it been built, quantifying the method's response to unexpected traffic developments. This new set of traffic projections will be based on the identical market assumptions that are used to produce the traffic projections described at the start of this section (see Figure 5-1). After each simulated traffic development, the project's NPV is registered. The statistical distribution of the resulting set of NPV's is depicted in Figure 5-6.

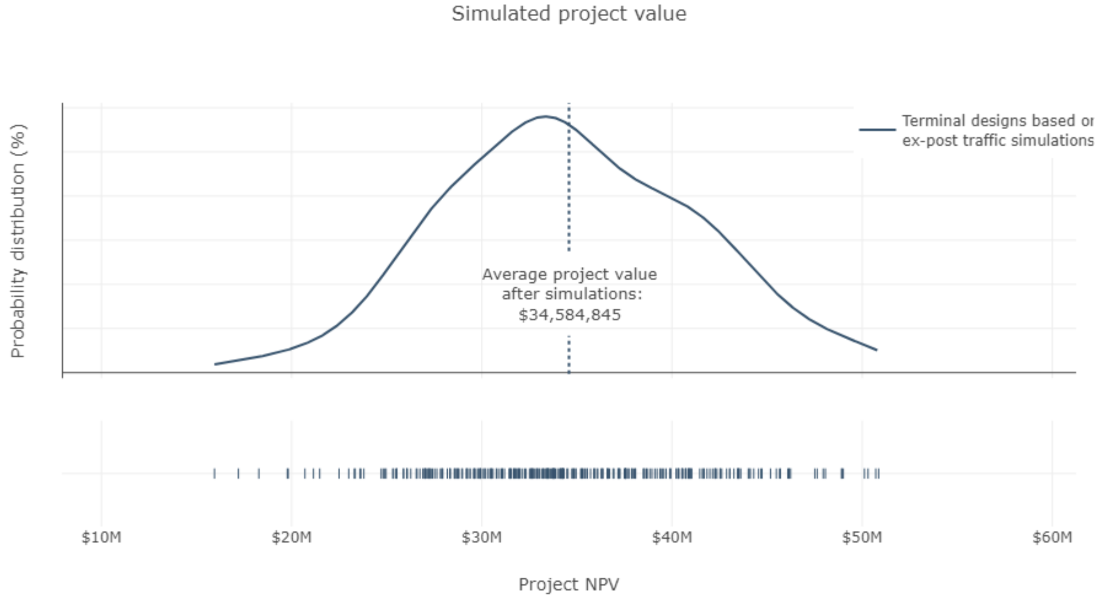


Figure 5-6: Registered project values after simulation using the work method based on perfect foresight

5.2.5 Accuracy evaluation

The estimated project value can now be compared with the NPV's generated in the simulation run, allowing us to assess the work method's accuracy (see Figure 5-7). The smaller the difference between the estimated project value and the averaged simulated project values, the better the work method is equipped to estimate a project's potential.

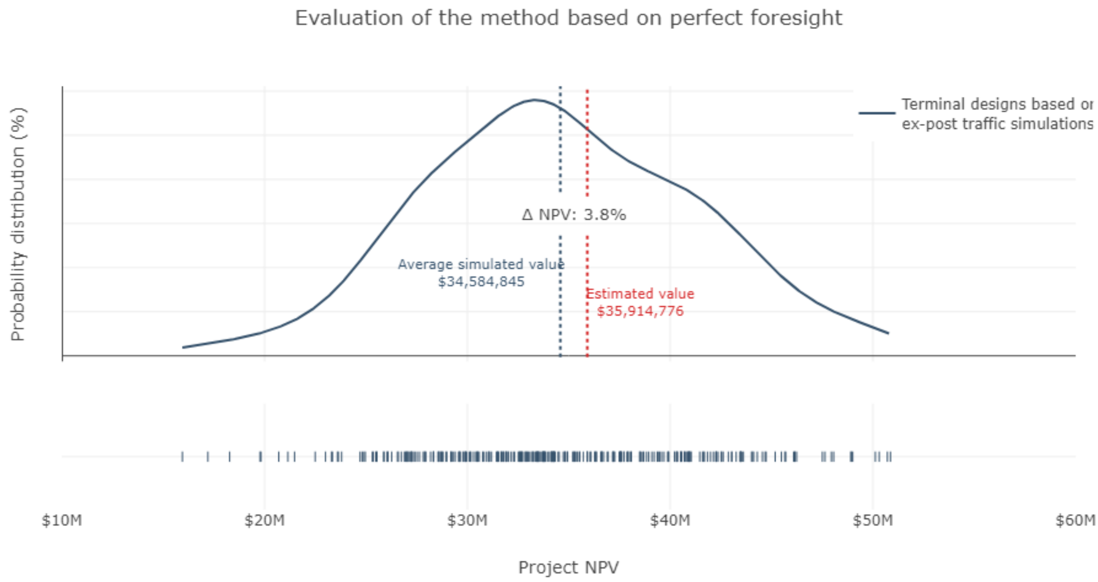


Figure 5-7: Assessing the accuracy of the work method based on perfect foresight

The results show that the work method based on perfect foresight, which is currently seen as common practice, indeed overestimates a project's value. Depending on the size of the project and the market's volatility this over-estimation is in the range of 3% (steady market growth) to 20% (volatile markets). This can be explained as follows: modelling investment decision based on the assumption of perfect foresight presumes projected traffic volumes to always come true. This is a distortion of the actual decision-making process that takes place in the real world. Decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decision. Therefore, in overperforming markets lagging terminal investments will lead to capacity saturation (i.e. unmet demand) and in underperforming markets overinvestment will lead to excess expenditures. Models that simulate investment decisions based on perfect foresight ignore such negative consequences of over- or underperforming traffic developments and the fact that this leads to sub-optimal terminal development strategies.

5.3 Current performance method

In an attempt to increase the accuracy when assessing a project's potential, a second work method was developed. This second work method bases its investment decisions on a terminal's current performance and is referred to as the *current performance method*. Basing design assumptions on a terminal's current performance implies that capacity-expanding alterations to a terminal design will be postponed until the performance of individual terminal elements degrades past a certain acceptable threshold. This acceptable threshold is in turn dictated by performance triggers.

Furthermore, this work method will capitalize on the fact that the translation of traffic projections into terminal designs has been automated. As the process is automated, each individual traffic projection can be translated into a terminal design with an accompanying set of cashflows and a resulting project value. This implies that, instead of producing a single project value estimate, this work method will be able to give a bandwidth of expected project values.

All in all, the extent to which this method incorporates the impact of unforeseen traffic developments will be assessed. This is done by comparing the method's estimating accuracy to that of the method based on perfect foresight, currently seen as common practice. This chapter will therefore help us answer the following research question: *"How does the estimating accuracy of the current performance method compare to the established common practice regarding the financial evaluation of terminals?"*

The various processes, executed by the computer model when applying the current performance method, are visualized in Figure 5-8. The traffic projections that form the bases of this approach are identical to the set used in the previous method (see Figure 5-1). Each process will briefly be discussed in the following sub sections.

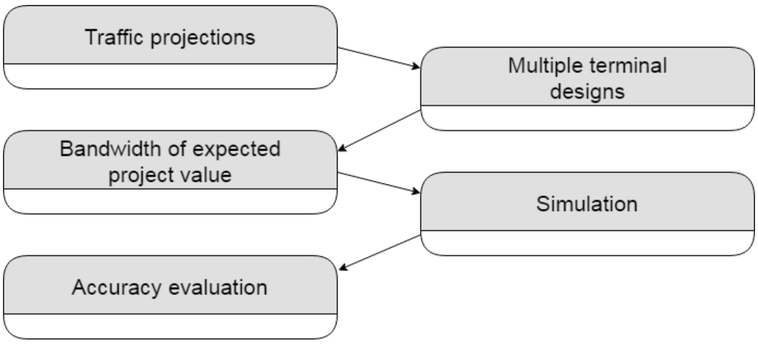


Figure 5-8: The design process using the current performance method

5.3.1 Multiple terminal designs

Once the array of traffic projections has been fed into the model, the first step is to translate each projection into an individual terminal design. Within this study, the traffic projections used to compare the various methods consists of 1000 possible trajectories, resulting in 1000 different terminal designs. Each design adheres to the identical set of performance triggers used within the previous work method. However, whereas the performance triggers in the previous method are linked to future traffic volumes, the triggers used within this method are pegged to the current performance of the terminal. Current, in this case, indicates that the traffic volume is gauged in the same year in which the investment decision is made (see Figure 5-9). The investments-decisions resulting from this method can therefore be seen as reactive, as they will first require demand to actually materialize before initiating a capacity-expanding investment.

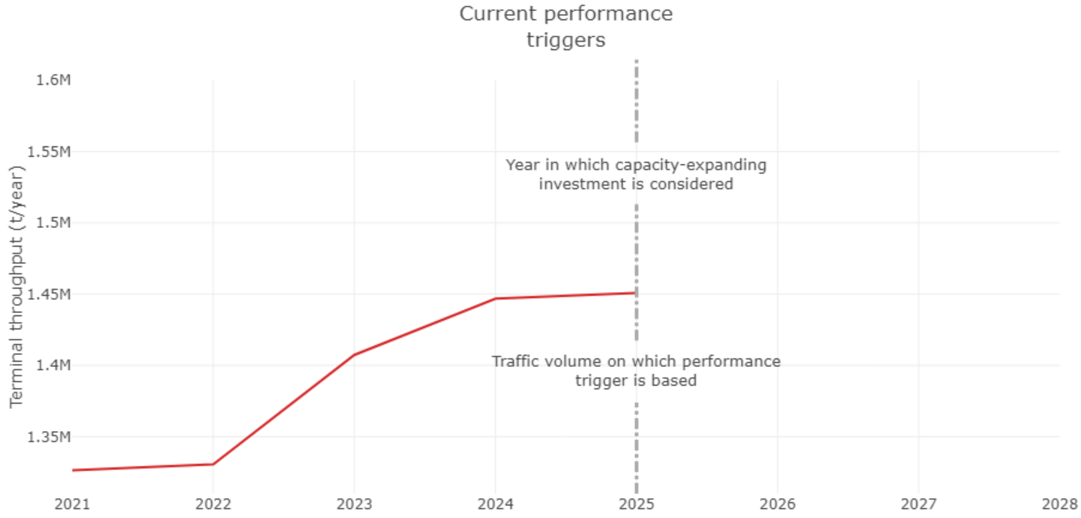


Figure 5-9: Current performance triggers

5.3.2 Project value estimation

Once the terminal designs have been created, each design is converted into a set of discounted cashflows after which the design's NPV, or estimated project value, is computed. In contrast to the work method based on perfect foresight, this work method results in a bandwidth of estimated project values (see Figure 5-10). The project value can now be estimated by averaging the resulting set of NPV's.

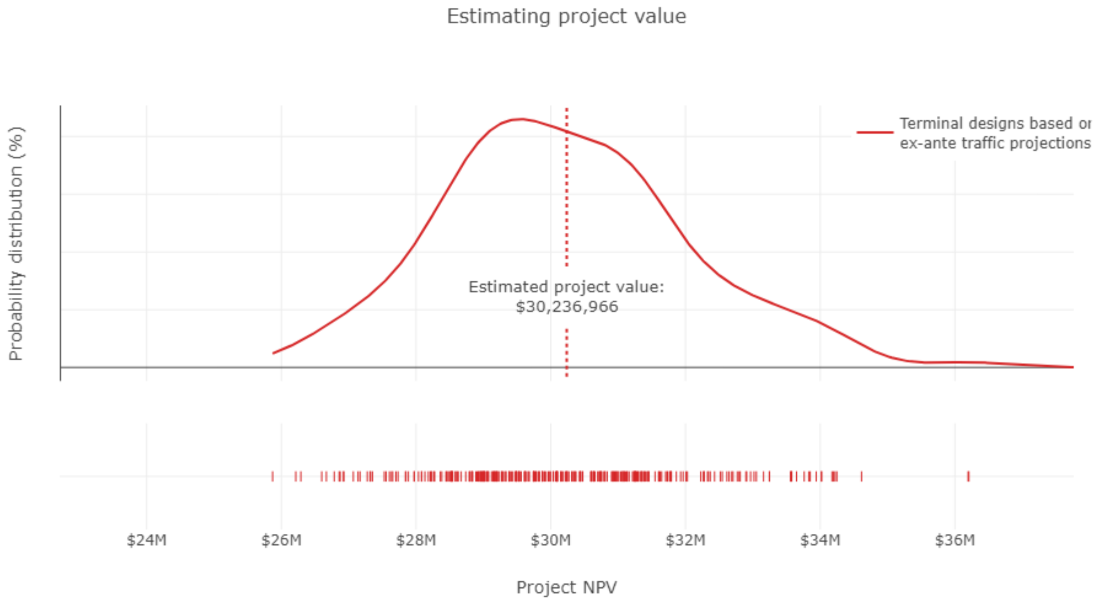


Figure 5-10: Project value estimation

5.3.3 Traffic simulations

The process of subjecting the work method to a new set of traffic projections simulates the method's response to unexpected traffic developments and is identical to the simulation process used in the previous method (see section 5.2.4). The statistical distribution of the resulting set of NPV's is depicted in Figure 5-11.

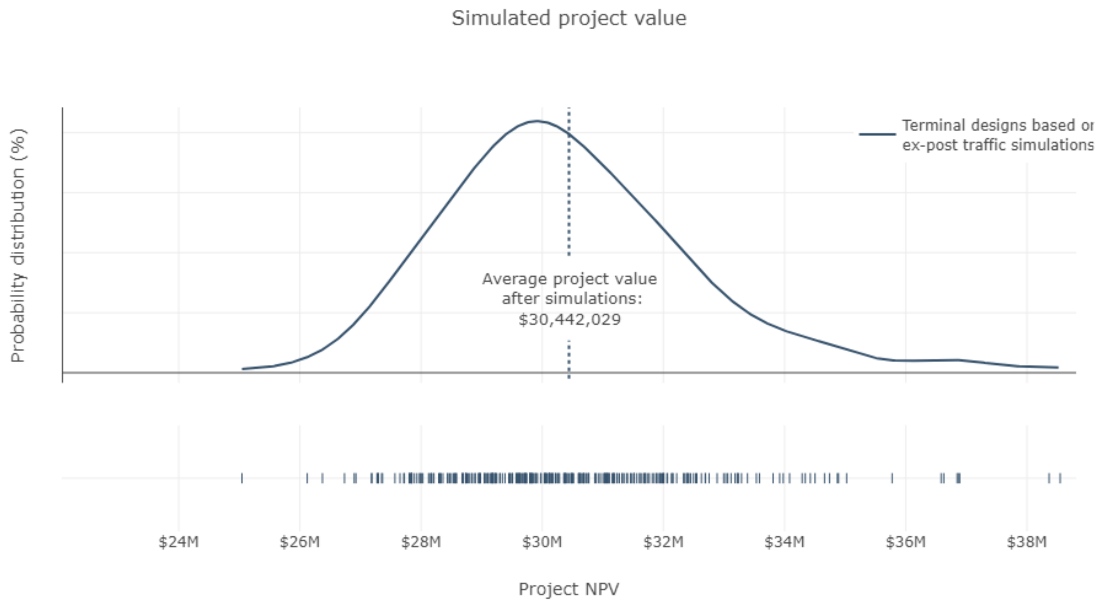


Figure 5-11: Registered project values after simulation using the work method based on current performance

5.3.4 Accuracy evaluation

Similar to the approach described in the previous work method, the estimated project value can now be compared with the NPV's generated in the simulation run, allowing us to assess the work method's accuracy (see Figure 5-12).

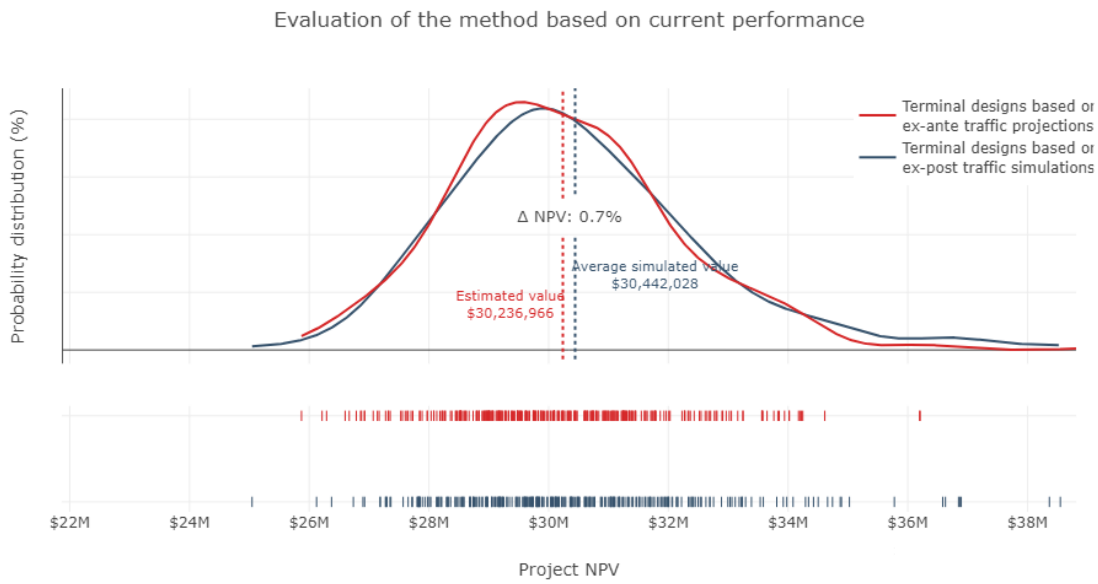


Figure 5-12: Evaluating the current performance method

The results show us three things; the first is that the estimated project value is much closer to the simulated project value, which represents the financial performance of the terminal had it been built. In other words, by applying a work method based on the current performance of a terminal, the project may still be susceptible to unexpected traffic developments but is less so than under the notion of perfect foresight.

The second aspect which can be derived from the results is that the spread in possible project values has become significantly smaller. This implies that the uncertainty, and thereby the risk, of the project is reduced. This positive development carries financial significance and could be fed back into the model by lowering the weighted average cost of capital for instance. However, such developments fall without the scope of this study.

The final aspect that is to be noted is that this work method significantly brings down the estimated value of a project. So much so, that the average project value of a terminal modelled using the current performance is lower than the average simulated project value based on the established common practice (see Figure 5-7). This can be explained by the fact that, when using this work method, the development initiates an investment at the moment it is already needed. This leads to a trailing terminal capacity and unmet demand. The next method will set out to improve project value by basing investment on forecasted volumes.

5.4 Forecast method

In reality, terminal decision-makers base their investment decisions on yearly traffic forecasts in a bid to expand terminal capacity in an effective manner. This often requires finding the optimum in fulfilling capacity requirements, delaying investments and avoiding excessive mobilization costs. The process of basing investment decisions on interim traffic forecasts will be simulated using the *forecast method*. This work method postpones terminal expansion until an asset's *forecasted* performance degrades past a certain acceptable threshold.

Similar to the previous method, the forecast method translates each individual traffic projection into a terminal design with an accompanying set of cashflows and a resulting project value. This implies that, instead of producing a single project value estimate, this work method will give a bandwidth of expected project values.

Whether this method addresses the impact of uncertain traffic developments will be evaluated by comparing the method's estimating accuracy to that of the method based on perfect foresight. The final research question discussed in this chapter therefore reads: *"How does the estimating accuracy of the forecast method compare to established common practice regarding the financial evaluation of terminals?".*

The various processes executed by the computer model are identical to one found in the current performance method. The only exception is that the process of making yearly forecasts, on which the performance triggers will be based, has been integrated into the model's terminal design process (see Figure 5-13). Each process will briefly be discussed in the following sub sections.

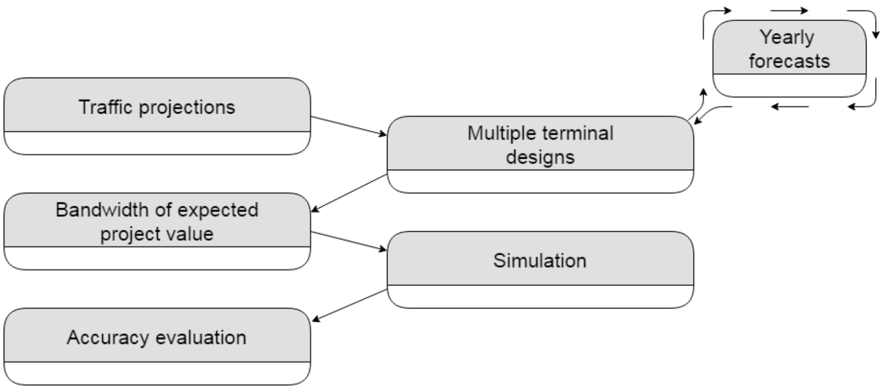


Figure 5-13: The design process using the current performance method

5.4.1 Multiple terminal designs

The process of converting numerous traffic projections into an array of terminal designs is identical to the process discussed in the previous work method (see section 0). However, whereas the performance triggers in the previous method are linked to the terminal's materialized traffic volumes, the triggers used within this method are based on forecasted traffic volumes (see Figure 5-14).

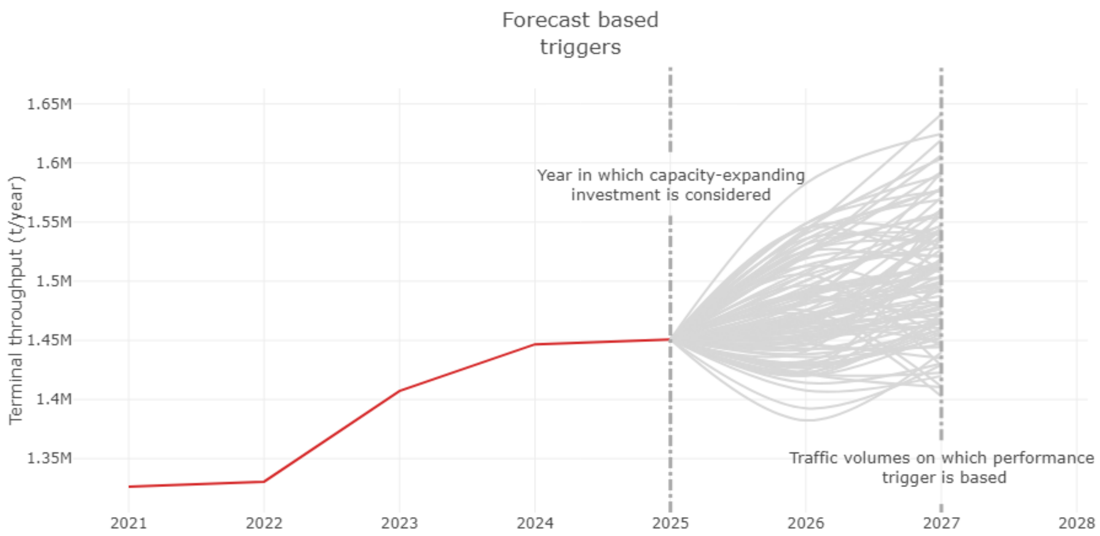


Figure 5-14: Forecast based triggers

5.4.2 Yearly traffic forecasts

This section sets out to clarify the forecasting methodology used within the computer model to create yearly traffic forecasts. There are two ways to classify various forecasting methods; a method can be seen as either statistical or judgmental. Statistical forecasts are applied when sufficient quantitative data is available, whereas judgmental forecasts are applied in cases where little or no quantitative data is available but sufficient qualitative data exists (van Dorsser 2015).

Within this study, the yearly forecasts are made using a statistical, *univariate* forecasting model. This means that the computer model sets out to identify patterns within materialized traffic volumes. Historic data points within the time series (in this case yearly traffic volumes) are used to forecast the next data point. Such historic data points are referred to as *lagged observations.* These patterns are then extrapolated into the near-future, providing a traffic forecast on which investment decisions can be based. After comparing the performance of various forecasting approaches, model results showed that linearly extrapolating lagged observations provided the most accurate short-term forecasts.

It is important to note that univariate forecasting methods are entirely based on internal datasets (i.e. historic values within their own time series, using no outside explanatory variables in their assessment) (van Dorsser 2015). As a result, such methods are not very suitable for long-term projections. This is due to the fact that forecasted values become increasingly reliant on the method's own forecasted values the further you progress into the future, increasing the chance of misrepresentation of reality. However, as the forecasting approach used in this study will only be used to forecast the near-future, this approach is deemed suitable. In this case the near-future is defined as two years; the time it takes to construct a quay wall, the asset with the longest time between acquisition and delivery.

Configuring the autoregression within the forecaster means finding a lag that allows the forecaster to make representative projections. A forecast based on 10 lags, for instance, implies that 10 historic data points are used to forecast the next data point. The number of lags needs to be sufficient to incorporate underlying, multi-year trends, but should minimize the effect of uncorrelated data, clouding the forecast and making it inaccurate. Identifying the optimal lag for the forecaster was done using historical maize consumption data of two sub-Saharan African countries; Nigeria and South Africa. The configuration has been visualized in Figure 5-16. The forecasting method was run multiple times, configured using varying lags. Ultimately, by assessing the residual error of each configuration, the lag configuration within the forecaster was set to five years as this led to the smallest error (see Figure 5-15). The resulting linear regression model can be written as follows:

$$T(t+\Delta t) = T_t + \Delta t \sum_{i=1}^{n} \frac{1}{n}\left(\frac{\partial T}{\partial t_t} + \frac{\partial T}{\partial t_{t-1}} \dots + \frac{\partial T}{\partial t_{t-(n-1)}}\right)$$

In which:

T	*Traffic demand in tonne per year*
t	*Timestep in years*
$t+\Delta t$	*Forecast horizon in years (with $\Delta t \leq 2$)*
n	*Number of lagged observations (with $n_{optimal} = 5$)*

The forecaster's performance has been visualized in Figure 5-17, in which the first subplot depicts a trivial test case; when traffic volumes grow in a strictly linear fashion, the forecaster will never make a mistake. In such a case, the forecasting method provides a project value estimate which is identical to the method based on perfect foresight (i.e. in which no mistakes are made either). The second subplot shows how the forecaster reacts to market shocks and the final subplot visualizes the typical forecasting accuracy related to the traffic projections used throughout this report.

Figure 5-15: Residual errors as a result of forecasting

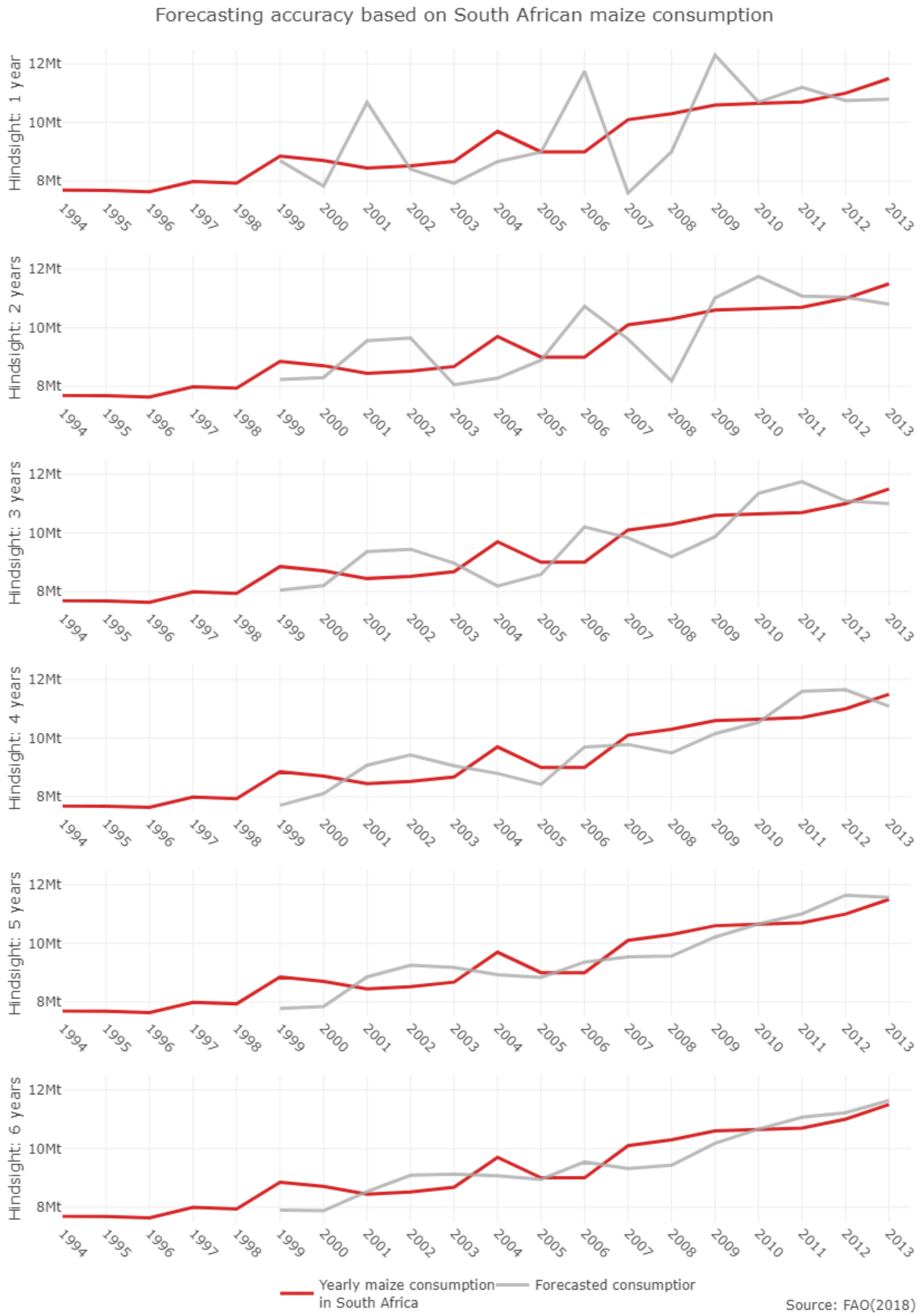


Figure 5-16: Forecasts based on South African maize consumption

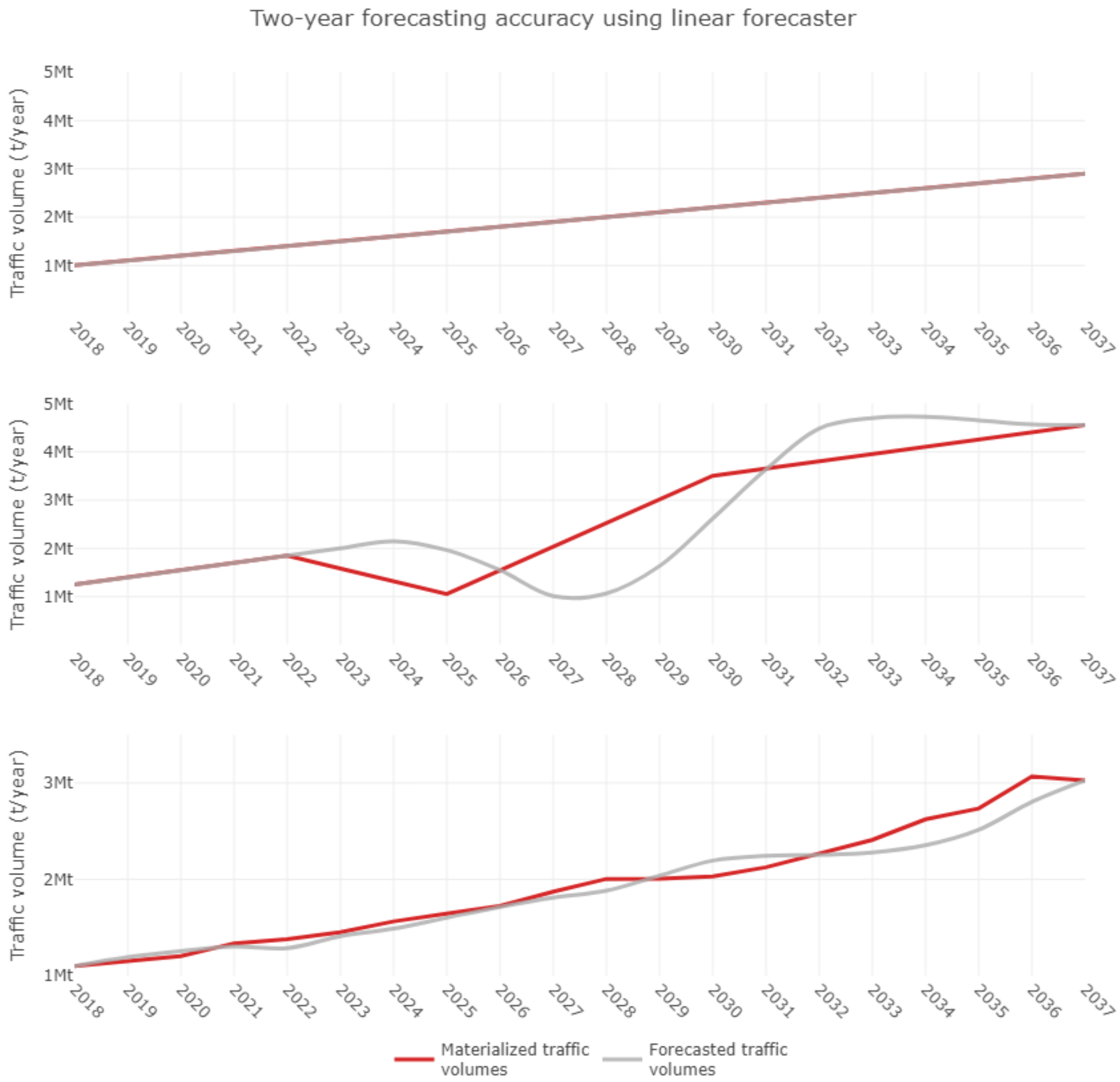


Figure 5-17: Two-year forecasting accuracy

5.4.3 Project value estimation

Once the terminal designs have been created, each design is converted into a set of discounted cashflows after which the design's NPV, or estimated project value, is computed. Such a set of NPV's are subsequently statistically distributed and the average value is seen as the estimated project value. This process is identical to the process discussed in section 5.3.2.

5.4.4 Traffic simulations

The process of seeding the work method with a new set of traffic projections simulates the method's response to unforeseen traffic developments and is identical to the simulation process used in the previous method discussed in section 5.2.4.

5.4.5 Accuracy evaluation

The estimated project value can now be compared with the NPV's generated in the simulation run, allowing us to assess the work method's accuracy. Again, the approach is identical to the one stated under the previous work method. The results have been visualized in Figure 5-18.

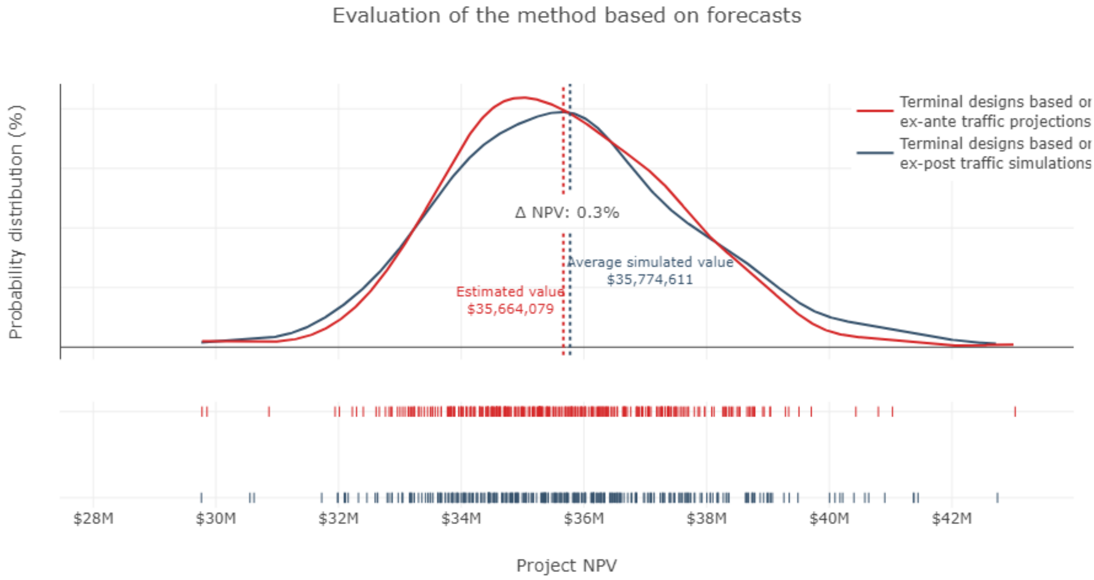


Figure 5-18: Evaluating the forecast method

The results show that assessing the value of a terminal using the work method based on forecasts is more accurate than the method based on perfect foresight. This is due to the fact that the project's estimated values are based on a wide array of traffic projections in contrast to a couple of plausible scenarios.

Furthermore, the work method shows signs of an enhanced financial performance compared to the work method based on current performance. Using this work method to model terminal development will provide a project value estimate which is lower than the established common practice based on the notion of perfect foresight, but the project's evaluation will be a more realistic one.

5.5 Comparing work methods

Up to this point, we have compared three work methods which can be used to model terminal development in order to assess a project's feasibility. The capability of producing a terminal with a high project value was tested together with the work method's estimating accuracy. The results of the various assessments are shown in Figure 5-19 and summarized in the table below.

	Common practice	Current performance method	Forecast method
Estimated project value	$35.914.776	$30.236.966	$35.664.079
Project value after simulation	$34.584.845	$30.442.028	$35.744.611
Standard deviation	$6.666.227	$2.092520	$2.052453
Accuracy	Overestimates by 3.8%	Estimates ± <1%	Estimates ± <1%

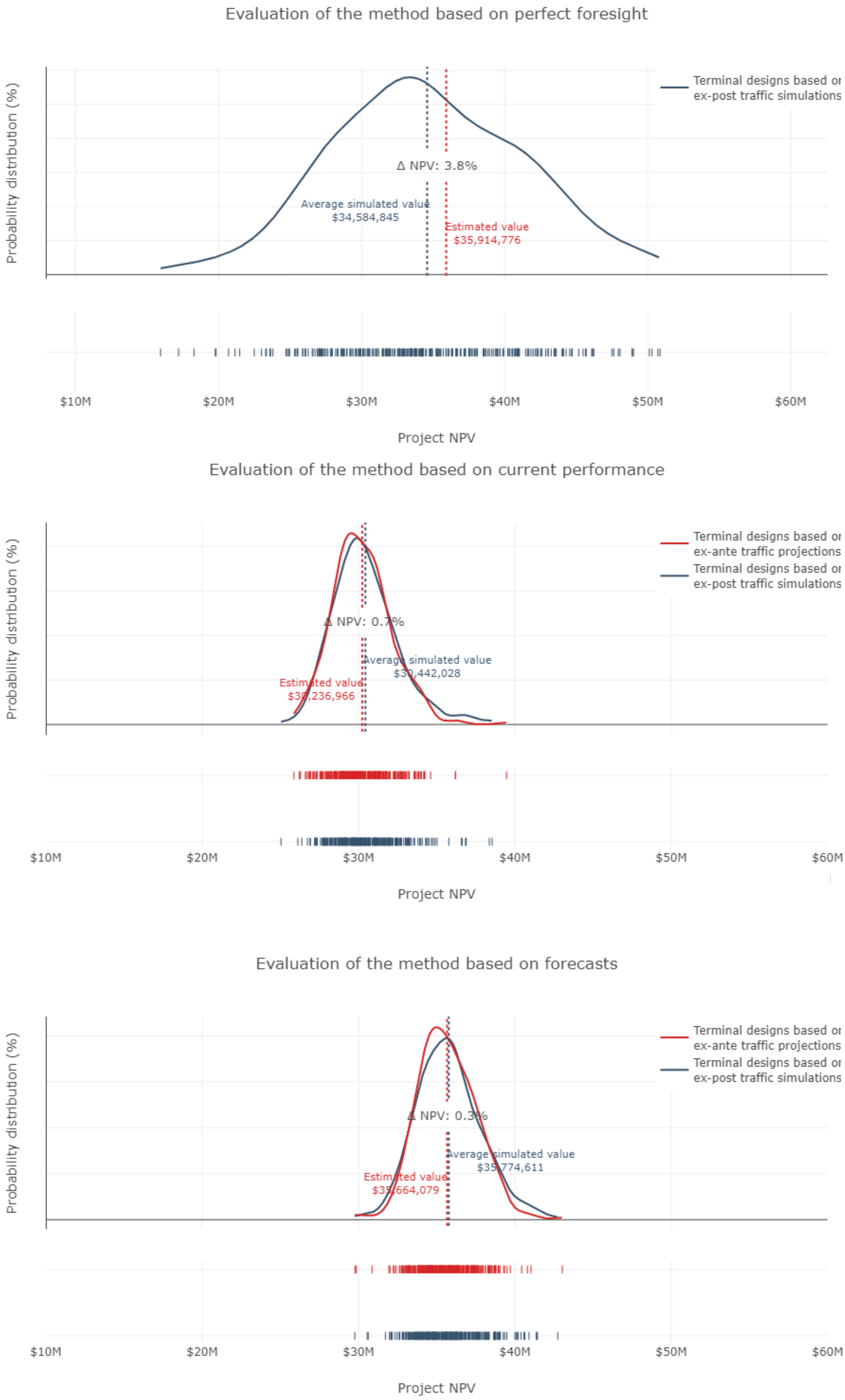


Figure 5-19: Comparing various work methods

5.6 Rerunning the trigger optimization

Up until this point, the comparison of various work methods within this chapter has been done by applying an identical set of conventional performance triggers in each approach:

- Vessel waiting times should stay below 30% of service time
- The terminal is assumed to turn over its inventory 20 times a year, resulting in a commodity dwell time of 18 days
- Train waiting time should be below 50% of service time

However, when comparing the financial performance of different methods, using identical trigger values will inevitably lead to errors within the comparison. Take the current performance method for instance. This investment approach can be seen as reactive (i.e. it requires traffic volume to materialize before initiating an investment) and therefore shows better financial results when using more conservative performance trigger. In this case the stricter trigger value compensates the fact that the investment would otherwise be initiated too late. In other words, each method has its own set of optimal performance triggers.

Chapter 4 has shown that the allowable vessel waiting time had a significant impact on a project's value. For this reason, the optimization regarding the allowable vessel waiting time was rerun. In this second round of optimizations, each run was conducted using a different work method (see Figure 5-20).

As the optimization in chapter 4 was based on the work method which is currently seen as common practice, the results based on the perfect foresight method are identical to the results shown in chapter 4. The optimal allowable vessel waiting time in this case is equal to 70% of service time (see Figure 5-20a).

The results based on the current performance method, show an optimum of 63% of service time (see Figure 5-20b). This finding is in line with the hypothesis presented at the start of this section; the optimal set of triggers are stricter in order to compensate the fact that investments would otherwise be initiated too late in this reactive investment strategy.

As the forecast method will occasionally lead to sub-optimal investments, due to a mismatch between the *forecasted* and *materialized* traffic volumes, it benefits from more lenient performance triggers. The optimum waiting time under these conditions is 77% of service waiting time (see Figure 5-20c).

Now that the optimal performance triggers have been identified for each work method, the comparison is rerun. The results are visualized in Figure 5-21 and summarized in the table below and tell us three things . The first is that the work method based on perfect foresight overestimates a project's value. Depending on the size of the project and the market's volatility this over-estimation is in the range of 3% (steady market growth) to 20% (tight margins and volatile traffic). The second is that the current performance method still underperforms from a financial point of view. The assessment of the final work method has shown that modelling a terminal based on yearly forecasts results in an accurate feasibility assessment while maintaining a high financial performance.

	Common practice	Current performance method	Forecast method
Estimated project value	$45.510.781	$39.831.371	$43.789.820
Project value after simulation	$44.042.366	$39.861.159	$43.356.637
Standard deviation	$5.204.568	$2.629.872	$3.662.902
Accuracy	Overestimates by 3.3%	Estimates ± <1%	Estimates ± <1%

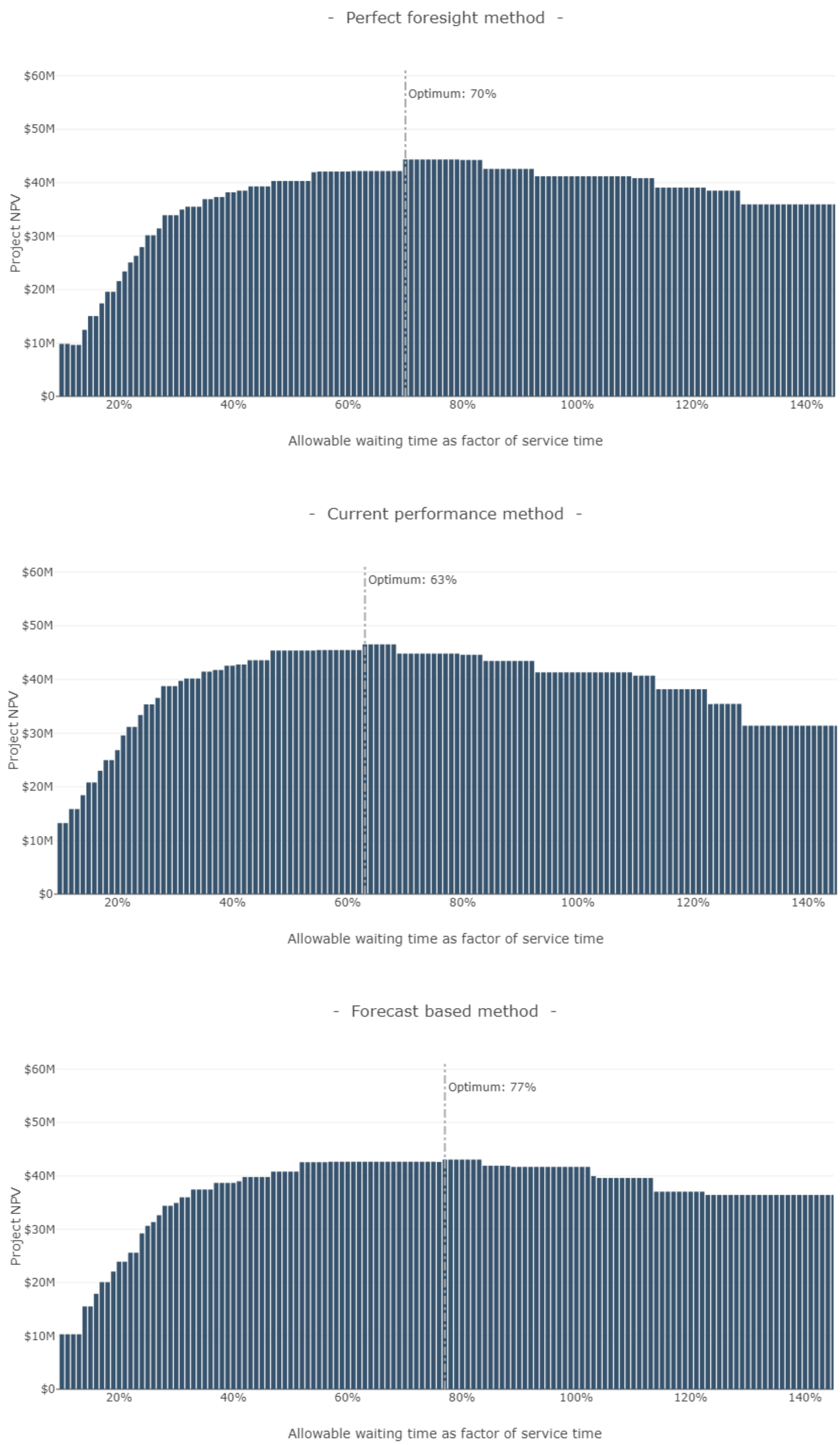


Figure 5-20: Varying optimum using different work methods

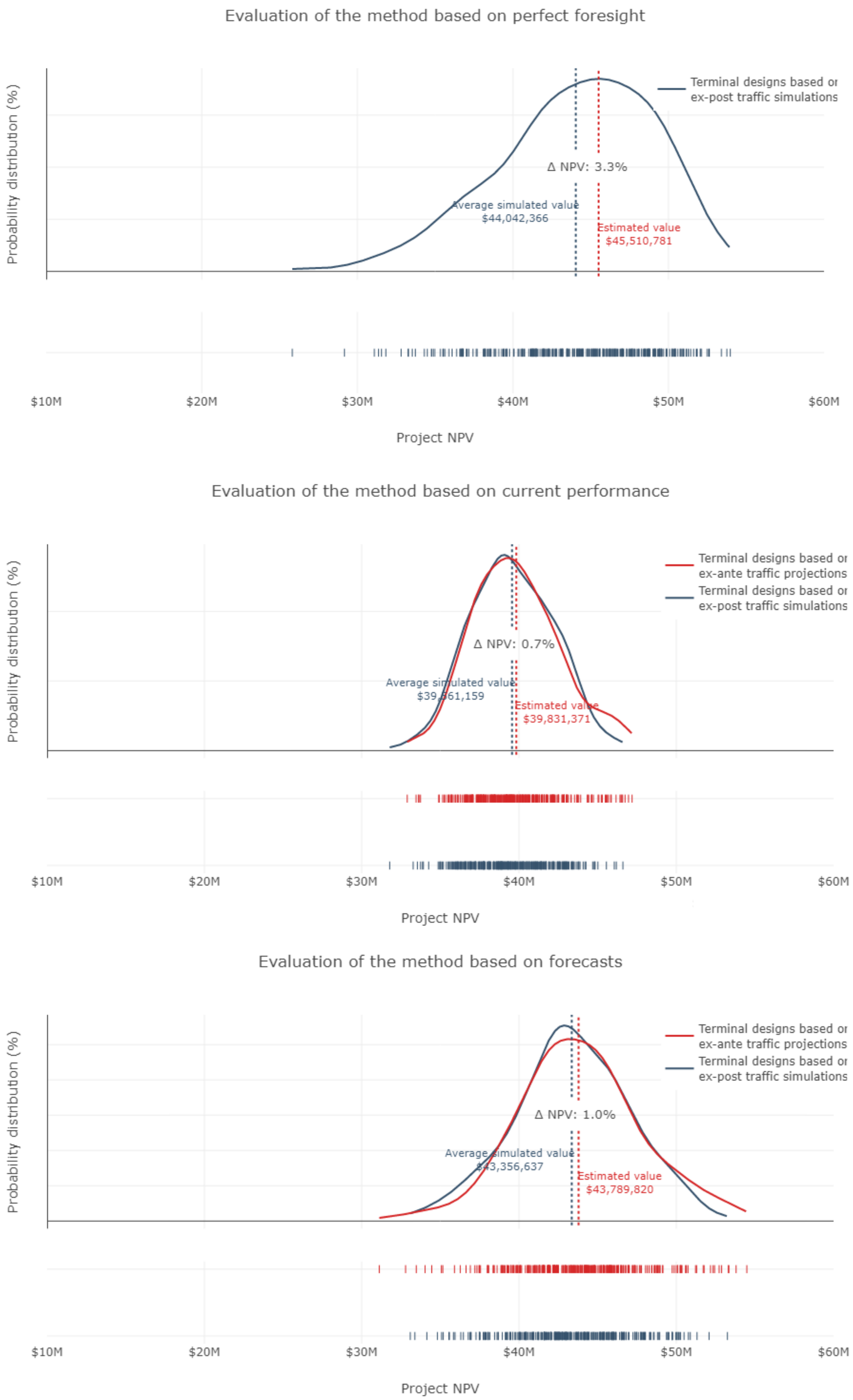


Figure 5-21: Comparing work methods using optimized triggers

5.7 Conclusions

Let us reexamine the research questions we asked ourselves at the start of this chapter. The first research question that was treated reads: *"How accurately can project value be estimated using a work method based on the assumption of perfect foresight?"* As the notion of perfect foresight resembles current common practice regarding the modelling of terminal development, this first analysis provides a good benchmark against which alternative work methods can be compared. The results show that the work method based on perfect foresight overestimates a project's value. Depending on the size of the project and the market's volatility this over-estimation is in the range of 3% (steady market growth) to 20% (tight margins and volatile traffic). This can be explained as follows: modelling investment decision based on the assumption of perfect foresight presumes projected traffic volumes to always come true. This is a distortion of the actual decision-making process that takes place in the real world. Decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decision. Therefore, in overperforming markets lagging terminal investments will lead to capacity saturation (i.e. unmet demand) and in underperforming markets overinvestment will lead to excess expenditures. Models that simulate investment decisions based on perfect foresight ignore such negative consequences of over- or underperforming traffic developments and the fact that this leads to sub-optimal terminal development strategies.

The next research question which was treated was: *"How does the estimating accuracy of the current performance method compare to current common practice regarding the financial evaluation of terminals?".* The results of this analysis show us that although the accuracy of project valuation has gone up by using the work method based on perfect foresight, it has done so at the expense of project value. However, by postponing investments until they materialized traffic volumes have made them necessary has led to a reduced project risk, signaled by the reduced standard deviation in project values after simulation. This positive development carries financial significance and could be fed back into the model by lowering the weighted average cost of capital for instance. However, such feedback mechanisms fall outside the scope of this study.

The final research question which was discussed in this chapter reads: *"How does the estimating accuracy of the forecast method compare to established common practice regarding the financial evaluation of terminals?".* The assessment of this final work method has shown that modelling a terminal based on yearly forecasts results in an accurate feasibility assessment while maintaining a high financial performance. This is due to the fact that the project's estimated values are based on a wide array of traffic projections in contrast to a couple of plausible scenarios, while the built-in forecaster ensures that investments are initiated in a timely fashion.

6 Conclusions and Recommendations

With agribulk trade trends pointing towards burgeoning global crop consumption, growing volumes of crops are expected to be shipped all over the globe. This increase in maritime trade will have to be met with a wave of terminal development. This holds especially true in regions that can expect a strong hike in consumption in the near-term, driven by high population growth accompanied by an increase in welfare, such as sub-Saharan Africa. As a result, potential terminals projects will have to be assessed in order to decide if they show sufficient potential for investors so that the project can advance past the feasibility phase. This process consists of translating a traffic projection into a terminal design, which is then financially assessed in order to test a project's feasibility.

This study has focused on the translation from traffic projection to terminal design, which is referred to as a *work method*, and has analyzed the financial impact of various guidelines and design assumption which form its basis. Furthermore, as the timeline of such projects is in the order of decades, the project will inevitably face many uncertainties. One of the uncertain factors that is of major influence on the project's feasibility is the cargo volume that will flow through the terminal. Both aspects have been investigated using a computer model purposely developed to answer this study's main research question: *"How can the financial performance of an agribulk terminal be optimized, incorporating all investment decisions over the project's lifecycle, while taking into account uncertain throughput development?"*

Within the *Conclusions* section, this question has been dissected into five sub questions, which will all be addressed before rounding off with the answer to the study's main research question. In the process of answering these questions, various aspects were found which would be interesting to assess in further research. Such components are discussed in the following *Recommendations* section.

6.1 Conclusions

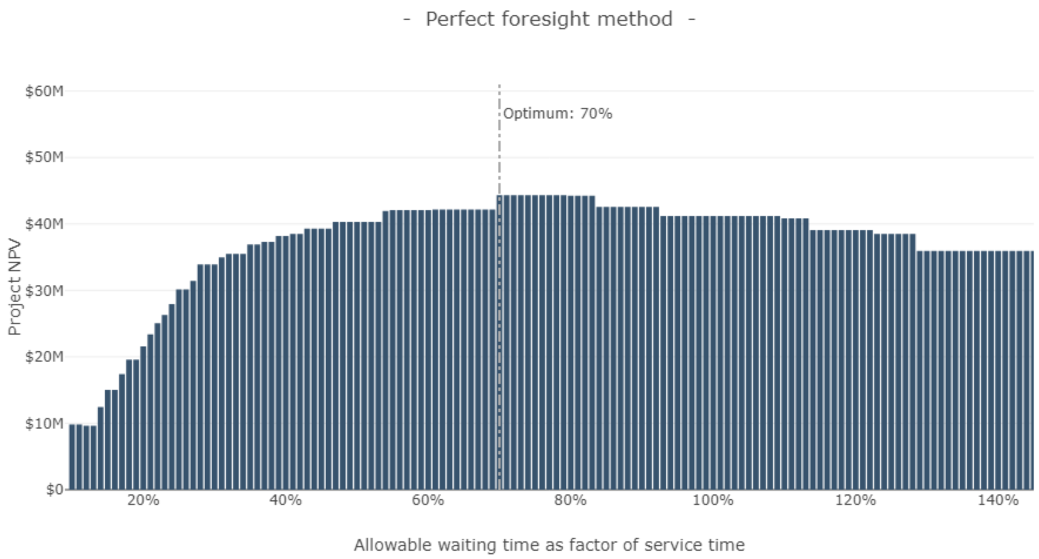
As stated in the introduction of this chapter, this research has analyzed the financial impact of various guidelines and design assumption which form the basis for the process of translating traffic projections into terminal design, which is referred to as a work method. The first sub question therefore reads: *how can the financial performance of a work method be evaluated?*

The answer to this question can be found in chapter 2, in which is shown how, through the use of a computer model, the process of translating traffic projections into a terminal design has been automated. This automation allows us to execute numerous runs, while changing the underlying design assumptions ever so slightly. Analysing the financial performance of the resulting terminal enables the user to investigate the financial impact, or financial performance, of the various underlying design assumptions that make up a work method.

It is important to note that this study makes a clear distinction between the two aspects that make up a single design assumption; the first being the performance threshold which triggers an investment, e.g. '*if the average waiting time of vessels exceeds 30% of service time, expand unloading capacity at the quay*'. The second aspect is the temporal nature of this trigger; do we gauge the waiting time at this moment in time or do we base the trigger on a future, *expected* waiting time, allowing us to invest now and ensure that the new asset is up and running once we need the extra capacity. We shall first discus the analysis regarding the threshold value of various investment triggers at the terminal before inspecting how to model them temporally. By inspecting the financial impact of various performance thresholds, we will answer the following sub question: *"How can the performance triggers used within terminal planning be altered in order to optimize an agribulk terminal's financial performance?"*

Literature provides high-level guidelines regarding what performance thresholds, referred to as *performance triggers*, should be used to design a terminal. Despite their generalist nature, high-level design guidelines are an essential component in terminal feasibility planning. This is because stakeholders are often deprived of extensive and complete technical and economic data at this early project stage. Using the developed computer model, an analysis was conducted to see if such triggers could be further optimized. All in all, the financial impact of investment triggers related to the development of the quay, the unloading equipment, the storage- and the loading facilities have been individually assessed.

When examining the terminal's receiving operations at the quay, the average waiting time of vessels at the terminal has been identified as the key performance indicator on which investment decisions can be based. By monetizing the negative consequences of low-quality service at the terminal using demurrage rates, the average allowable vessel waiting time has been optimized. Existing guidelines, published by PIANC, state that terminal investments are typically based on maintaining an average ratio of waiting time to service time between 20% and 30% for bulk terminals. However, results from the computer model have shown that, if a terminal were to incorporate the notion of demurrage rates into its business model, waiting times could be allowed to rise to 70% of berth service time, unlocking substantial project value. Allowing higher waiting times is especially beneficial in markets that show signs of high volatility.



When examining the design assumptions related to a terminal's storage facilities, it is clear that terminal operator will always want to minimize commodity dwell time in order to increase project value. Furthermore, results have shown that terminals boasting dwell times shorter than 10 days start to be bounded by the fact that they have to be able to accommodate the entire cargo of the largest vessel calling to port. In such cases, bypass systems which enable hinterland transport being loaded directly from the vessel may prove beneficial. Lastly, results show that although commodity dwell times severely impact a grain import terminal's project feasibility, the impact of a volatile market on storage costs is minimal.

The final performance trigger which was analyzed was related to the loading bays for trains. However, in absence of reliable daily train freight rates, this analysis remains inconclusive. On the other hand, results have shown that investments regarding the train loading bay do not weigh as heavily as investments related to quay or storage operations in respect to project feasibility. In the end, the loading bay was modelled using queuing theory and assumed an allowable train waiting time equal to 50% of service time, based on reference projects in eastern Europe.

Once the analysis regarding performance triggers was completed, the computer model was used to analyze the temporal nature of performance triggers. When modelling a terminal, should investment decisions be based on a terminal's *current* performance, or should investments be based on a terminal's *expected* performance given a certain traffic forecast? The financial performance of three work methods were compared, with each method having a different temporal setup for their performance triggers. The methods are briefly described in the following paragraphs after which the results of the comparison are discussed.

The first work method that was evaluated models investment decisions based on the notion of *perfect foresight,* a presumption that the traffic projections on which investments are based will always come true. This technique is currently seen as common practice, making it a good benchmark against which other work methods can be compared. By designing a terminal using a work method and then simulating how it would have performed financially, had it been built, allows us to assess the modelling method's accuracy regarding the estimation of project value. This has been summarized in the following research question: *"how accurately can project value be estimated using a work method based on the assumption of perfect foresight?"*

The second work method that was evaluated bases its investment decisions on the performance of the terminal, gauged at the same moment at which an investment decision is considered. This method is therefore referred to as the *current performance method* and the accompanying research question reads: *"how does the estimating accuracy of the current performance method compare to current common practice regarding the financial evaluation of terminals?"*

The final work method that is analyzed bases its investment decisions on yearly traffic forecasts in a bid to expand terminal capacity in an effective manner. This work method will postpone terminal expansion until an asset's *forecasted* performance degrades past a certain acceptable threshold and is therefore referred to as the *forecast method*. Whether this method addresses the impact of uncertain traffic developments will be evaluated by comparing the method's estimating accuracy to that of the method based on perfect foresight summarized in the following research question: *"How does the estimating accuracy of the forecast method compare to established common practice regarding the financial evaluation of terminals?"*

All three work methods were used to model terminal development in order to assess a project's feasibility. The capability of producing a terminal with a high project value was tested together with the work method's estimating accuracy. The results of the various assessments are summarized in the table below.

	Common practice	Current performance method	Forecast method
Estimated project value	$45.510.781	$39.831.371	$43.789.820
Project value after simulation	$44.042.366	$39.861.159	$43.356.637
Standard deviation	$5.204.568	$2.629.872	$3.662.902
Accuracy	Overestimates by 3.3%	Estimates ± <1%	Estimates ± <1%

The results show that the work method based on perfect foresight overestimates a project's value. Depending on the size of the project and the market's volatility this over-estimation is in the range of 3% (steady market growth) to 20% (volatile markets). This can be explained as follows: modelling investment decision based on the assumption of perfect foresight presumes projected traffic volumes to always come true. This is a distortion of the actual decision-making process that takes place in the real world. Decision-makers will never be entirely sure how traffic volumes will develop in the years following their investment decision. Therefore, in overperforming markets, lagging terminal investments will lead to capacity saturation (i.e. unmet demand) and in underperforming markets overinvestment will lead to excess expenditures. Models that simulate investment decisions based on perfect foresight ignore such negative consequences and the fact that this leads to sub-optimal terminal development strategies.

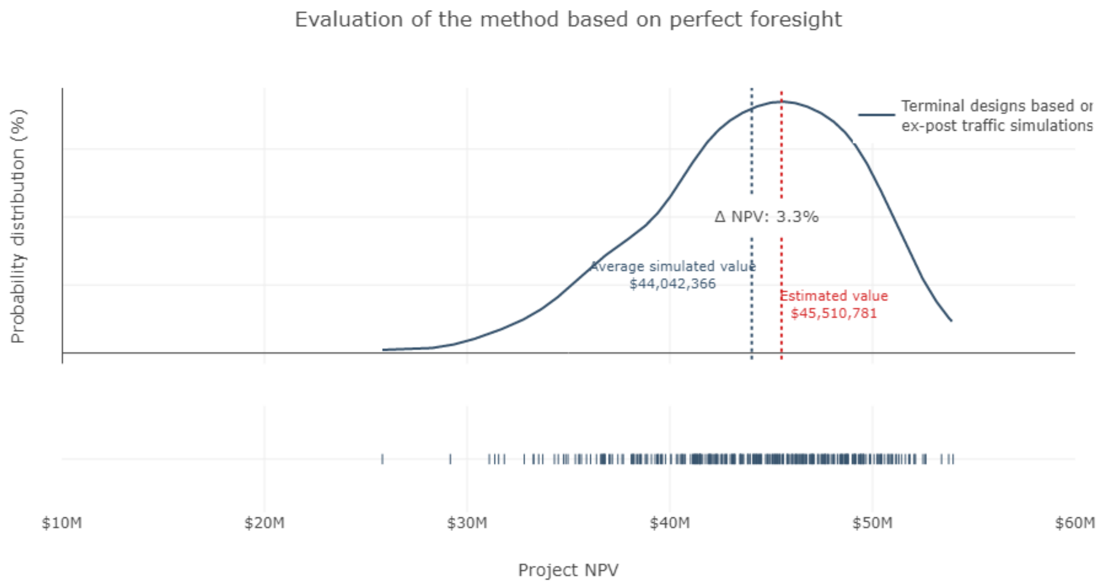
The results of this analysis show us that although the accuracy of project valuation has gone up by using the work method based on perfect foresight, it has done so at the expense of project value. However, by postponing investments until materialized traffic volumes have made them necessary has led to a reduced project risk, signaled by the smaller standard deviation in possible project values. This positive development carries financial significance and could be fed back into the model by lowering the weighted average cost of capital for instance. However, such developments fall outside the scope of this study.

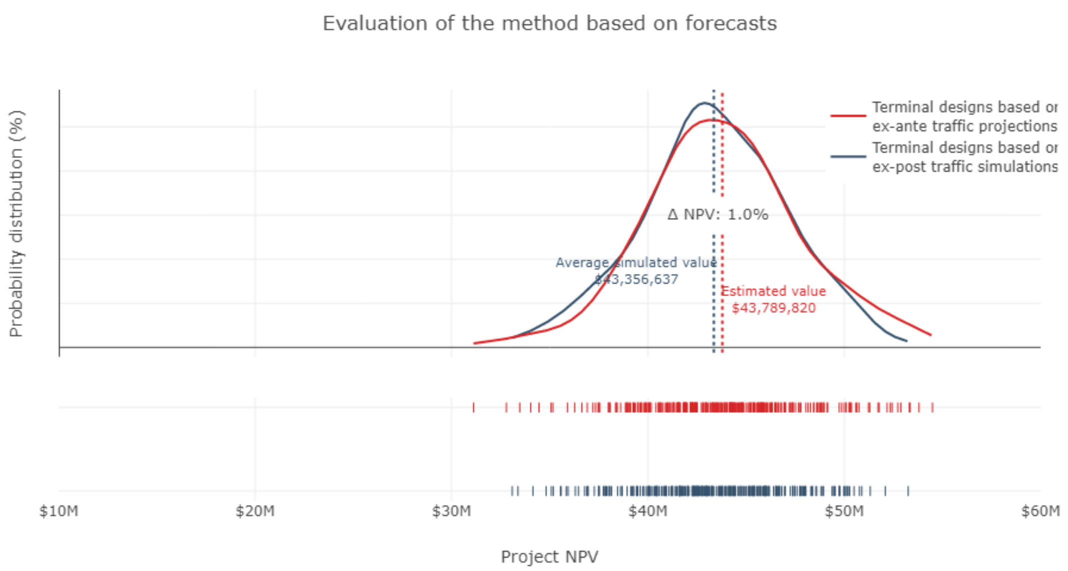
The assessment of the final work method has shown that modelling a terminal based on yearly forecasts results in an accurate feasibility assessment while maintaining high financial performance. This is due to the fact that the project's estimated values are based on a wide array of traffic projections in contrast to a couple of plausible scenarios, as is currently seen as common practice, while the built-in forecaster ensures that investments are initiated in a timely fashion.

To conclude, the main research question in this study was *"how can the financial performance of an agribulk terminal be optimized, incorporating all investment decisions over the project's lifecycle, while taking into account uncertain throughput development."*

By analyzing the financial impact of various performance triggers this study has found that allowable vessel waiting times provided by guidelines on the design of dry bulk terminal planning are conservative from a financial perspective. Results show that allowing vessel waiting times to rise to 70% of service time unlocks significant project value. However, allowing waiting times to rise above the 30% threshold stated within these guidelines will require terminal operators to incorporate demurrage rates into their business model.

When assessing what work method should be used to assess a project's feasibility, the method based on yearly forecasts has proven it is capable of slightly increasing the estimating accuracy of a project's value. The real added value of such an approach, however, is the fact that it has automated the translation process from traffic projections into terminal designs. This will allow a terminal developer to run countless traffic projections in contrast to a couple of plausible scenarios, which is currently seen as common practice. This in turn quantifies the range of project values which are to be expected, given the uncertainty of traffic developments over a project's lifetime.





6.2 Recommendations

Due to the holistic nature of this research, which encompasses both technical and financial aspects of terminal development, several aspects of the design process have been excluded from the scope of this study as a result of time constraint. This section will name what components could be included in future research to improve and build on the findings of this study.

The first recommendation is related to improving the general applicability of the developed computer model by expanding the list of terminal elements that fall within the scope of this study. The current model has used import grain terminals as case study but could, in theory, be used to assess other types of terminal fairly easily, if the accompanying elements were added. Possibilities include the addition of jetties, loading facilities for trucks and barges and the inclusion of dredging works.

Furthermore, it would be very interesting to couple the findings regarding the optimization of the allowable vessel waiting time to empirical data. Preliminary results show that quite some gains can be made from a financial perspective. However, queueing theory, which forms the basis for the modelling approach used in this study, is still somewhat crude. Extensive research into applicable arrival- and equipment productivity distributions related to queue forming has been conducted by, among others, van Vianen (van Vianen 2015). In his research, real-world data was gathered at five unnamed coal and iron ore import terminals, after which the various stochastic distributions were compared to the terminal's empirical data in order to find the best fit. The Erlang-2 distribution proved to be the best fit in most cases for both arrival rates and equipment productivity, but far from all cases, proving that more research on this subject is desirable.

The third recommendation relates to the comparison of the various work methods, which is discussed in chapter 5. The financial performance of the various work methods is analysed, and results show that basing project value estimation on numerous traffic projections increases the accuracy of the estimate. In theory, this can be interpreted as a reduction of project risk and could reduce a project's weighted average cost of capital (WACC). The financial impact of such a move is significant, as is shown in Figure 6-1. Further research proving that enhanced modelling techniques leads to a reduction in project risk is therefore recommended.

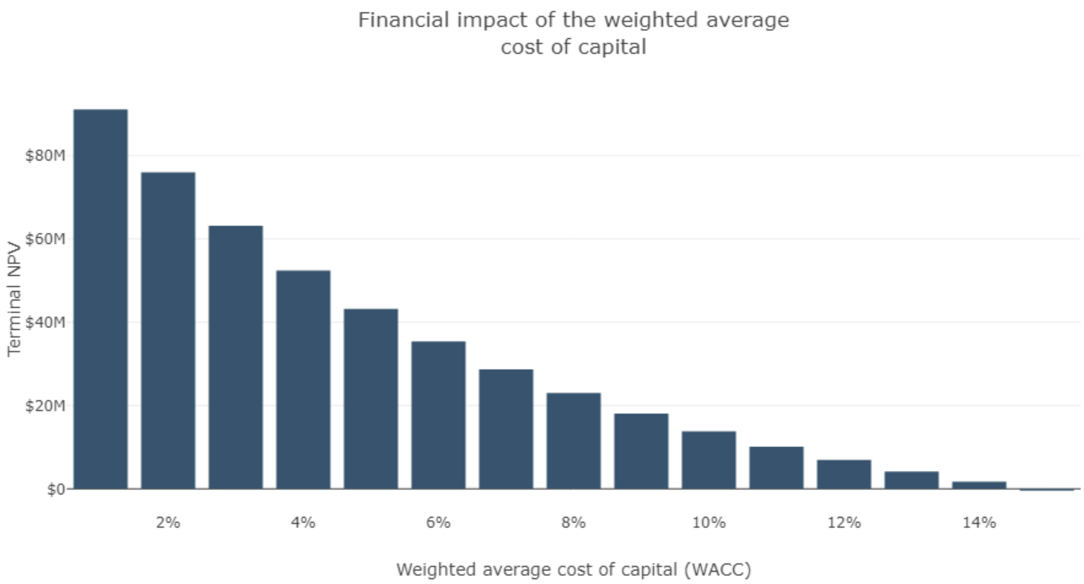


Figure 6-1: Sensitivity analysis regarding project WACC

Another focus of future research could be on unconventional capacity-expanding terminal investments. This study has led to the development of a model which is capable of quantifying the financial impact of various capacity-expanding terminal investments. The type of investments that fall within the scope of this study however, have all been quite conventional (e.g. quay wall expansion, crane acquisition, silo construction). Now that the model has been developed, it would be interesting to use it to assess the financial consequences of innovative capacity expanding opportunities such as floating infrastructure (e.g. quays, cranes or storage). Another possibility would be to determine whether it could be beneficial to over-dimension certain terminal elements such as quay walls, requiring a higher initial investment but greatly reducing expansion costs once traffic volumes require more capacity.

The final recommendation is to include more project phases in the computer model to enhance its representation of the actual processes that lead up to a project's final investment decision. Five design stages within terminal development are shown below (van Dorsser 2018). This research includes the first and second stages together with components of the third stage.

Cargo projections	Expected throughput volumes, tariff levels and resulting revenues
Terminal design	Port engineer prepare design which is then translated into capital expenditures (capex) and operational expenditures (opex)
Financial evaluation	Economists analyze the financial feasibility of the project and consider inflation rates, depreciation levels, finance structure and tax payments
Economic evaluation	Economists analyze the project feasibility from an economic perspective, which includes the (non)desirable effects from a societal point of view. Required for subsidies and grants
Project funding	Financial experts investigate the options to fund the project by creating conditions in which the returns and risk level of the project are acceptable to the lender, unlocking the capital required to initiate the project

Including more phases into the model scope may lead to a better and streamlined design process. Due to the multidisciplinary nature of the five steps, it may be inefficient to try to combine all steps into a single assessment tool. However, examining the interfaces between the various steps, and their respective areas of expertise, could lead to efficiency gains within the high-level assessment of potential terminal projects.

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Annex

A Code Archive

This section provides links to the Python code developed within this study. The code has been tailored to match the outline presented in this report and can be attained by following the QR codes below.

Subject	Figure	QR code
Testing receiving operations	Figure 3-1 Figure 3-2	
Testing quay – storage transport operations	Figure 3-5	
Testing storage operations	Figure 3-7	
Testing storage - loading transport operations	Figure 3-9	

Subject	Figure	QR code
Testing loading operations	Figure 3-11 Figure 3-12	
Financial impact of stricter performance triggers	Figure 4-1	
Financial impact of charter rates	Figure 4-4	
Financial impact of the allowable vessel waiting time	Figure 4-6 Figure 4-7	

Subject	Figure	QR code
Financial impact of the commodity dwell time	Figure 4-8	
Financial impact of the allowable train waiting time	Figure 4-10	
Comparing work methods based on PIANC guidelines	Figure 5-5 Figure 5-6 Figure 5-7 Figure 5-10 Figure 5-11 Figure 5-12 Figure 5-18 Figure 5-19	
Trigger optimization based on various work methods	Figure 5-20	
Comparing work methods based on optimized triggers	Figure 5-21	

B Trade trends

The literature study into commodity trends sets out to identify what type of bulk terminals can expect substantial development in the coming years, making them an interesting subject for further research. The initial focus of this research was on optimizing terminals that were specialized in the handling of major industrial commodities such as iron ore and coal. However, it quickly became clear that most of these terminals are dedicated to large import/export facilities such as power plants (import) and mines (export). Such dedicated terminals are increasingly owned by the same companies that own the mines and powerplants that are being supplied by the port, as a result of a global push for vertical supply chain integration. This causes a conflict with this research's objective, as project feasibility of an individual terminal often becomes subordinated to the phasing strategy of the underlying power station or mine. The current agricultural maritime trade, on the other hand, has not seen the same extent of vertical integration. Coupled with the fact that the sector is on the verge of substantial growth, makes research into agribulk terminals intriguing and relevant.

Commodity scope

This research focuses on terminals related to the import of wheat, maize and soybeans, as they form the major component of volumes currently traded on the shipping market. This trend is set to continue as all three commodities are deeply embedded in global diets. Wheat, for instance, provides 20% of the daily consumed calories for 4.5 billion people (FAO 2012a). Maize is also seen as a staple food, but even in countries where maize is heavily represented in the population's daily diet, human consumption is heavily outweighed by animal consumption, as is shown in figure B-1 (Ranum, Peña-Rosas, and Garcia-Casal 2014). This is due to the fact that maize constitutes the major calorie source for feedstock (IOP Science 2003). For protein, feedstock relies heavily on soybeans through soymeal (Herrero et al. 2013), explaining how global soybean demand is being driven by an increase is global meat consumption.

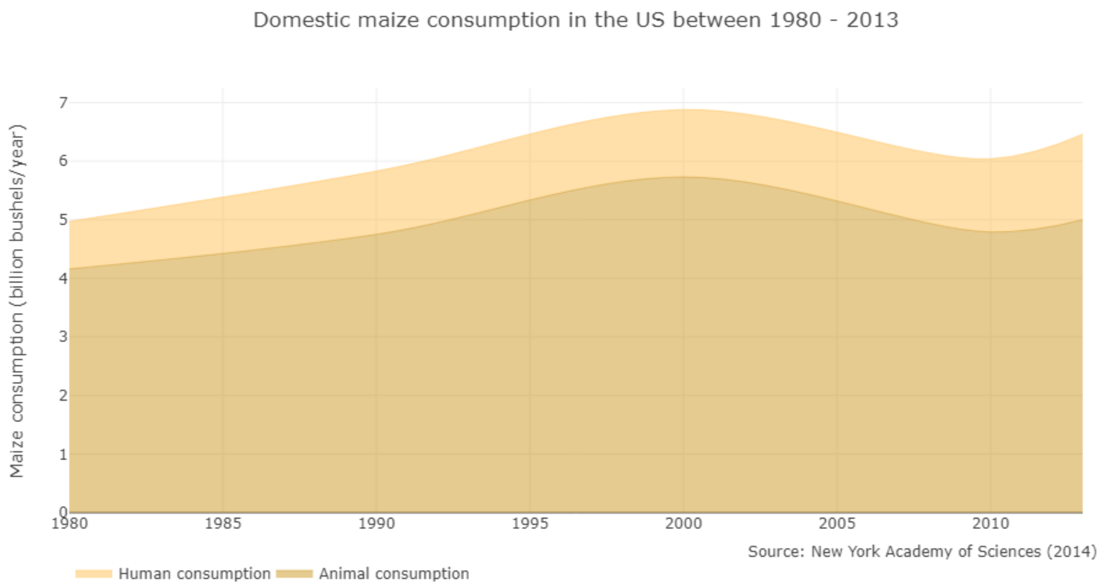


Figure B-1: Maize consumption in the US

Commodity trends

Global production of agricultural commodities is highly concentrated. So much so, that in 2017 the four major exporting countries; US, Brazil, Argentina and Ukraine accounted for over 70% of global maize export for instance. When examining soybean trade flows, the consolidation is even more severe with the US, Brazil and Argentina serving 80% of the global trade flows (OEC 2018). This global consolidation of crop production leads to large intercontinental shipping volumes, which in turn stimulates the development of agribulk terminals.

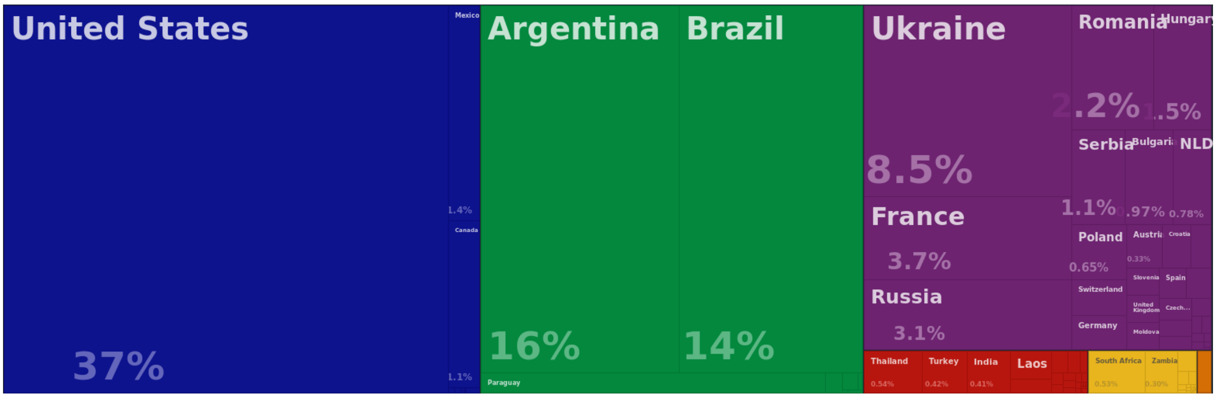


Figure B-2: Global maize export values

The maritime trade trends regarding wheat, maize and soybeans are best understood when analyzing respective consumption and production patterns, as a nation's trade potential can be defined as the difference in domestic consumption and domestic production. This chapter will elaborate on such patterns, in which correlations related to crop consumption are further dissected into human consumption and animal consumption. These findings will ultimately form the basis for future projections that can be used as input for the terminal model. As population growth and an increase in welfare form the main drivers for crop demand (Bodirsky et al. 2015), there are two regions of key interest when looking at global trade trends:

China

China, with a population of over 1.41 billion people (UN Population Division 2017), boasts the strongest GDP growth figures in the world (IMF 2018) and is already witnessing a strong shift in dietary composition. The average meat consumption increased from 3.8 to 61.8 kg per capita between 1990 and 2013 and this trend is set to continue (Lee et al. 2012).

Africa

Africa's population growth rates are the highest in the world and are expected to lead to an estimated 4 billion inhabitants on the continent at the turn of the century (UN Population Division 2017). Although somewhat delayed, a phase of extensive economic development is expected to boost GDP growth over the coming decades (Bodirsky et al. 2015).

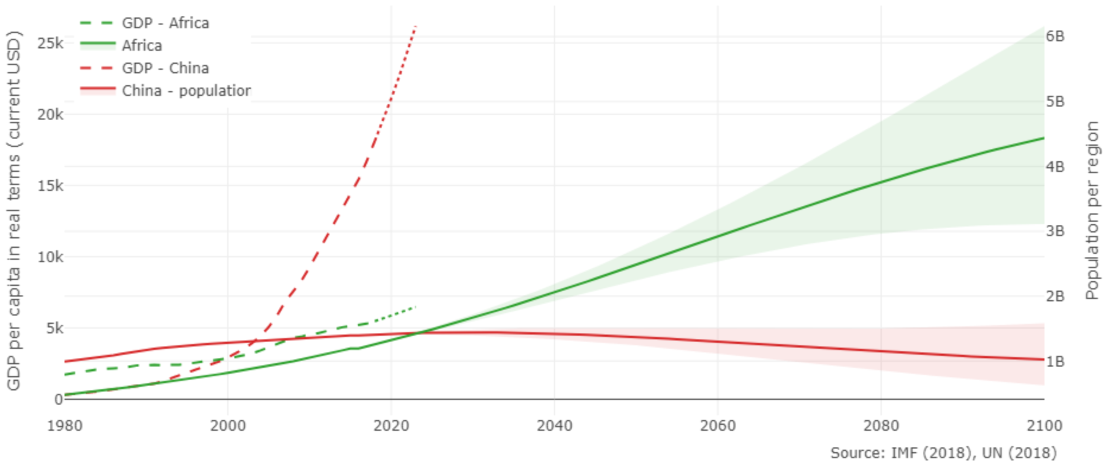


Figure B-3: GDP and population trends (UN Population Division 2017)

In this research it has been assumed that China is further in the development of their required agribulk terminals in comparison to Africa, partly because demand in Africa is yet to mature. This chapter will therefore predominantly focus on the commodity trends in sub-Saharan Africa, as this region will be responsible for the lion's share of the continent's pending population boom, making it relevant for agribulk terminal developments.

Human consumption

The extent to which a commodity is linked to either human or animal consumption differs. In Africa for instance, wheat and maize form a major component in the population's daily diet, whereas soybeans do not play any significant role in human consumption (see figure B-4).

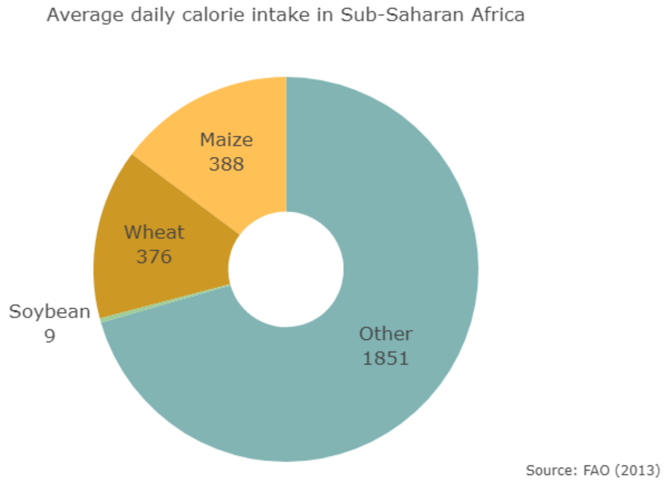
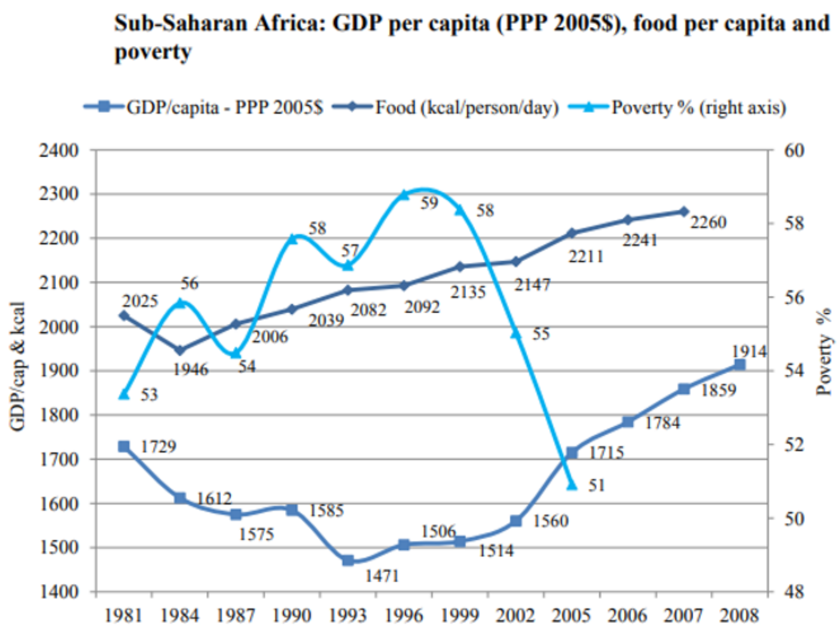


Figure B-4: Average daily calorie intake in Sub-Saharan Africa

Human consumption is driven by population growth and, to a lesser extent, welfare. However, in regions showing low GDP figures such as Sub-Saharan Africa, welfare is especially influential with regards to human consumption. Figure B-5 depicts how food consumption surged in Sub-Saharan Africa as GDP per capita increased (FAO 2012b).



Source: GDP and Poverty: WB, WDI Accessed Oct. 2010; kcal: FAOSTAT, accessed Dec. 2010.

Figure B-5: Relating GDP to daily calorie intake

How this increase in overall food consumption influences crop consumption differs per commodity. Wheat, for instance, shows a positive correlation with GDP throughout the region, depicted Figure B-6. Consumption data regarding maize, shown Figure B-7, is less conclusive. It seems that there is a strong variation in maize consumption throughout the region. In Angola and Zimbabwe for instance, maize culturally forms the major staple food in the nation's diet, whereas in countries such as Nigeria and Ghana this role is fulfilled by other cereals (e.g. millet, sorghum etc.). Furthermore, it seems that maize consumption generally does not increase as GDP per capita rises. The increase is total daily calorie intake is compensated by a dietary shift away from maize to animal products and alternative staple foods, such as wheat.

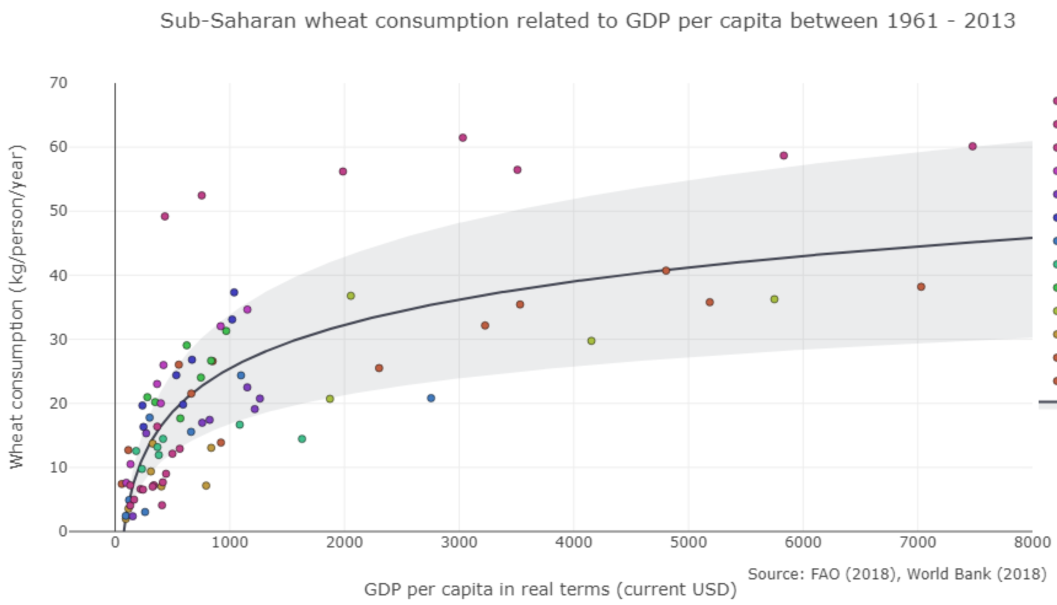


Figure B-6: Sub-Saharan wheat consumption

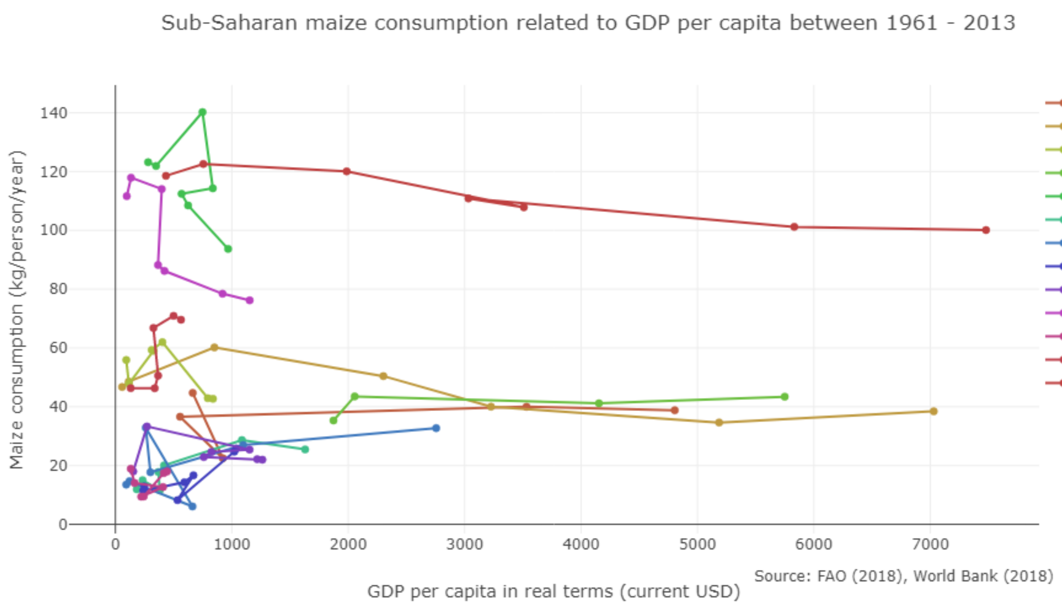


Figure B-7: Sub-Saharan maize consumption

Animal consumption

Currently, about 32 percent of the world consumption of cereals is consumed as feed, whereas in developed countries, characterized by high meat consumption, this figure stands at 68 percent with the bulk of it being maize (Elferink et al. 2008; FAO 2012b). The interdependency between crop demand and meat consumption becomes clear when examining the amount of feed required to produce a kilogram of meat. Figure B-8 depicts a study done by the World Bank into worldwide *feed conversion ratio's*, representing the amount of feed required to produce various animal products (Alexander et al. 2016).

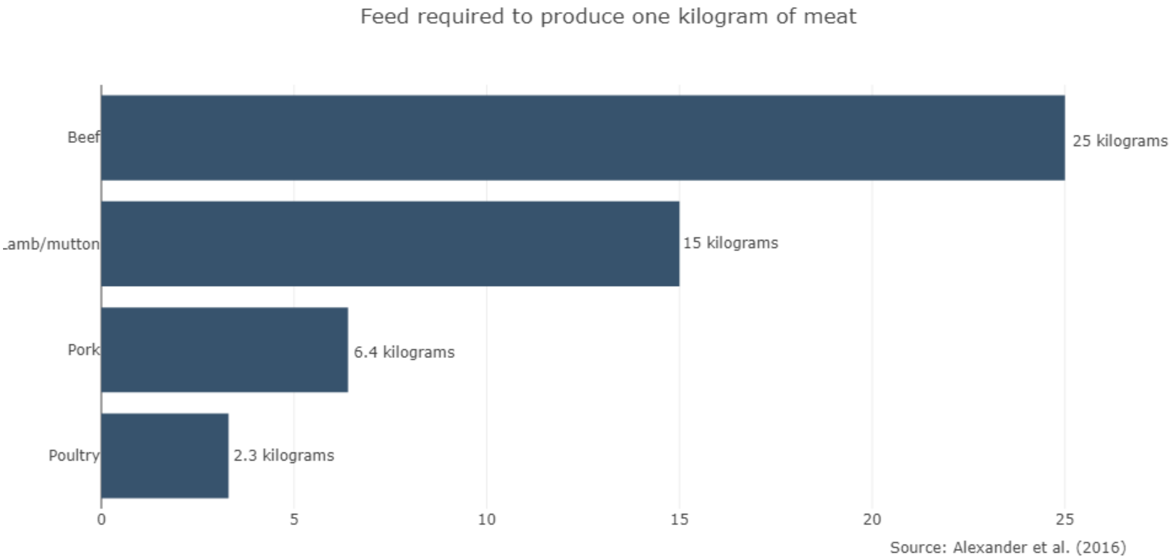


Figure B-8: Feed conversion ratio's

As no literature concerning conventional feed ingredients in Africa was found, this research assumes animal feed to have a similar composition throughout the world. In Germany, the US and New Zeeland, maize conventionally constitutes to about 35% of the dry matter in feed for instance, whereas soymeal represents 9 % of total feed composition of animal feed in the EU (Banaszkiewicz 2011; Kleinmans et al. 2016). Empirical data provided by Bunge, a major soybean importer in Amsterdam, shows that 73 percent of imported soybean volumes can be translated into soymeal through dedicated production plants (Daas 2018). All in all, this results in the following assumption regarding animal feed composition, depicted in Figure B-9.

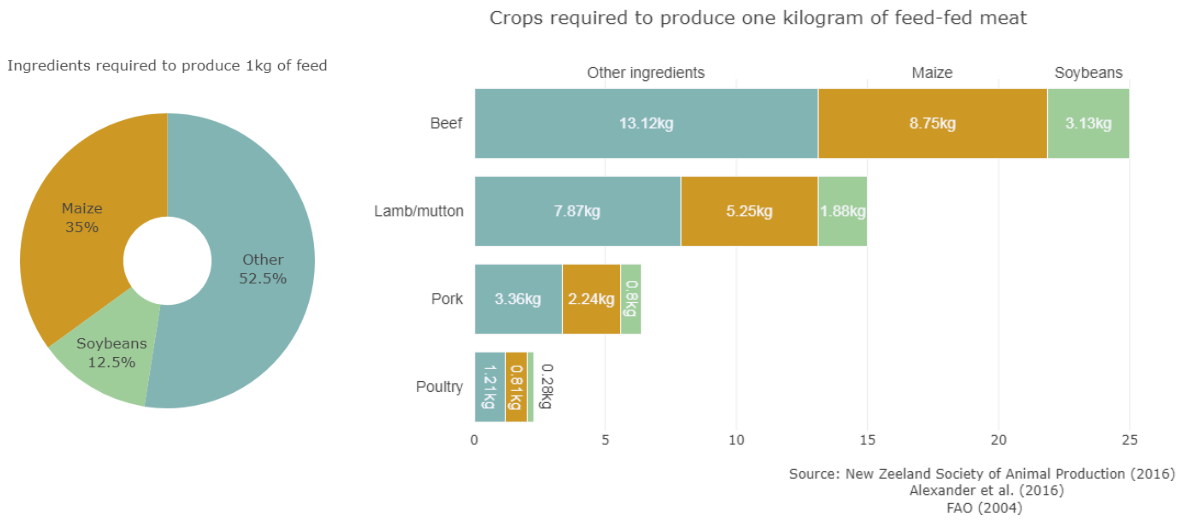


Figure B-9: Feed conversion ratio's per commodity

It should be noted that a large portion of global animal products are produced based on non-feed diets (e.g. through pastures), withholding their impact on crop demand. Research on the subject estimates that the percentage of animal products based on feed has increased from 27% in 1961 to 44% in 2009, as the large areas required for rangelands and pastures becomes increasingly scarce (Davis and D'Odorico 2015). How this feed-fed percentage is distributed over the various livestock groups is not elaborated on and this research therefore assumes that it is homogeneously applicable on all livestock groups.

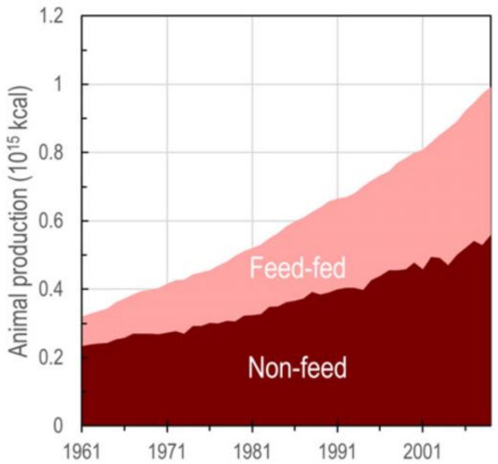


Figure B-10: Developments regarding feed-fed animal production (Davis and D'Odorico 2015)

As countries become richer, populations tend to eat more meat, as is shown in Figure B-11**.** This is especially the case in GDP regions up to $10.000 a year. One such example is China, where the surge in the country's GDP has led meat consumption to increase twentyfold in the past 25 years. There are regions, however, that do not follow this global pattern. One such example is India, where the population clearly eats less meat than other countries with comparable GDP figures. This is probably due to the country's large Hindu and Muslim populations, in which religion discourages the consumption of beef and pork. Furthermore, it seems that Africa is not following suit either, although current trend analysis is rather preliminary, as few sub-Saharan countries have broken into the higher GDP regions (i.e. ± $10.000 per year). Figure B-12 depicts the correlation found within sub-Saharan countries and visualizes the deviation from the global consumption trend.

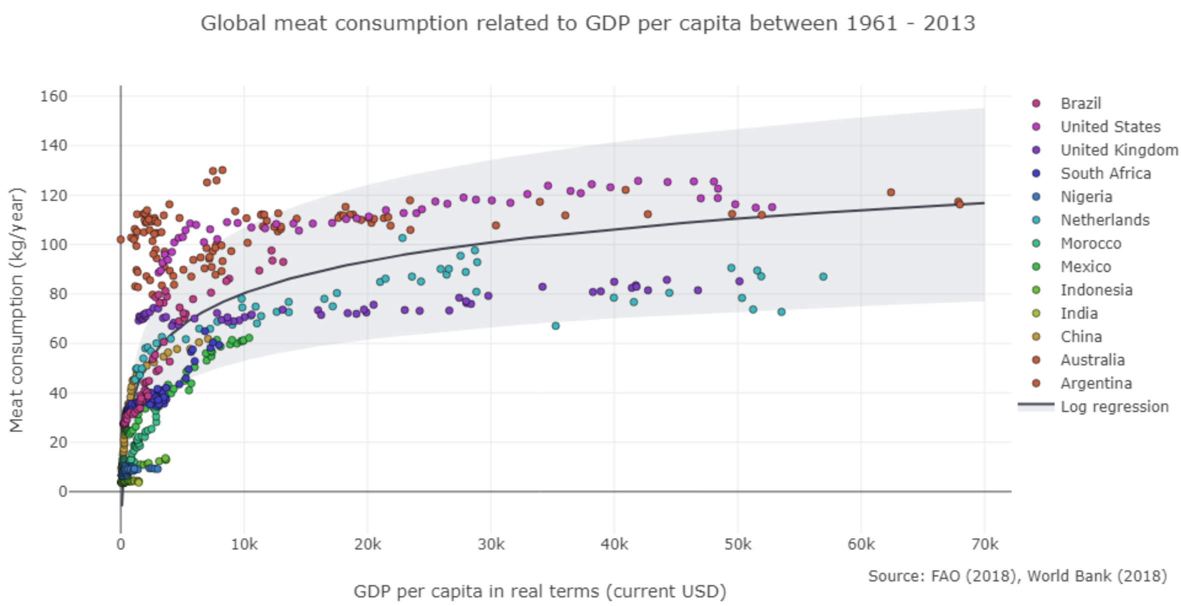


Figure B-11: Global meat consumption trend

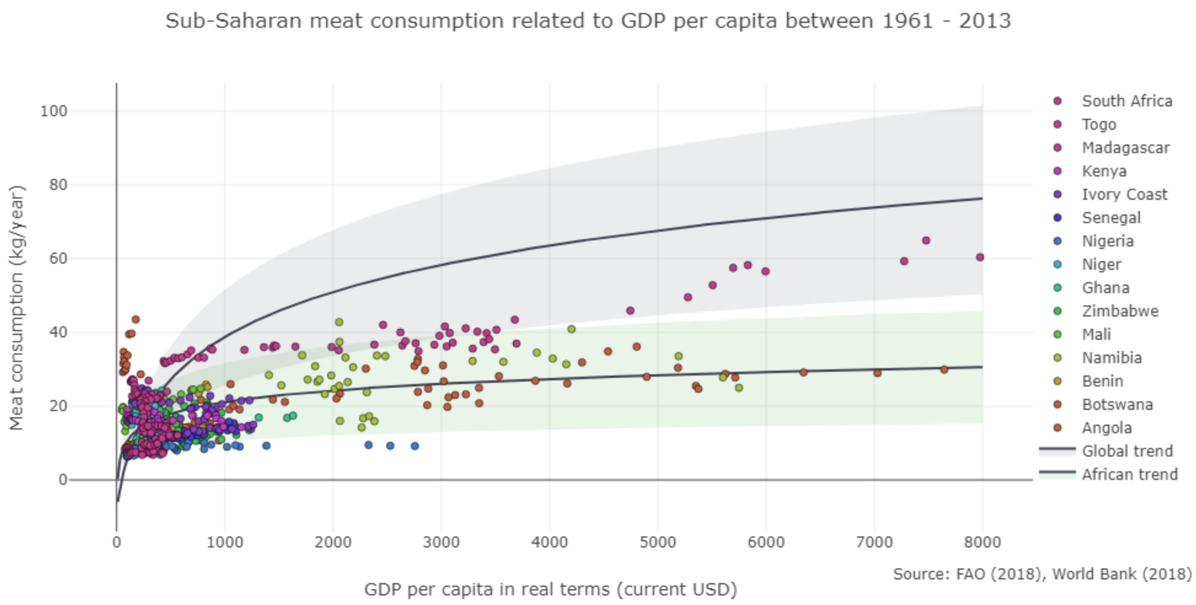


Figure B-12: Meat consumption trends in Sub-Saharan Africa

Crop Production

Trade potential for agribulk commodities can be quantified by assessing the difference in the country's commodity consumption and production capacities. A country's crop production can be estimated by assessing the land area being used to cultivate a certain crop combined with its corresponding yield. Projections regarding crop area expansion in Sub-Saharan Africa estimate a strong increase (41%) in agricultural area used for the production of maize, whereas almost no increase in areas destined for wheat cultivation are foreseen(FAO 2012b). Soybean production has barely developed on the continent and this may explain why no literature was found regarding projections for agricultural area destined for the production of soybeans.

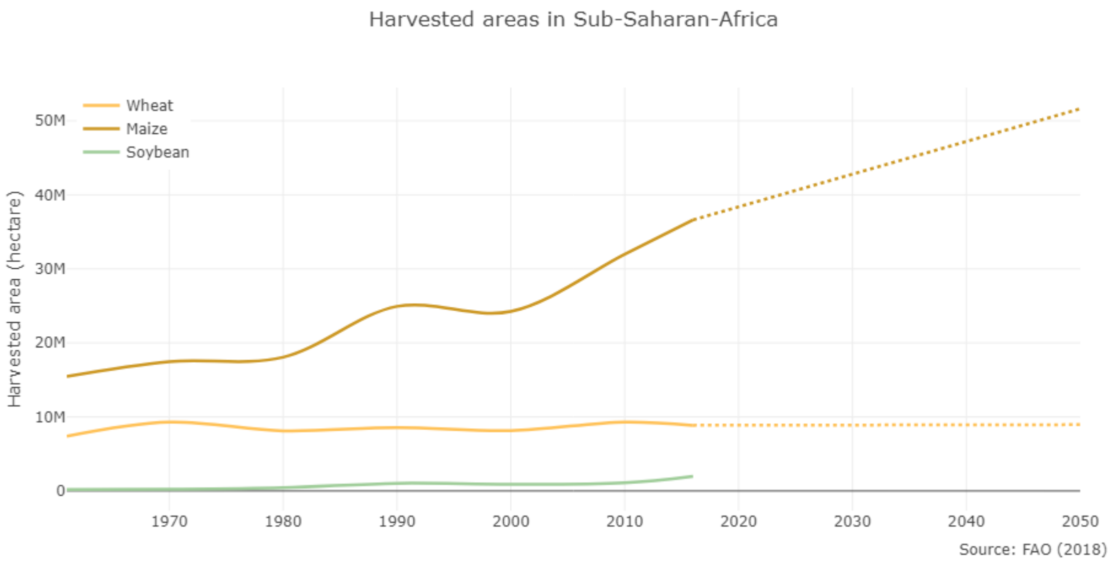


Figure B-13: Areas destined for crop cultivation

Despite having large areas destined for agriculture, sub-Saharan Africa suffers from underdeveloped farming practices, resulting in low agricultural productivity efficiencies, or yields. However, as welfare and education will continue to improve over the coming decennia, farming practices are expected to improve. Closing the yield gap in Sub-Saharan Africa would increase and diversify global production away from the two major net-exporting regions in North and South America. Figure B-14 shows the average crop yields of wheat, maize and soybean found in Sub-Saharan Africa and includes the projected increase in yields, assuming Sub-Saharan Africa is on par with other developing countries by 2050 (FAO 2012b; Food and Agriculture Organization of the United Nations 2014).

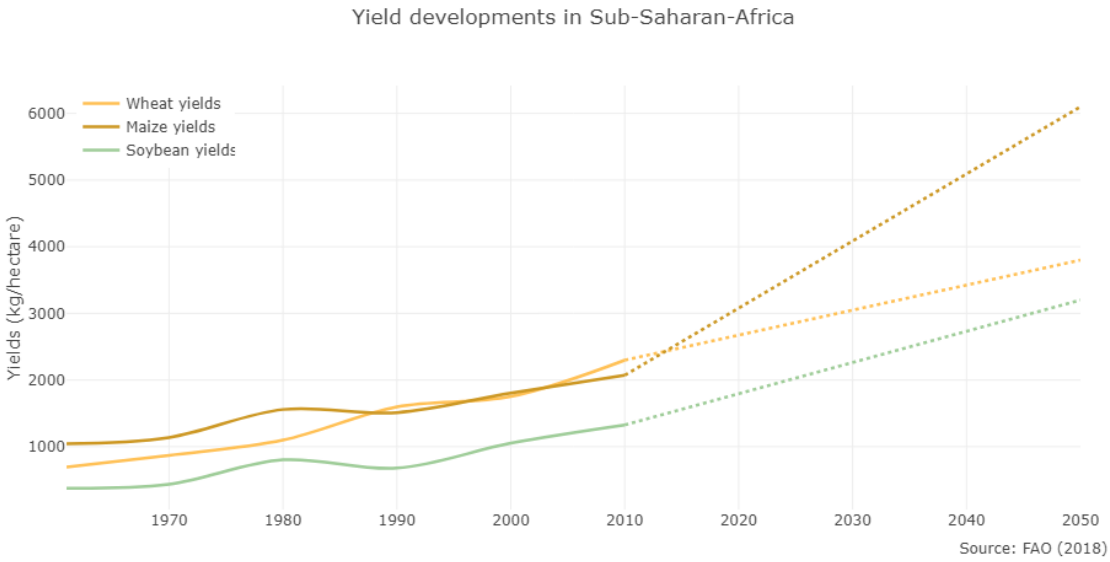


Figure B-14: Yield development

Conclusions

This chapter has elaborated on the global trends found within the trade of wheat, maize and soybeans. Aggregated consumption trends for Sub-Saharan Africa show a large uptick in demand for the coming decennia. It is expected that the increase in the region's production capabilities, driven by an increase in dedicated agricultural areas and an increase in farming potential will not be able to keep up with the surge in crop consumption. This hike in consumption is a result of an ongoing population boom accompanied by a dietary shift towards animal products, which in turn are increasingly feed-fed. This assumption is backed by long term crop projections published by the FAO, in which Sub-Saharan Africa is clearly flagged as a large net-importing region for all three commodities; maize, wheat and soybeans.

C The Financial Evaluation of Terminals

Discount rates

Port and terminals investments generally require extensive expenditures at the start of a project before generating revenues on the long term. From a financial perspective, the moment in time that money changes hand is of importance and is referred to as the *time value of money.* (Brealey, Myers, and Allen 2011)

The time value of money implies that money available at the present time is worth more than the identical sum in the future due to its potential earning capacity. This core principle of finance holds that, provided money can earn interest, any amount of money is worth more the sooner it is received. In other words, a future cash flow is worth less than an identical cash flow received at the present time and should therefore be discounted. Translating cashflows into their respective current values is referred to as a *discounted cash flow analysis* and is used to assess the viability of a project.

The extent to which future cash flows should be discounted is quantified using the *discount rate.* As the model used within this research is based on an aggregated annual time scale, an annual discount rate is applied within the model. This discount rate is based on the notion of the *cost of capital.*

The cost of capital refers to the rate of return that could have been earned by putting the same amount of capital into a different investment with equal risk. Thus, the cost of capital is the rate of return required to persuade an investor to make an investment in a given project. The higher the project risk, the higher the cost of capital. Taken from a terminal developer point of view, the cost of capital is the interest rate you can expect on the loans needed to develop a terminal project (Lee and Lee 2013).

The two types of loans that fall within the scope of this study are loans based on *debt* and *equity*. Issuing debt holds less risk than issuing equity loans. This is because, if a project turns out to go bankrupt, debt issuers have a higher claim to the project's assets than equity ones. In turn, debt investments are linked to lower interest rates than equity investments (Brealey et al. 2011).

The project evaluations depicted in this report illustrate an arbitrary business case for an agribulk import terminal in South Africa. It is assumed that the project has a *gearing* of 60%, implying that 60% of the required funds are provided through a loan from a bank (in this case the World Bank) and 40% of the required funds are provided in the form of equity. The applicable discount rate is equal to the *weighted average cost of capital*, or WACC, which represents the combined interest payments to debt and equity issuers that are to be expected in such a project.

The WACC in this report is based on figures found within comparable, recent terminal development projects in the Sub Saharan Africa region. The final assumption related to project finance is that the country in which the terminal is to be developed has a corporate tax rate of 28%, equal to the current rate applied in South Africa. All in all, these assumptions lead to a nominal WACC of 15.83%. The applied method to determine the weighted average cost of capital is shown on the next page. Note that all terms are presented in nominal terms.

However, all cashflows within the model are denoted in *real terms* and have been adjusted for inflation. The *real WACC* is computed by as follows:

$$WACC_{real} = \frac{WACC_{nominal} + 1}{i_{South\ Africa} + 1} - 1 = 9.23\ \%$$

In which:

$\boldsymbol{WACC_{nominal}}$	15.83%	*The nominal WACC, which is calculated on the next page*
$i_{South\ Africa}$	6.04%	*The average South African annual inflation rate, taken over the past 10 (The World Bank 2018b)*

$$WACC_{nominal} = D_{\%} \cdot (1 - Tc) \cdot D_C \quad + \quad E_{\%} \cdot E_C \quad = \quad 15.83\ \%$$

$D_{\%}$	60%	Percentage of total project costs covered by debt, also known as *gearing*.
$(1 - Tc)$	78%	Referred to as the tax shield. The tax shield implies that interest payments on debt are deductible from taxable income (Brealey et al. 2011). The corporate tax in South Africa is assumed to be 28%, implying a tax shield of 78%.
D_C	13.62%	The cost of debt can be determined as follows:

$$D_C = r_p + r_{f,local}$$

$\boldsymbol{r_p}$	4.00%	The risk premium. This premium is project specific and is mainly based on a project's risk and the project's sponsor. Other components include; the loan type, loan period, and the debt-to-equity ratio. In the case of infrastructure projects initiated by a company that has a reputation of being able to handle large scale infrastructure projects, the risk premium lies somewhere between 3.2%, for projects in Western Europe, and 9% for projects in Sub-Saharan Africa (MTBS 2018).
$r_{f,local}$	9.62%	The risk-free rate within South Africa. This can be seen as the return rate on investments that carry negligible risk.

$$r_{f,local} \quad = (1 + r_{f,ref})\frac{(i_{local})}{(i_{ref})} - 1 + (r_{m,local} - r_{m,ref})$$

$r_{f,ref}$	2.80 %	The global risk-free rate, such as a 10-year US (or German, when using a model based on Euro's) treasury bond coupled to an interest rate collar. This implies that the bond's rate of return is pegged to a constant inflation. This risk free rate currently stands at 2.8%. (MTBS 2018)(The World Bank 2018b)
i_{local}	6.04%	The yearly inflation within South Africa, averaged over 10-years
i_{ref}	1.80%	The yearly inflation within America, averaged over 10-years
r_m		The market premium. This premium is country specific and is mainly based on a country's stability, liquidity and financial institutions. A 2017 survey identified a market risk premium, adjusted for the risk-free rate of 5.08% for developed, mature markets. Risk premiums for other countries were identified and go up to 15%, as is shown in Figure C-1 (Damodaran 2018).
$r_{m,local}$	7.62%	The market premium of South Africa
$r_{m,ref}$	5.08%	The market premium of America

$E_{\%}$ 40% Percentage of total project costs covered by equity. Equity refers to a loan that typically holds more risk than debt. This is because, if a project turns out to go bankrupt, debt investors have a higher claim to the project's assets than equity investors. In turn, equity loans are linked to higher interest rates than debt loans.

E_C 24.86% The cost of equity can be determined as follows:

$$E_C = r_{f,local} + \beta \cdot r_{m,local}$$

$r_{f,local}$ 9.62% See previous page.

β 2.0 The industry's beta. This can be seen as a sector-specific risk factor. Sectors dealing with relatively high risks, such as tech companies, boast relatively high beta values. Sectors dealing with relatively low risks, such as utility companies, have relatively low beta values. Two beta indicators in the port sector are:

1) A brownfield project in Europe will have a beta of around 1.25
2) A greenfield project in Africa will have a beta of around 2.0
(MTBS 2018)

$r_{m,local}$ 7.62% See previous page.

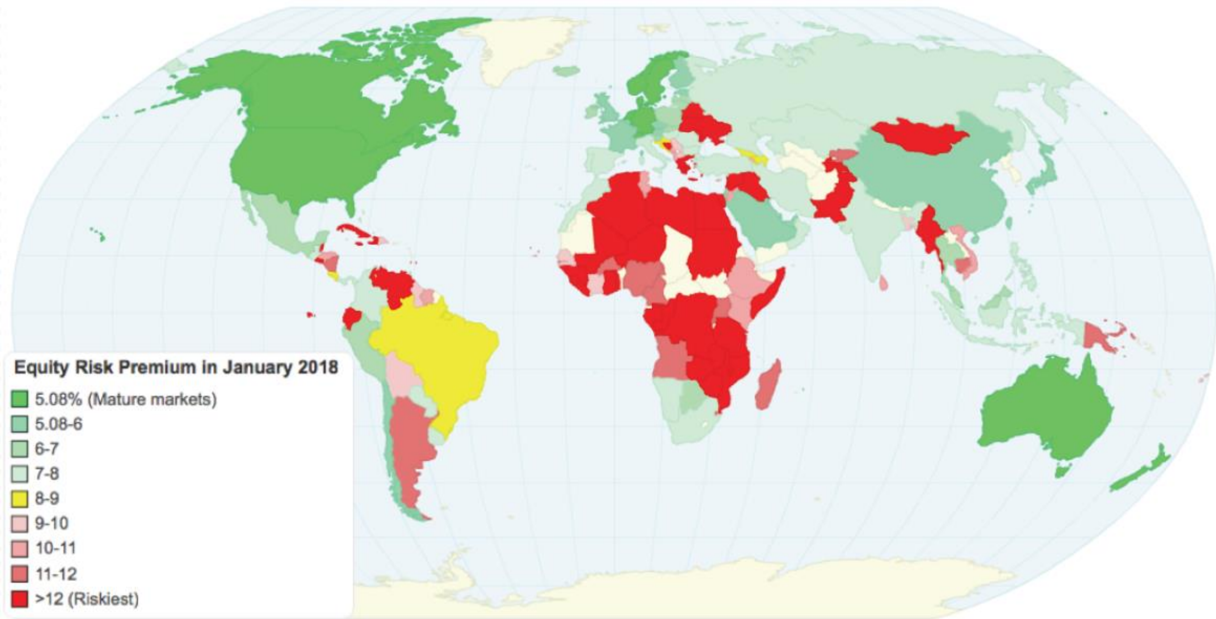


Figure C-1: National market premiums (Damodaran 2018)

The financial impact of assumptions regarding a project's risk, and therefore its weighted average cost of capital, becomes clear when running a sensitivity analysis using the computer model. Figure C-2 illustrates how terminal development, characterised by high investments at the start of a project and steady revenues that continue far into the future, is susceptible to high risks. A high risk leads to a high WACC, which in turn disproportionately discounts revenues over expenditures, leading to lower project value.

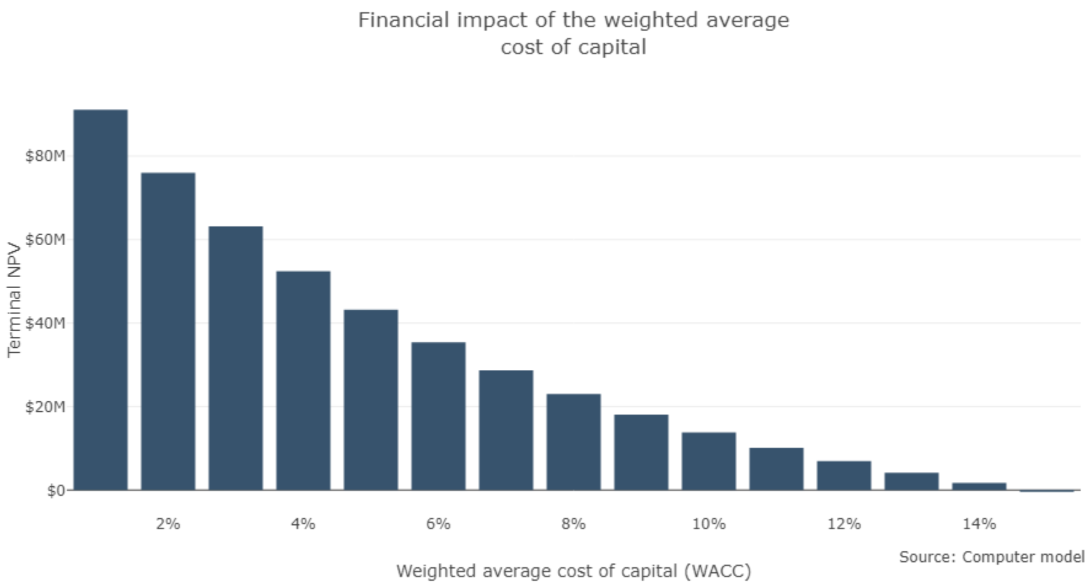


Figure C-2: Financial sensitivity regarding the weighted average cost of capital

Net present value

Within this study, the project of a value is assumed to be represented by a project's net present value, or NPV, a concept which is widely used to determine the financial feasibility of a project. It assesses the total revenues, offset by the investments and the annual operating costs of a project, while incorporating the time value of money (discussed in section 0).

Once a terminal design has been made, the computer model converts the design into a set of yearly cashflows presented in real terms (i.e. the cashflows do not include inflation). Because project financing and tax operations fall outside the scope of this study, the NPV is determined by aggregating the *pre-tax free cashflow to the firm*, taken over the project's entire lifecycle, and translated to *present value* terms. The free cash flow for the firm (FCFF) represents the amount of cash flow from operations available for distribution after depreciation expenses and investments are paid. FCFF is essentially a measurement of a company's profitability after all expenses and reinvestments (MTBS 2018). The process of calculating a terminal's NPV is visualized in Figure C-3.

The present value of the FCFF is determined by discounting all the cashflows using a yearly discount factor, based on the weighted average cost of capital (WACC) discussed in the previous section. This WACC factor is defined as an input parameter for the model and depends on project characteristics such as market volatility, financial debt-equity distributions, etc. Essentially, this factor quantifies the reduced value of cashflows received in future years.

The result is a quantified representation of the project's value. Note that the NPV is not the same as the project's entire value but represents the project's value *compared* with similar projects that adhere to the same level of risk. This implies that every project that results in an NPV higher that zero is deemed feasible, i.e. it is a wise decision for investors. To conclude, a feasible project does not necessarily lead to a positive investment decision. Other financial aspects, such as the *payback period* or *capital exposure* of investors may withhold a project from advancing past the feasibility phase. Such financial analysis' fall outside the scope of this study, however.

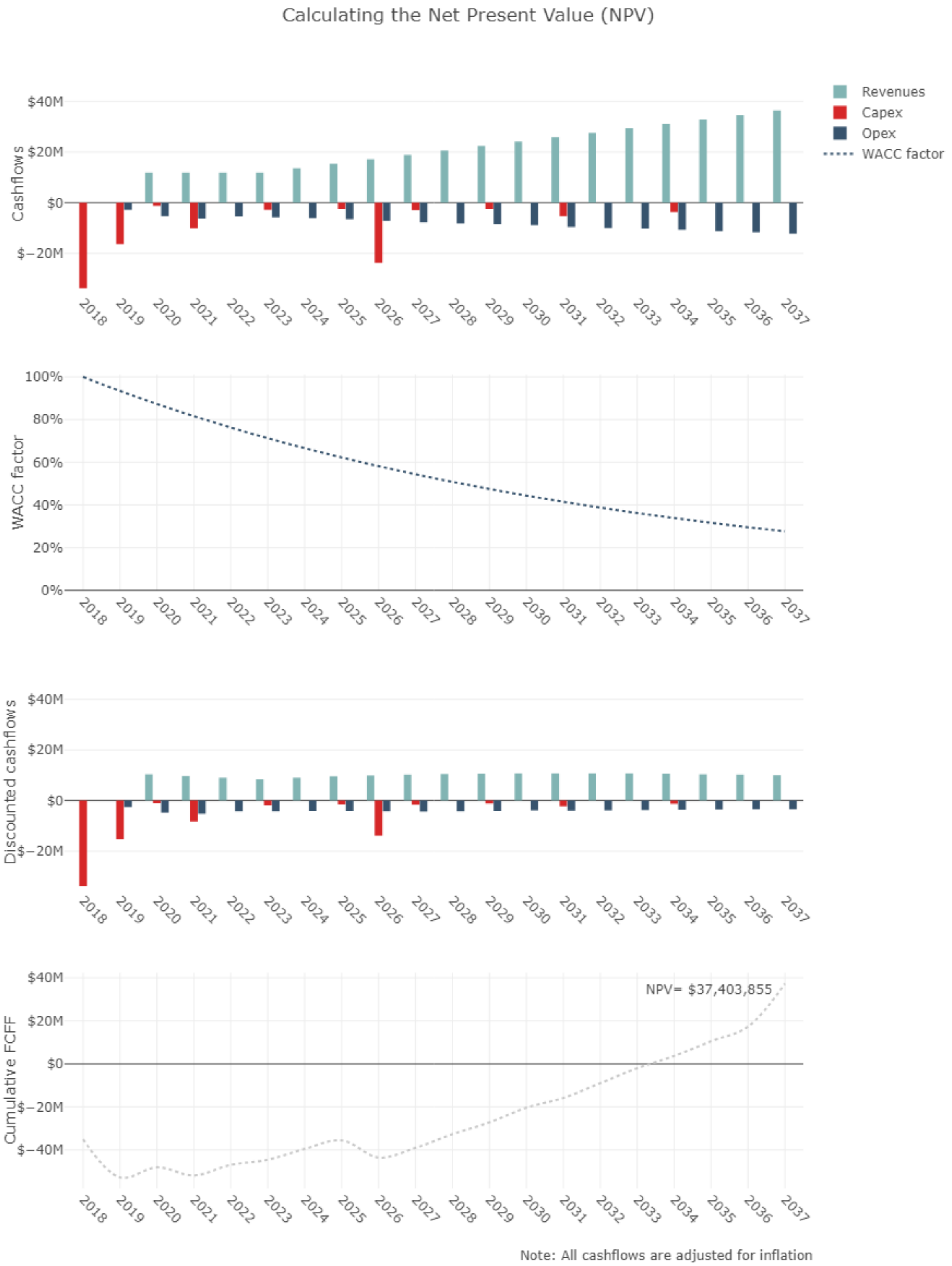


Figure C-3: Calculating the NPV

D Agribulk Terminal Characteristics

This chapter will set out to provide a clear overview of the various elements of an agribulk terminal together with their technical and financial characteristics. This is done through a literature study and combines empirical data gathered during terminal visits within the Benelux. Existing design guidelines and rules of thumb for each component will also be addressed.

Vessel characteristics

Vessel characteristics play a major role in the terminal design process. Vessel sizes greatly influence the required dimensions of maritime infrastructure (e.g. water depth, berth length, etc.) and the call size of the vessel has major implications for the design strategy of the terminal's equipment configuration (e.g. cranes, storage, etc.). The vast majority of the agribulk trade is conducted using bulk carriers, cargo vessels in which the loose cargo is loaded directly into a ship's hold. Bulk carriers can be grouped into classes depending on their cargo capacity, expressed in Deadweight Tonnage (DWT). The vessel dimensions of all registered operational vessels within each class have been averaged for each class and are shown in Table D-1. **Error! Reference source not found.**(Clarksons 2018a; UNCTAD 2009).

Vessel class	DWT	Vessel length	Vessel breadth	Vessel draught
Handysize	< 35.000t	170m	25.9m	9.9m
Handymax	< 55.000t	192m	28.1m	11.5m
Panamax	< 80.000t	225m	32.4m	14.0m
Baby-Capesize	< 150.000t	252m	41.0m	16.2m
Capesize	> 150.000t	299m	47.7m	18.5m

Table D-1: Vessel characteristics

In the past two decennia, the consolidation of global supply chains has led to ever larger vessels in the shipping sector. Bulk carriers have followed this trend, clearly illustrated in Figure D-1. The majority of newbuilt vessel capacity falls within the large *Capesize* class and are used for the shipment of iron ore and coal. Vessels within the agribulk sector have also grown over the recent decennia, be it on a smaller scale.

The relatively confined growth of vessel dimensions in the agribulk trade can be explained by assessing the underlying supply chain. Traditionally, vessel dimensions are governed by port dimensions used for export. As the supply chains of iron ore and coal have become increasingly consolidated, exporting ports have become bigger and bigger. These major export hubs have made investments in deep sea basins feasible, allowing the fleet's vessel dimensions to increase. The supply chain of wheat, maize and soybeans has also witnessed a degree of consolidation, but to a much lesser extent. Furthermore, a large portion of the agribulk production in major exporting hubs such as America and Brazil are located along rivers such as the Mississippi and Amazon. This poses a major constraint for shipping, as the large sediment volumes transported downstream by these rivers make it very costly to dredge rivers beyond their natural depth. In downstream regions of the Mississippi for instance, depths have been dredged, but only to approximately 13m and only until Baton Rouge, LA. Navigation depth quickly deteriorates as you go further upstream, lowering a vessel's cargo capacity or requiring lightering procedures. This natural cap on vessel dimensions in the agribulk trade has resulted in most of the global shipments to be shipped in the Handysize, Handymax and Panamax vessel classes. The developed tool therefore only incorporates these three vessel classes.

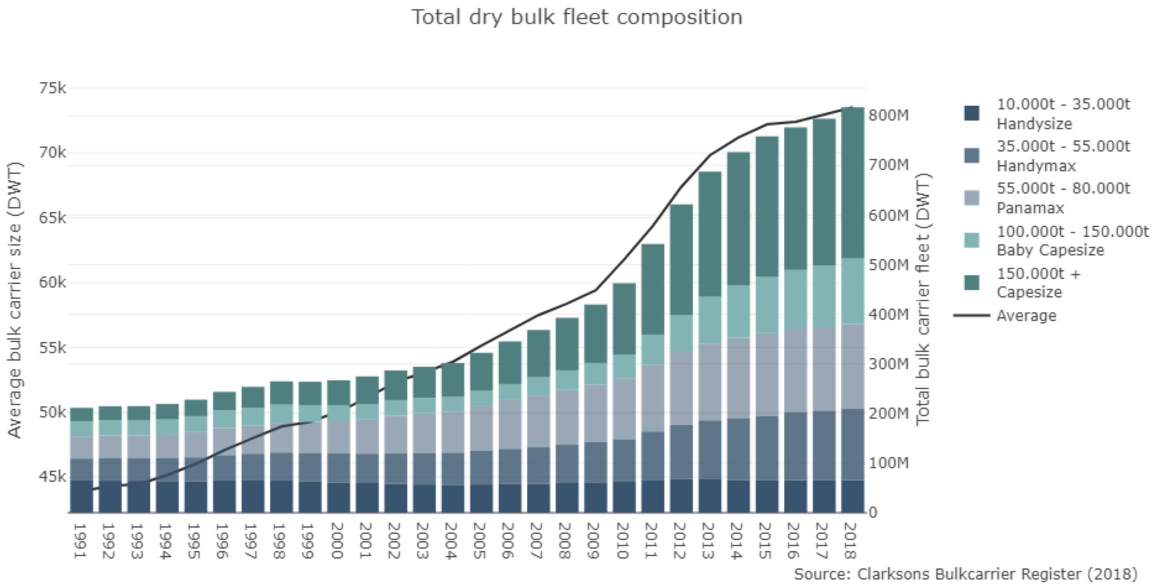


Figure D-1: The dry bulk fleet

Terminal elements

The remaining sections of this chapter will be dedicated to the maritime infrastructure and superstructure elements that are found within agribulk terminals. Each element will have its own dedicated section with a general introduction, followed by an overview of how the element is represented in the model. The process-interaction approach was followed when modelling the terminal. This approach can be summarized by the following three steps (van Vianen 2015):

1) Decompose the system into relevent element classes, preferably patterned on the real-world elements.
2) Identify the attributes of each element class.
3) Provide process descriptions that govern the dynamic behavior of these elements and their interaction with other elements.

The terminal elements that fall within the scope of this research are shown below:

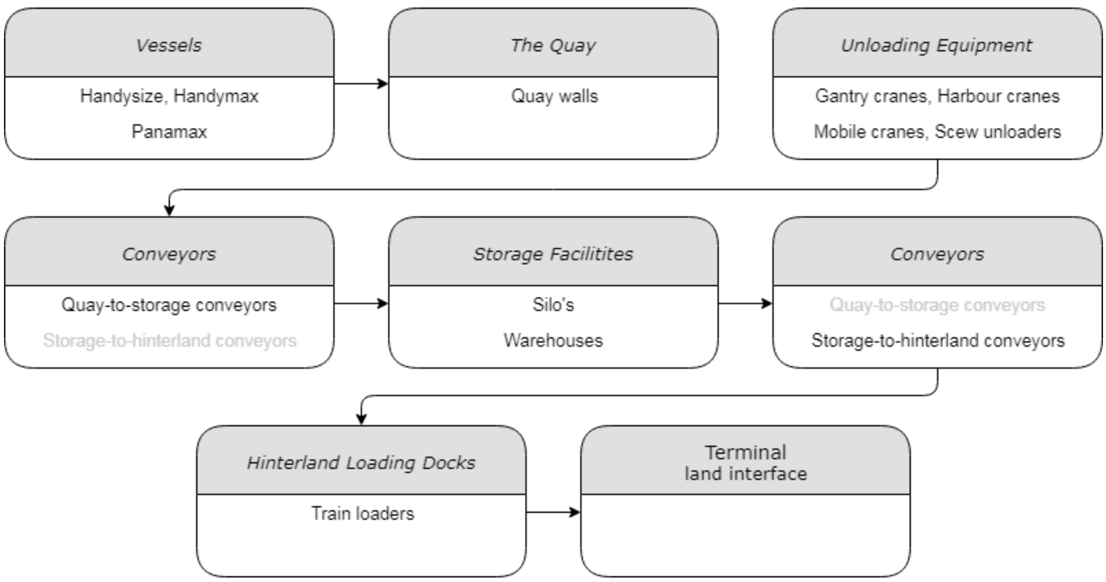


Figure D-2: Terminal element scope

The quay wall

The quay acts as the interface between arriving vessels and the processes located at the terminal. The quay consists out of berths, allowing vessels to dock so that they can be unloaded by specialized equipment stationed at each berth. Modelling quay investments is an important component when designing a terminal, as the quay represents a substantial portion of the overall capital investments required in terminal development (Kox 2016). The quay dimensions are dictated by the requirements set out by the quay's berths.

When designing a quay wall, it is important to consider the characteristics of the vessels that are expected to call at the terminal. Given that this research focusses on the agribulk trade, three types of vessel classes have been incorporated into the computer model; the Handysize, Handymax and Panamax class. Corresponding vessel characteristics, along with a further explanation regarding the choice of vessel class, can be found at the start of this chapter.

When running the computer model, the process of assigning vessels to berthing locations alongside the quay is referred to as *berth allocation*. Extensive research regarding berth allocation has been conducted, be it that the majority of the papers focus on the container sector. All in all, the modelling of berth requirements can roughly be divided into three methods (Imai et al. 2005; Rodrigues et al. 2016):

Discrete quay layout	Figure D-3.a	The quay is divided into berths and each berth can only serve one vessel at a time
Continuous quay layout	Figure D-3.b	Berths have no spatial constraints and vessels can berth anywhere along the quay if there is sufficient room
Hybrid quay layout	Figure D-3.c	The quay is divided into berths, but large vessels can occupy more than one berth

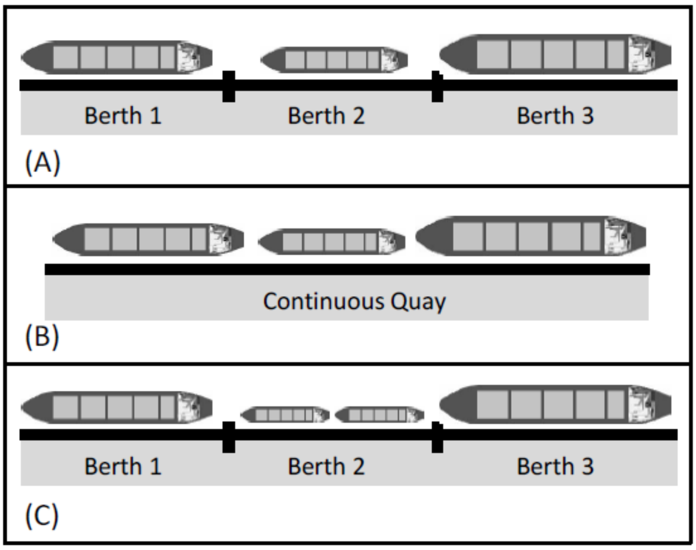


Figure D-3: Different quay layouts.
a) discrete layout b) continuous layout c) hybrid layout

As this research only covers import agribulk terminals, the discrete quay layout has been applied within the computer tool. This is justified by the fact that horizontal transport within the terminal is done by fixed conveyors, requiring fixed berthing locations. Furthermore, it has been assumed that each berth should be big enough to accommodate every type of vessel that calls at the terminal. This simplification may lead to a slight over dimensioning of the quay wall, but as the lengths of the vessels that are incorporated within the model do not show very large differences (170m for Handysize versus 225m for Panamax vessels) this simplification is deemed reasonable.

Within this research, it has been assumed that the quay wall is constructed as a sheet pile quay wall, consisting out heavy primary elements (e.g. tubular piles) with intermediate corrugated steel profiles that are driven into the subsoil and anchored into a patch of stable soil behind the wall (see Figure D-4 and Figure D-7). This type of quay wall has been chosen for two reasons; sheet pile walls are often used in cases requiring deep berths and they can be built in soils with low bearing capacities (i.e. clay) (Karamperidou 1976), leading to increased model applicability.

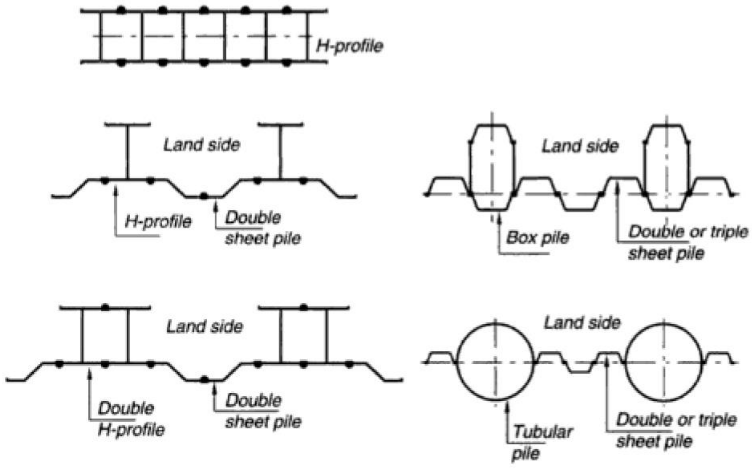


Figure D-4: horizontal cross sections of various sheet pile quay walls (de Gijt and Broeken 2014)

The quay wall and berths are both represented as separate elements within the computer model. The attributes of both elements are shown in Figure D-5 and Figure D-6.

Element: Quay wall		
Element inputs	**Value**	**Description**
t0 length	0m	Existing quay length prior to project
delivery_time	2 years	Years between aquisition and launch of asset
lifespan	50 years	Number of years before reinvestment is needed
mobilization_min	$2.500.000	Minimum mobilization costs
mobilization_perc	2%	Mobilization costs as percentage of aquisition cost
maintenance_perc	1%	Maintenance costs as percentage of aquisition cost
insurance_perc	1%	Insurance costs as percentage of aquisition cost
freeboard	4m	The vertical clearance between MSL and the apron
Gijt_constant	757.2	Constant used to determine aquisition costs
Gijt_coefficient	1.2878	Coefficient used to determine aquisition costs
Element interaction with other terminal elements		
length		The length of newly aquisitioned quay wall
depth		The berth depth in front of the quay wall
delta		Meters of quay wall aquisitioned in current year
purchase date		Year on which asset is purchased
online date		Year on which asset will come online

Figure D-5: Attributes related to quay wall elements within the model

Element: Berth		
Element inputs	**Value**	**Description**
t0 quantity	0 berths	Existing number of berths prior to project
crane_type	Mobile cranes	Type of cranes utilized at berth
max_cranes	3 cranes	The maximum number of cranes per berth
Element interaction with other terminal elements		
capacity		Yearly unloading capacity of the berth
utilization		Percentage of capacity being utilized
occupancy		The average occupancy taken on yearly basis
delta		Number of berths aquisitioned in current year
effective unloading rate		The cumulative effective unloading rate of cranes at the berth
waiting factor		The average waiting time of vessels, given as factor of service time
available crane slots		The remaing slots that can be used to add a crane

Figure D-6: Attributes related to berth elements within the model

Design assumptions

There are four technical characteristics that play a role when designing a quay wall in an early design phase; a quay wall's required freeboard, its retaining height, the number of berths and the resulting length of the quay.

Freeboard

A quay's freeboard refers to the horizontal clearance between the highest astronomical tide level and the deck. The required freeboard is site specific and is related to the astronomical tide and wave penetration present in the harbor basin. Within the computer model it has been assumed that the required freeboard is 4m.

Retaining height

In the research conducted by de Gijt (de Gijt 2010; de Gijt and Broeken 2014), quay construction costs have been correlated to the quay's *retaining height*. The retaining height (L) is the entire vertical length of the quay wall; the freeboard ($L_{freeboard}$), the berth depth (d_{Quay}) and the distance the wall has be driven into the seabed ($L_{subsoil}$). Assuming that the sub-soil length is equal to the summated freeboard and berth depth (Kox 2016), as is shown in Figure D-7, the retaining height can be expressed as:

$$L = 2 \cdot (L_{freeboard} + d_{quay})$$

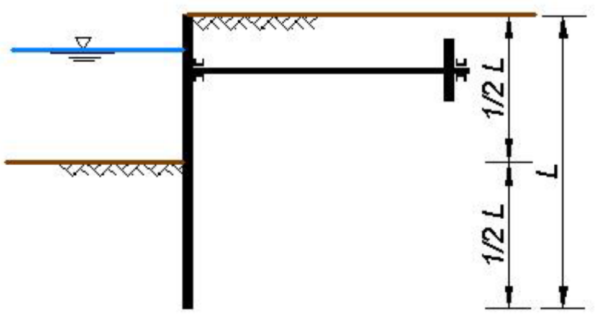


Figure D-7: A quay wall's retention height

Number of berths

The required number of berths at a terminal is determined by assessing the allowable turnaround time of vessels calling at that terminal. The turnaround time of a vessel (t_t) is defined as the time it takes for the vessel to be unloaded, or serviced (t_s), the mooring and de-mooring time of a vessel (t_m) and the time it takes for a vessel to wait for an available slot at a berth (t_w):

$$t_t = t_s + t_m + t_w$$

The service time (t_s) is governed by the callsize of the vessel (W_{call}) and the summated unloading productivty of the equipment position at the berth (P_{unload}).

$$t_s = \frac{W_{call}}{P_{unload}}$$

The unloading capacity of unloading equipment will be treated in detail in chapter 0. Furthermore, it is assumed that the vessel classes that fall within the scope of this research all have a combined mooring and de-mooring time (t_m) of three hours. Once the service and mooring times are known, the average waiting time of a vessel (t_w) can be estimated with the help of queuing theory. This approach requires the assumption that the variation in inter-ship arrival times and the service times can be represented through a standardized statistical distribution. These distributions are summarized in a so-called Kendall notation, which is depicted below. The nature of the *vessel arrival distribution (X)* and *service rate distribution (Y)* can be grouped into three classes:

	X	/	*Y*	/	*n*
Kendall's notation:	*Vessel arrival distribution*		*Service rate distribution*		*Number of berths*

Negative exponential distribution (N.E.D)	$(\boldsymbol{M})$	*High stochastic variability*	$\boldsymbol{f(t) = \lambda e^{-\lambda \cdot t}}$	$\boldsymbol{\lambda} =$	mean
Erlang-k distribution	(E_k)	*Less stochastic variability*	$f(t) = \dfrac{(k \cdot \mu)^k \cdot t^{k-1} \cdot e^{-k \cdot \mu \cdot t}}{((k-1))!}$	$k =$	Kendall - integer
Deterministic	(D)	*No stochastic variability*	$f(t) = constant$	$\mu =$	Berth utilization

Extensive research into applicable distributions has been conducted by, among others, van Vianen (van Vianen 2015). In his research, real-world data was gathered at five unnamed coal and iron ore import terminals (T1 – T5), after which the various stochastic distributions were compared to the terminal's empirical data in order to find the best fit. His conclusions are summarized in the following table:

Terminal	Annual throughput	Number of vessels registered	Best fitted arrival distribution (*X*)	Best fitted service distribution (*Y*)
T1	18 Mt/y	345	Weibull/Erlang-2	-
T2	37 Mt/y	898	NED	Erlang-2
T3	44 Mt/y	186	Weibull/Normal	-
T4	16 Mt/y	115	Weibull	Erlang-2
T5	12 Mt/y	202	Erlang-2	Erlang-2

Table 0-1: Source: (van Vianen 2015)

Building on the findings presented above, this research assumes that both the vessel arrival and service rate is best represented by an Erlang-2 distribution. This assumption is further justified by the conclusions presented by Kuo et al. (Kuo et al. 2006), which state that stochastic variation increases as a system's scale grows. As the import terminals for wheat, maize and soybeans are often smaller than the smallest terminal presented above, extrapolating these findings to agribulk terminals can be seen as a conservative assumption. Figure D-8 illustrates the correlation between a berth's occupation and the average waiting time of a vessel, depicted as a fraction of its corresponding service time (t_w/t_s), assuming both vessel arrivals and terminal service rates are representable by an Erlang-2 distribution (Douma, Schuur, and Jagerman 2011; Kuo et al. 2006; van Vianen 2015). It is important to note that this approach assumes that each vessel that calls to the terminal can moor at every berth. In other words, each berth should be large enough to be able to accommodate the largest vessels expected to call at the terminal.

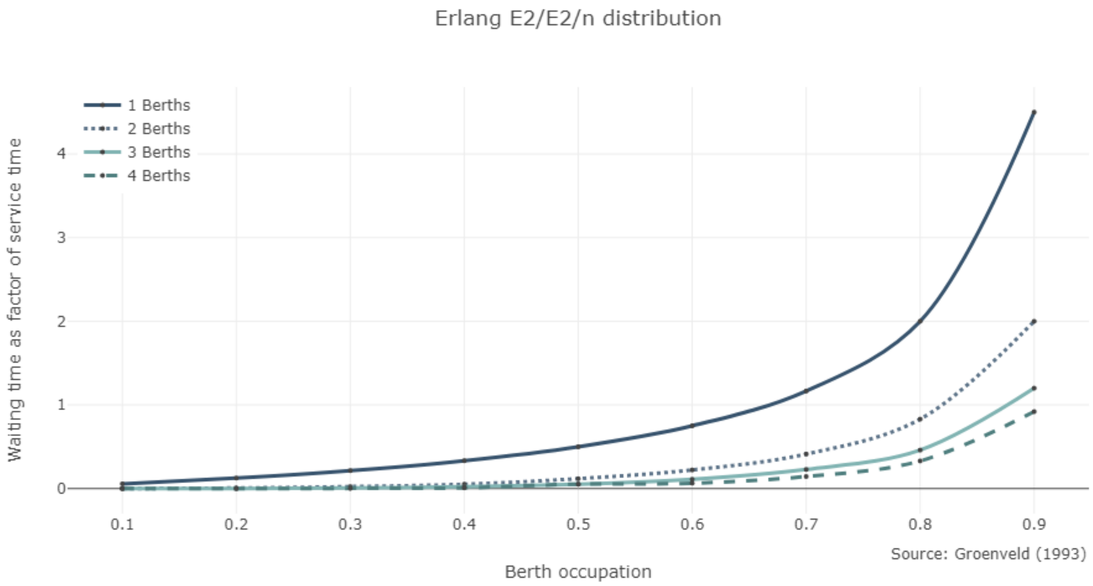


Figure D-8: Correlating berth occupation to a vessel's expected waiting time

Length

The quay is defined as a set of connecting berths built in an elongated straight configuration. Once the required number of berths is known, the resulting quay length (L_{quay}) can be calculated using equation 9.4, based on the number of berths (n) and the vessel length of the largest vessel expected to call to port ($L_{s,max}$) (PIANC 2014).

$$L_{quay} = \begin{cases} L_{s,max} + 2 \cdot 15 & n = 1 \\ 1.1 \cdot n \cdot (L_{s,max} + 15) & n > 1 \end{cases}$$

Financial characteristics

The financial characteristics of each asset within the terminal can be dissected into two groups. The first are characteristics associated with the purchasing of an asset and fall under the category capital expenditures, or CAPEX. The second group of costs are operational expenditures, or OPEX, and incorporate all yearly recurring costs such as maintenance and insurance. All costs named within this section are the *direct construction costs*, which include building materials and labour and exclude contingency and engineering costs. The three CAPEX characteristics of a quay wall that are included in the computer model are the unit cost, the mobilization cost and the construction time, the time between the purchase of an asset and the date the asset comes online.

CAPEX – *Unit cost*

The unit cost, or construction cost per meter quay, is strongly correlated to the required depth of the harbor basin. The empirical relation found by de Gijt even states that up to 75% of the capital expenditures associated with quay walls are related to its retaining height (see Figure D-9).

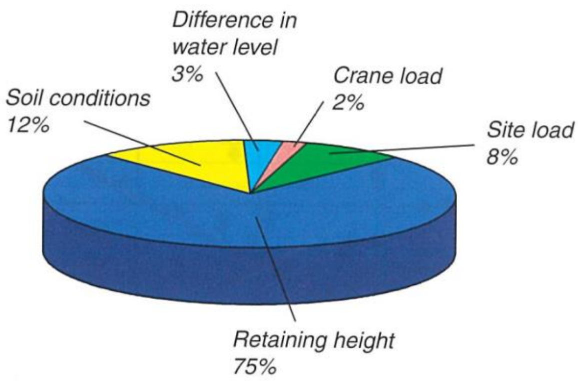


Figure D-9: Influence of various factors on the quay's construction cost (de Gijt and Broeken 2014)

The research conducted by de Gijt based its findings on the construction data of over 200 quay walls, which he received from port authorities located throughout the world. For this research, quay wall data was filtered on projects completed after 1990 with a minimum retaining height of 10m, approximated to guarantee a berth depth of at least 5m. To further support de Gijt's conclusions, MTBS project data was included in the comparison which is illustrated in Figure D-10. Through polynomial regression, equation 9.5 summarizes the correlation between the unit price of quay walls (R_{Quay}), expressed in present value US$, and the required depth at the berth (d_{Quay}). With a correlation coefficient of 0.58 the correlation is deemed decent, but a couple of anomalies remain. This might be the result of special circumstances during construction such as difficult soil conditions. Furthermore, it should be noted that the correlation is stronger in the lower depth regions (< 15m), increasing its compatibility with the developed computer model.

$$R_{quay} = 834 \cdot {d_{quay}}^2 \cdot d_{quay} + 48261$$

$$C_{quay} = R_{quay} \cdot L_{quay}$$

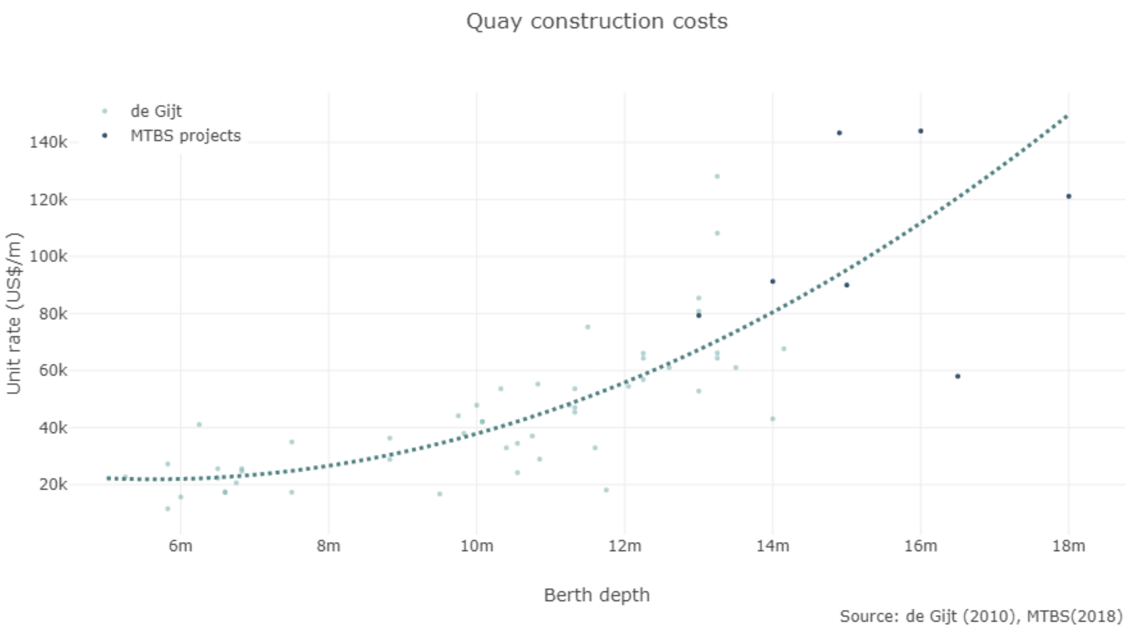


Figure D-10: Quay construction costs

CAPEX – *Mobilisation cost*

The mobilization costs are costs associated with mobilizing the construction equipment, -material and labor force. Based on projects within MTBS, the mobilization costs of quay walls (MC_{Quay}) are set at 1% of the quay's unit rate (R_{Quay}) multiplied by its length (L_{Quay}), with a minimum of 2.500.000 US$. By combining the unit rate and mobilization cost, the total construction cost (C_{Quay}) of the quay wall can be determined, as is shown in equation 9.6.

$$M_{quay} = 0.01 \cdot R_{quay} \cdot L_{quay} \qquad\qquad \geq 2.500.000$$

$$C_{quay} = 0.01 \cdot R_{quay} \cdot L_{quay} + M_{quay}$$

CAPEX – *Time until delivery*

Within the model it is assumed that it takes two years for a quay to become useable after purchasing, irrespective of the length of quay that is to be built.

OPEX – *Maintenance*

In order to guarantee asset continuity, it is standard practice to reserve a yearly budget for maintenance activities. Literature into the subject states that in 2003, the Port of Rotterdam reserved 0.5% - 1.5% of the initial quay investment as yearly maintenance. This is line with the findings made within MTBS and therefore, within the computer model, it has been assumed that 1% of the initial quay investment is required as yearly maintenance.

OPEX – *Insurance*

It is standard practice to insure the assets on a terminal. Based on expertise within MTBS, this research assumes that 1% of an asset's initial investment is reserved as yearly insurance.

OPEX – *Reinvestment*

When an asset reaches the end of its lifespan, it requires a re-investment, either because it is at risk of collapsing or because maintenance works become increasingly costly as assets become older. In the case of quay walls, current common practice stipulates that quay walls be designed for a lifespan of 50 years. Although this 50-year timeframe outlives the timeframe range of the computer model, it is assumed that depending on an asset's remaining lifetime, it still carries worth at the end of the model's timeframe. This is referred to as *depreciation* and it is assumed that this value reduction occurs linearly, as is shown in equation 9.7. Asset value (V) is related to the asset's initial cost (C), an asset's age (t_{age}) and its excpected lifespan ($t_{lifespan}$).

$$V = C \cdot (1 - \frac{t_{age}}{t_{lifespan}})$$

Unloading equipment

There are various type of equipment capable of unloading dry bulk vessels. Some do this in a continuous fashion, such as screw unloaders, whereas some cranes are equipped with grabs enabling them to unload vessels in a discontinuous manor (Ligteringen and Velsink 2017). Besides the vertical screw unloader, three types of discontinuous unloaders have been included in the scope of this research; gantry cranes, harbor cranes and mobile harbor cranes.

This section will elaborate on the characteristics of the different types of unloading equipment. This data was gathered through literature study, terminal visits, MTBS projects and contact with various equipment manufacturers. The characteristics of each type of equipment will be subdivided into two sections, the first covering its technical unloading attributes the second examining its financial characteristics.

Before moving on to equipment specifics, this section introduces the calculations and assumptions that form the base of an equipment's unloading attributes. According to PIANC, the unloading procedure of the holds of a bulk carrier can be subdivided into three phases, with each phase having its own corresponding unloading capacity (Verschoof 2002).

Peak capacity	-	*The peak capacity* relates to the optimal unloading rate at the beginning of an experienced operator's shift, during which the cargo hold is full. This unloading rate will be the design capacity to which other terminal components within the model will be geared.	1.0
Rated capacity	-	*The rated capacity* is also known as the *free-digging rate* and refers to the average unloading rate during the first half of a hold's unloading procedure.	0.8
Effective capacity	-	The effective capacity resembles the average hourly rate of unloading the entire cargo of a vessel. This includes trimming, cleaning and switching holds. For continuous unloaders, the efficiency factor is slightly higher as less cleaning operations are required and the achievable rates of discharge are less susceptible to the amount of cargo remaining in the hold (Daas 2018; Kranendonk 2018; PIANC 2014).	0.35 – 0.5

These findings have been cross-referenced with data gathered during terminal visits and the conclusions show strong similarities. Figure D-11 shows the statistical productivity distributions of TATA steel's three gantry cranes. While each crane has a *peak capacity* of 2000 t/h, measurements show that the crane's average productivity, or *effective capacity*, is about half that ($\gamma_{eff} \approx 0.5$).

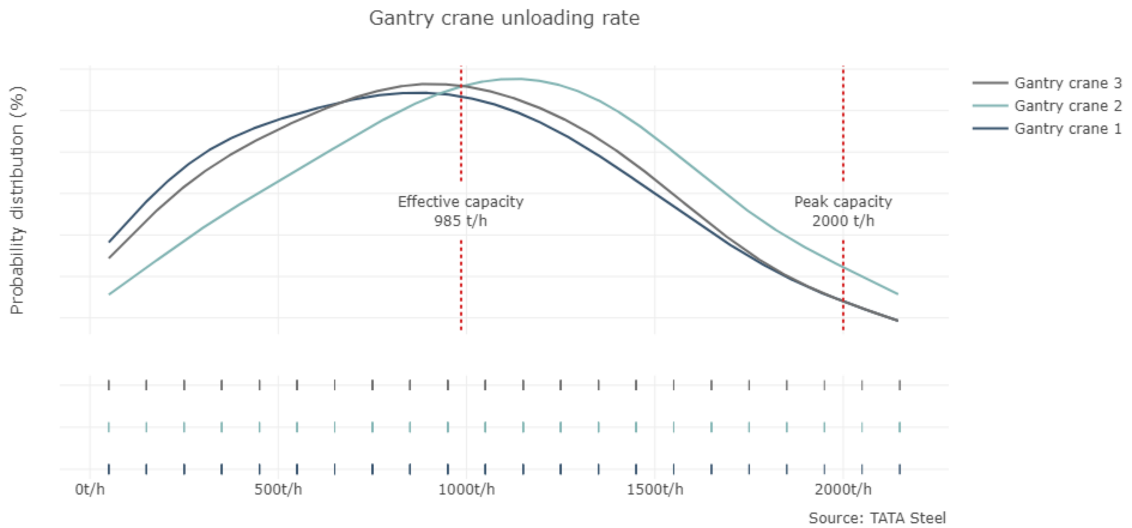


Figure D-11: Gantry crane productivity

Cranes equipped with grabs are the most commonly used method to unload dry bulk vessels for bulk cargo's, as they can handle a wide range of commodities(PIANC 2014). When handling free-flowing commodities such as agribulk, the traditional clamshell bucket has proven to be the most cost-effective grab mechanism (see Figure D-12) (Corbeau 2018).

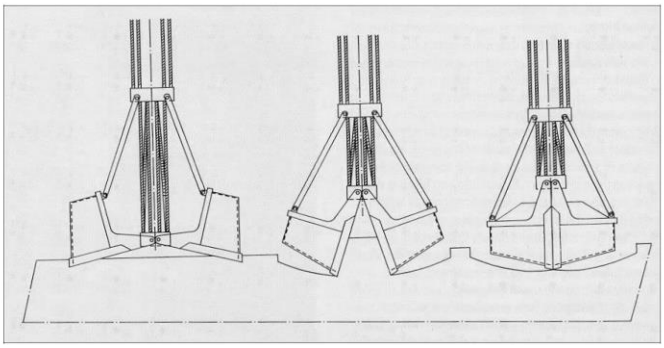


Figure D-12: Clamshell mechanics (Miedema 2006)

Grabs are used on gantry cranes, harbor cranes and mobile harbor cranes among others (UNCTAD 1985). The unloading capacity of such a crane is based on two components; the grab capacity of a crane and the speed at which a crane completes an unloading cycle.

Consulting grab producers and analyzing the loadout of cranes on existing terminals has shown that there is a linear correlation between a crane's *lifting capacity* and the corresponding *grab payload* (i.e. the amount of cargo lifted with one grab cycle) regardless of the type of crane or the type of commodity being handled (see Figure D-13) (Nemag 2018; Verstegen 2018). The only severe anomalies are related to the handling of wood pellets due to their very low volumetric density (400 – 450 kg/m^3). By excluding the data related to wood pellet terminals, the required lifting capacity of a crane (W_{lift}) can be correlated to the cranes grab payload ($W_{payload}$) through linear regression and follows the expression shown in equation 9.8. The empirical data has been further dissected and linked to various types of cyclic unloaders, shown in Figure D-14.

$$W_{payload} = \frac{W_{lift} - 2.4}{1.4}$$

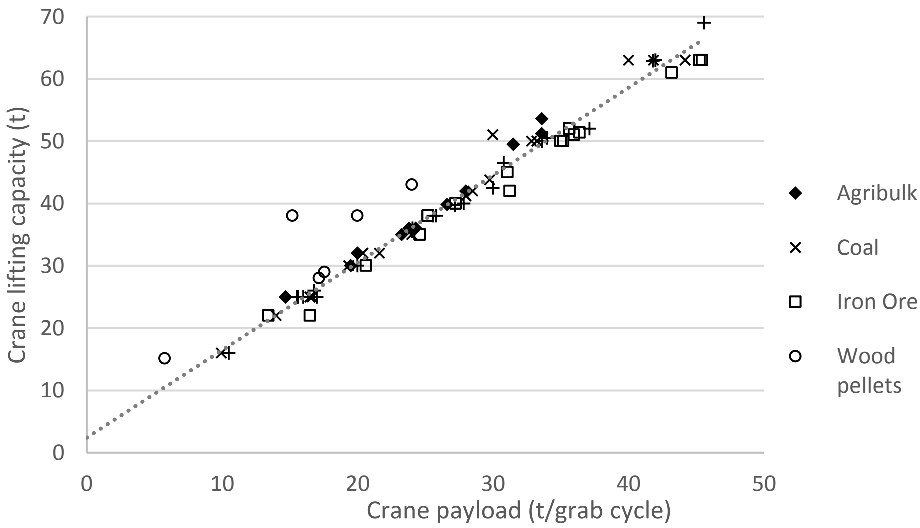


Figure D-13: Empirical crane data (Nemag 2018; Verstegen 2018)

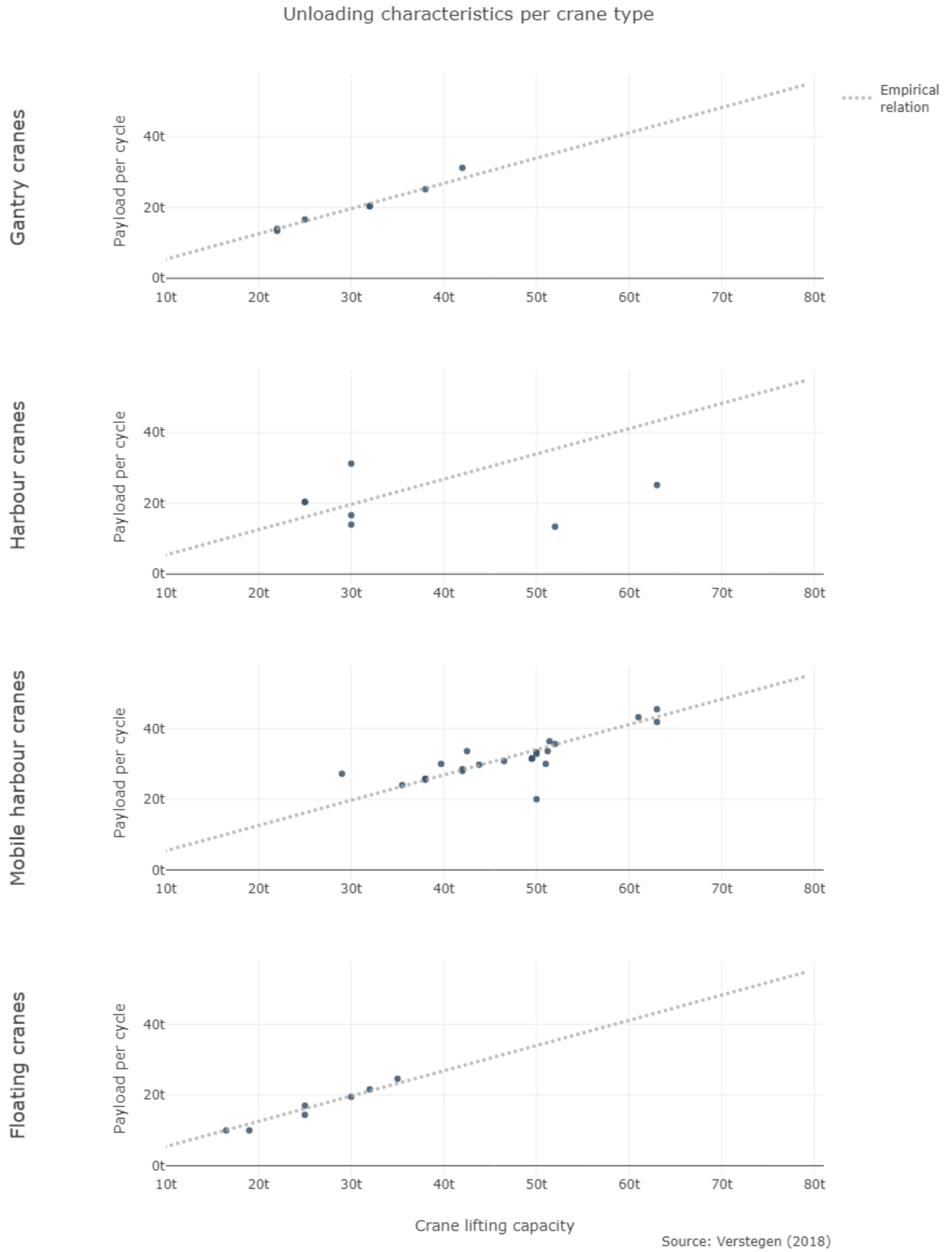


Figure D-14: Crane characteristics

Element: Cyclic unloader		
Element inputs	**Gantry- : Harbour- : Mobile crane**	**Description**
t0 quantity	-- 0 cranes --	Existing number of unloaders prior to project
delivery_time	-- 1 year --	Years between aquisition and launch of asset
lifespan	-- 40 years --	Number of years before reinvestment is needed
unit rate	USD 9.75M : USD 7.88M : USD 3.33M	Aquisition cost of asset
mobilization_perc	-- 15% --	Mobilization costs as percentage of aquisition cost
maintenance_perc	-- 2% --	Maintenance costs as percentage of aquisition cost
maintenance costs	USD 195.000 : USD 157.600 : USD 66.000	Yearly cost of maintenance
consumption	561 kWh : 210 kWh : 485 kWh	Hourly energy consumption is kWh
insurance_perc	-- 1% --	Insurance costs as percentage of aquisition cost
insurance costs	USD 97.500 : USD 78.800 : USD 33.300	Yearly cost of maintenance
crew	-- crew of 3 --	Number of operational crew
crane type	Gantry : Harbour : Mobile	The type of crane
lifting capacity	50t : 25t : 30t	The lifting capacity of the crane expressed in tonnes
hourly cycles	50 cycles : 40 cycles : 25 cycles	Number of unloading cycles completed per hour
effeciency factor	0.50 : 0.40 : 0.35	The ratio between a cranes's peak capacity and its effective capacity
payload	34t : 16t : 20t	Cargo payload per cycle
peak capacity	1700 t/h : 640 t/h : 500 t/h	Maximum unloading capacity
effective capacity	850 t/h : 256 t/h : 175 t/h	Average unloading capacity when unloading a vessel

Element interaction with other terminal elements	Description
purchase date	Year on which asset is purchased
online date	Year on which asset will come online
delta	Number of unloaders aquisitioned in current year
berth	The berth to which the crane has been assigned
energy costs	Yearly cost of energy consumption

Figure D-15: Attributes cyclic unloaders

Element: Continuous unloader		
Element inputs	**Values**	**Description**
t0 quantity	0 unloaders	Existing number of unloaders prior to project
delivery_time	1 year	Years between aquisition and launch of asset
lifespan	30 years	Number of years before reinvestment is needed
unit rate	$6.90M	Aquisition cost of asset
mobilization_perc	15%	Mobilization costs as percentage of aquisition cost
maintenance_perc	2%	Maintenance costs as percentage of aquisition cost
maintenance costs	$138.000	Yearly cost of maintenance
consumption	364 kWh	Hourly energy consumption is kWh
insurance_perc	1%	Insurance costs as percentage of aquisition cost
insurance costs	$69.000	Yearly cost of insurance
crew	crew of 2	Number of operational crew
crane type	Screw unloader	The type of crane
peak capacity	700 t/h	The crane's maximum unloading capacity
effeciency factor	0.55	The ratio between a cranes's peak capacity and its effective capacity
effective capacity	385 t/h	Average unloading capacity when unloading a vessel
Element interaction with other terminal elements		**Description**
purchase date		Year on which asset is purchased
online date		Year on which asset will come online
delta		Number of unloaders aquisitioned in current year
berth		The berth to which the crane has been assigned
energy costs		Yearly cost of insurance

Figure D-16: Attributes continuous unloaders

Storage facilities

Element: Storage		
Element inputs	**Silos : Warehouses**	**Description**
t0 capacity	-- 0t --	Existing storage capacity prior to project
delivery_time	-- 1 year --	Years between aquisition and launch of asset
lifespan	-- 30 years --	Number of years before reinvestment is needed
unit rate	60 : 135 $/t	Aquisition cost per tonne of storage capacity
mobilization min	-- $200.000 --	Minimum mobilization costs
mobilization perc	0.3% : 0.1%	Mobilization costs as percentage of aquisition cost
maintenance perc	2% : 1%	Maintenance costs as percentage of aquisition cost
insurance perc	-- 1% --	Insurance costs as percentage of aquisition cost
consumption	-- 2% of tonnage as kWh --	Energy consumption per tonne denoted in kWh
crew	1	Number of operational crew
storage type	Silos : Warehouses	Type of storage used
silo capacity	6000t	Storage capacity of a single silo

Element interaction with other terminal elements	Description
capacity	Total storage capcity
utilization	Percentage of capacity being utilized
purchase date	Year on which asset is purchased
online date	Year on which asset will come online
delta	Number of unloaders aquisitioned in current year

Figure D-17: Attributes of the storage facilities

Train loading facilities

Element: Loading stations		
Element inputs	**Values**	**Description**
t0 capacity	0 t/h	Existing loading capacity prior to project
delivery_time	1 year	Years between aquisition and launch of asset
lifespan	15 years	Number of years before reinvestment is needed
unit rate	$800.000	Aquisition cost per loading station
mobilization cost	$200.000	Mobilization costs
maintenance perc	2%	Maintenance costs as percentage of aquisition cost
insurance perc	1%	Insurance costs as percentage of aquisition cost
consumption	100 kWh	Energy consumption per loading station
crew	2	Number of operational crew
production	800 t/h	Effective loading capacity

Element interaction with other terminal elements	Description
capacity	Total loading capacity
utilization	Percentage of capacity being utilized
purchase date	Year on which asset is purchased
online date	Year on which asset will come online
delta	Storage aquisitioned in current year in tonnes

Figure D-18: Attributes of the train loading facilities

Conveyors

Element: Belt conveyors		
Element inputs	**Quay-Storage : Storage-Loading**	**Description**
length	200m : 400m	Existing conveying capacity prior to project
t0 capacity	-- 0 t/h --	Existing conveying capacity prior to project
delivery_time	-- 1 year --	Years between aquisition and launch of asset
lifespan	-- 10 years --	Number of years before reinvestment is needed
unit rate	-- $6 per t/h/m --	Aquisition cost per tonne per hour per meter
mobilization cost	-- $30.000 --	Mobilization costs
maintenance perc	-- 10% --	Maintenance costs as percentage of aquisition cost
insurance perc	-- 1% --	Insurance costs as percentage of aquisition cost
consumption constant	-- 81 --	Constant used to determine consumption costs
consumption coefficient	-- 0.08 --	Coefficient used to determine consumption costs
crew	-- 1 --	Number of operational crew
capacity steps	-- 400 t/h --	Minimum capacity added during each expansion

Element interaction with other terminal elements	Description
capacity	Total loading capacity
utilization	Percentage of capacity being utilized
purchase date	Year on which asset is purchased
online date	Year on which asset will come online
delta	Storage aquisitioned in current year in tonnes

Figure D-19: Conveyor attributes