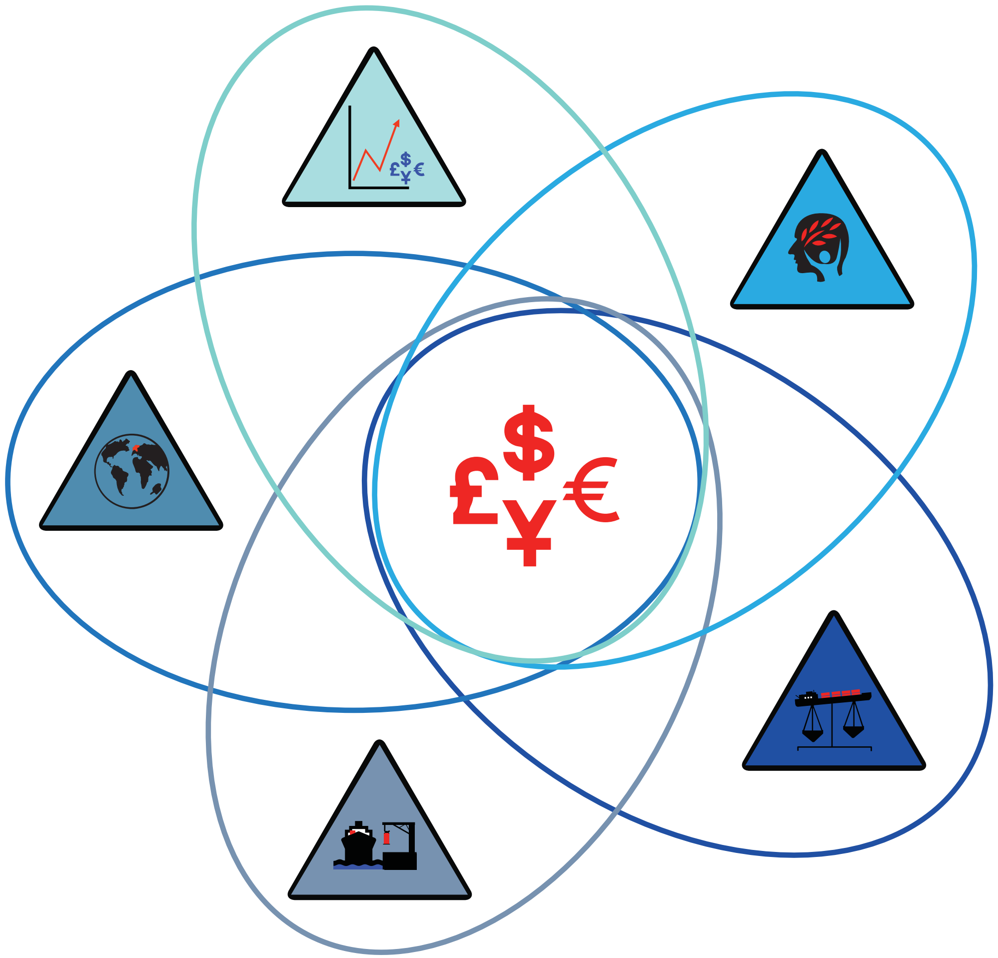

# Risk Assessment of Port Investment Projects

Master Thesis

Erasmus University

16 May 2012
Final Report

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## SUMMARY

Within a large port investment project the assessment and management of risks is very important. Without an extensive risk analysis the project might easily go over budget or will not be finished within the project deadlines. Or even worse: the project is cancelled before completion and loss of money is the result.

Large port investment projects regularly include several kinds of risks. The following main risk categories can be identified: country, market, project, environmental and regulatory risks. All these different risk categories should be assessed and their impact on the project needs to be identified.

Since port investment projects normally require very large investments in a dynamic and uncertain atmosphere, a clear risk analysis and identification of the critical path of the project is needed. Therefore investors of port projects are eager to receive strategic planning and investment advice. A reliable and thorough risk analysis is the basis on which the shareholders of an investor decide to commence, to continue with or to withdraw the investment. A strategic planning methodology is required to assess and manage the projects dynamically.

Within literature, little is written about risk assessment in large port projects and furthermore international port consultants require a method statement on how to provide and offer dynamic strategic planning advice to their clients. The main research question is therefore:

- Is risk assessment for port investment projects needed and what would be a solid methodology?

The following sub-questions are considered:

- What are the major risk factors involved in port investment projects?
- How do we present the risks within port projects and identify additional possible cost?
- How do we prioritize issues in time and provide insight into the critical path of the project?

The primary objectives for this thesis resulting from the research questions are 1) to develop the input for a systematic methodology to identify and assess the risks specific for port development projects and 2) to qualify, quantify and prioritize the relative importance of the identified risks.

Risk Management comprises the structuring of project tasks, the identification of the project risks and the control of these most important project risks. Risk Management usually consist of the following steps: risk assessment, risk mitigation and control and risk management evaluation. In this thesis the focus is on the first step of the risk management cycle: the risk assessment including risk identification and analysis.

Performing a risk assessment for investment projects may result in several results and benefits. The project and accompanying investment will be continuously reconsidered through the project

life cycle resulting in a greater chance on achieving the strategic project objectives, or as a last resort by rethinking the strategic project objectives itself. A more realistic planning can be prepared as possible delays in the projected schedule can be identified in early stages and as a result there will be a larger chance on achieving the business planning. Due to better planning in cost and time, resources can be more effectively used and services will be improved as a result of the stricter management.

Since the construction of very large infrastructural projects, budget overruns are well-known. The challenge in project evaluation is to value the investment correctly and to continue with an investment that will add value. To achieve this, project risks and strategies must be incorporated in the capital budgeting process. If the decision is made to proceed with the project, these risks and strategies must be monitored during the project.

The nature of port projects shows the need for a risk analysis as these are generally large projects with large cash flows, having many different and diffuse players, containing various types of risk events and the impact of these projects goes beyond the regional boundaries of the port. The increasing size of investments in port development projects result in risks having a growing impact on the project's performance. Larger and longer projects are more sensitive to cost overruns. Furthermore stakeholders will have different perceptions of risk and uncertainty. Risk assessment is considered to contribute to a positive project outcome especially for complex projects like port developments. The use of a risk assessment may result in investors being prepared for existing and potential risk and organisations having increased confidence in achieving the desired outcome of the investment. Investors will be able to take informed decisions about investments based on clear forecasting and assumptions and constrain the impact of risk events by taking mitigating measures. Risk assessment takes into account what might occur and will save time, money and stress today and in the future.

Risk identification is the first step of the risk assessment process with the aim to understand all the key risk events that are relevant to the port investment project and to define all potential consequences. The risk identification process for port investment projects is recommended to consist of a standard checklist, scenario analysis and/or flow chart, stakeholder workshops and expert interviews. A risk register need to be setup to keep track of the risks of the project and act as a repository of knowledge and initiate the risk analysis process. By ranking the risks the importance of the risks with regard to likelihood and impact is indicated.

It is advised to apply both qualitative and quantitative methods in the risk assessment. Not all risks can be transferred into monetary values and/or time impact. The risk events within a project are joined by corresponding costs that influences the decision taking about the project and the amount of budget and time that should be used for mitigating the risk.

A (semi) qualitative risk analysis is recommended for presenting the likelihood and impacts of the risk events. A risk rating matrix and risk map should be applied to visualize the risk events. Special attention should be paid to risk with a major consequence and a very low likelihood. These risks may result in severe environmental, social or project results or can be potential show stoppers for the business. These risks might be related to other events and this should be investigated carefully. It is recommended to indicate these risks in the Risk Register as exceptional risk and urgently evaluate them.

In case sufficient and reliable data is available a quantitative risk analysis can be added to the risk assessment by using the Monte Carlo method. Two sources of risks need to be identified, namely general contingencies and special events. General contingencies are taken into account for uncertainty in the unit rates, local prices and changes in the design. These general contingencies have a 100% probability in the quantitative analysis and are allocated to all elements of the capital cost estimate of the project. The special events have a probability of less than 50%. These special events have a relative small probability and are therefore not included in the deterministic cost estimate. In the probabilistic estimate the probability distribution of these risks is included. It is recommended to perform a sensitivity analysis and stress test to the results of the quantitative analysis.

The risk assessment methodology for port investment projects as set up in this thesis will contribute to providing investors strategic advice for their investments. International maritime consultants can apply the methodology for making carefully considered recommendations to their clients on the progress of the projects. The methodology for risk assessment provides engineering consultants a standard method statement that can contribute to a uniform way of working for strategic planning advisory projects.

# CONTENTS

APPENDICES

# 1 INTRODUCTION

## 1.1 Background and Objectives

Within a large port investment project the assessment and management of risks is very important. Without an extensive risk analysis the project might easily go over budget or will not be finished within the project deadlines. Or even worse: the project is cancelled before completion and loss of money is the result.

Large port investment projects regularly include several kinds of risks. The following main risk categories can be identified: political, cultural, economic, market, technical, environmental, social, contractual and legal risks. All these different risk categories should be assessed and their impact on the project needs to be identified.

In this thesis, the construction of a methodology for risk assessment in port investment projects is examined.

Investors of port projects are eager to receive strategic planning and investment advice. This advice should map the risks over the project lifetime. For the lenders of investment projects, the expected risks and return on investments are crucial information. Since port investment projects normally require very large investments in a dynamic and uncertain atmosphere, a clear risk analysis and identification of the critical path of the project is needed. The lenders ask for thorough investigation, clearly showing the feasibility and potential risks over the investment and to minimize the uncertainties during the project. A reliable and thorough risk analysis is the basis on which the shareholders of an investor decide to commence, to continue with or to withdraw the investment. A strategic planning methodology is required to assess and manage the projects dynamically. This method statement should help the investors in making strategic planning decisions within their project.

Within literature, little is written about risk assessment in large port projects and furthermore international port consultants require a method statement on how to provide and offer dynamic strategic planning advice to their clients.

The main research question of this thesis is therefore:

- Is risk assessment for port investment projects needed and what would be a solid methodology?

The following sub-questions are considered:

- What are the major risk factors involved in port investment projects?
- How do we present the risks within port projects and identify additional possible cost?
- How do we prioritize issues in time and provide insight into the critical path of the project?

The research questions above result in the following primary objectives for this thesis: 1) to develop the input for a systematic methodology to identify and assess the risks specific for port development projects and 2) to qualify, quantify and prioritize the relative importance of the identified risks.

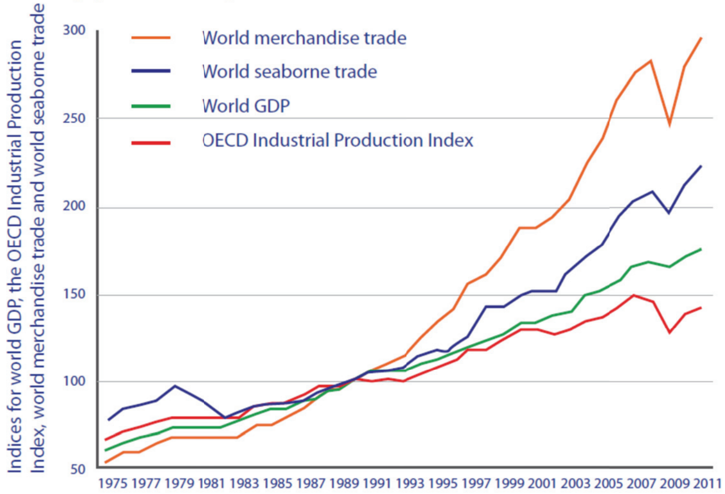
The overall goal of the thesis is to gain insight into port project performance and indicate the risks that have the highest impact. The method statement for risk assessment specific for port projects should contribute to improve the decision making process for port investments.

## 1.2 Problem Analysis

Port development projects usually require very large investments. In recent years, the size of the port investments has increased considerably. This is illustrated in Figure 1-1. The world Gross Domestic Product (GDP) is shown and the world industrial production which reflects the developments in world GDP. The world industrial production is a leading indicator of demand for maritime transport services (UNCTAD, 2011).

Figure 1-1 shows a strong correlation between industrial activity, GDP growth, merchandise and seaborne trade. UNCTAD (2011) states that shipping is largely influenced by the worldwide macroeconomic conditions. Developments in the world economy and the merchandise trade have direct influence on developments in the seaborne trade. UNCTAD (2011) mentions that port projects follow the trend of the trade volumes. In 2009 a brief pause in the port developments was noticed related to the uncertainty in trade volumes and the availability of finance.

**Figure 1-1 Indices for world GDP, the OECD Industrial Production Index, World Merchandise Trade and World Seaborne Trade (1995 – 2011) (1990 = 100)**




Source: UNCTAD, 2011

UNCTAD secretariat, on the basis of OECD Main Economic Indicators, May 2011; UNCTAD's The Trade and Development Report 2011; UNCTAD's Review of Maritime Transport, various issues; WTO's International Trade Statistics 2010, Table A1a; and the World Trade Organization (WTO) press release issued in March 2011, "World trade 2010, prospects for 2011". WTO merchandise trade data (volumes) are derived from customs values deflated by standard unit values and adjusted price index for electronic goods. The 2011 index for seaborne trade is calculated on the basis of the growth rate forecast by Clarkson Research Services.

The recovery of trade volumes during the first half of 2010 gave renewed confidence for the continuation of many port development projects (UNCTAD, 2011). The increasing investments in port development projects make that the risks within the project will have increasing impact on the project's performance. Namely the financial and time value of the risks is related to the size of the investments. Larger and longer projects are more sensitive to cost overruns as stated by Touran et al (2006). Therefore (private) investors are more and more asking for strategic advice on how to include a thorough risk analysis in the project and to manage the risk of their investments.

The demand for strategic risk analysis for investment projects is increasing because of the growing impact of these projects. This background results in the origin of the writing of this thesis which is found in the following three statements:

1. Risk assessment is becoming more important because the size of port and infrastructural investment projects is increasing. This leads to increasing demand of investors for strategic advice for their investments
2. International maritime consultants are increasingly requested by their clients to analyse the risks involved in their investment projects. Currently consultants are in search of a methodology which will assist them in making carefully considered recommendations to their client on the progress of the project and to provide them with strategic advice during project execution
3. In scientific literature little is written regarding risks assessment within port investment projects specifically. There are only nine articles on risk within the two main maritime journals over the past 12 years (refer Appendix A). From these nine only three are (partly) relevant for the subject discussed in this thesis, the others mainly concern the shipping market or risk on safety.

A link between theory and practice is needed to be able to analyse the risks within port investment projects. In this thesis a method statement is developed to create this link and to provide the strategic advice to the investors of large port projects. Before elaborating on this method statement, the problem of the lack of a risk assessment methodology for port investment projects is further explained with illustrating the statements as described above: 1) the increasing importance of risk assessment for investors and 2) the practical problem of international maritime consultants. Statement 3 is further discussed in Chapter 2 where the research in scientific literature is described.

### 1.2.1 Importance of Risk Assessment for Investors

A port investment is always a complicated process involving different kinds of actors. Furthermore a port investment project includes various areas of influences including political, environmental, socio-economic, financial and legal impacts. Therefore a comprehensive risk assessment can support the process of every port investment.

Risk assessment is very important for investors of port projects because the absence of a risk assessment or the failure to perform such an analysis sufficiently may cause very large additional unforeseen costs for the investor. The project may run over budget or the project can be delayed. Consequently, the deadlines might not be met resulting in additional costs for the project. A comprehensive risk analysis will prepare the investor to unexpected events and this will make the project investment manageable.

The problem of the lack of a risk assessment within an investment project is not only visible within the port investment sector. Also within other kind of large infrastructural projects the absence of a risk assessment has already resulted in a range of projects running over budget and out of time. This is illustrated for instance in the report of the parliamentary survey in the Netherlands concerning the projects of the 'Betuwe route' and the High Speed Line. Also during the construction of the North-South line in Amsterdam new risks were identified during the cause of the project. The conclusions from the survey committee show that the selection of the construction method was based on a limited technical and financial risk analysis.

The origin of the lack of a risk assessment can also be found within the approval process of the investments required for a port expansion or greenfield port project. Investments in port projects are initiated by private or public parties. Private parties need to show to their shareholders that the investment is justified. In accordance, public parties need to justify their investments to the associated government or board. To be able to strengthen the arguments of the investors for certain decisions in the process a thorough analysis should be presented clearly showing the background and assessment behind the project planning and management. The shareholders or board need to have confidence in the project. The risk assessment will help to create a clear and trustworthy presentation to the shareholders. Shareholders are interested in clear recommendations regarding the status of the port investment and need to be convinced with a transparent presentation showing the risks indicated during the project lifetime and recommendations for the progress of the project. Over the different phases of the project, a uniform report is required showing the risks over time. These reports should be based on a reliable analysis.

A stage gate model (refer section 2.5) is a useful model for representing the decision points for the progress of the project. However, usually the relationship between the stage gates and risks within the project is missing. At every stage gate an overview should be created showing the risks and corresponding financial impact at the different stages of the project. At every moment that a decision entails an additional payment, a risk log should be updated. The milestones along the journey are needed as gates to re-value the risks for the specific project phase. The set of stage gates will assist in managing the uncertainties and risks in the process.

The critical path of a port investment project describes activities in the project or during the investment that have the highest influence on the success or result of the project. The impacts of these critical activities determine the critical boundaries of the project and are normative for the outcome of the project. The critical path of an investment can be identified by assessing the impact of these normative activities on the investment planning and budget. In other words, by assessing the project risks the project's critical path can be identified. The risk assessment can assist in the decision-making process especially at the different stages of the project.

### 1.2.2 Method Statement for International Maritime Consultants

The awareness of lacking ability of making a trustworthy risk analysis is related to the broader role of engineering consultants within investment projects. In the last years they broadened their area of interest with respect to the consultancy advice they provide to their clients.

The consultants are getting more involved in the total ports business service covering the entire range from planning, trade forecasting, financial analysis, hydraulic modelling, maritime and operational simulation to materials handling, dredging, engineering and project management. Nowadays the engineering consultants also get involved in the early stages of a port investment project and are broadening their field of expertise including direct strategic advice to their clients. This asks for a methodology that can be applied by the consultants to perform solid assessment to provide high quality strategic advice to the clients. The engineering consultants have the capability and experience to provide these services to their client and a risk assessment methodology for port investments will support the consultants in their presentations to their clients.

### 1.2.3 Methodology for Risk Assessment

The above analysis describes the need for a methodology for risk assessment specifically for port projects. The goal of this thesis therefore is to develop a method statement that can be used to provide strategic advice. This method statement should be able to identify and assess the key risks in large port investment projects. The challenge for this research is to value the different risk elements of port investments and to provide the results in a clear and systematic way to support the decision making process for investors over the whole project lifetime. A consistent approach to risk and decision analysis should be ensured. The risk assessment should illustrate the overall viability of the investment at different stages of the project. This study will therefore focus on the strategic risk assessment of physical infrastructure projects within the context of the seaport.

## 1.3 Research Methodology

The research methodologies applied to achieve the primary objectives of this thesis are as follows.

A literature review is performed on risk management and investment projects. Information for this thesis is collected from literature of infrastructural investments, port investment projects and risk and project management. The literature study is applied to get insight into the information available with respect to the subject and to analyse the background and current challenges regarding risk assessment in port projects. Scientific research articles and several (international) reports on the subject have been included in this analysis.

Existing methods that are used to identify and assess risks are listed and their pros and cons are described to rank the methods. Methods are selected for application on risk assessment in port investment projects. Risk assessment management models and experience and knowledge from different actors in the port sector have been consulted to develop the risk assessment methodology.

A case study has been used to further develop and asses the risk assessment methodology for risk analysis within port projects. The case study shows how this risk methodology works in practice. Furthermore certain boundary conditions for the risk identification are introduced.

## 1.4 Structure of Report

The structure of the report is presented as follows. Chapter 2 describes risks and uncertainties within large infrastructural investments and ports and it further elaborates on the stage gate model. Chapter 3 focuses on the risk assessment of port projects. The chapter starts with the risk identification by presenting several methods and describing a risk list, risk register and risk ranking. Chapter 3 continues with the qualitative risk assessment and presents an analysis for port projects specifically. It further selects a quantitative method to apply in risk analysis for port projects. Chapter 4 discusses the case study and shows the application of the risk assessment methodology. Finally Chapter 5 presents conclusions and recommendations.

# 2 RISK AND PORT INVESTMENT PROJECTS

This chapter further elaborates on the problem description and basis for the research. The terminology for risk and uncertainty is described and the theory on risk assessment is further introduced. Then risks within infrastructural investments and specifically port projects is investigated and the stage gate model is presented.

## 2.1 Risk and Uncertainty

"Risk is defined as any factor, event or influence that threatens the successful completion of a project in terms of time, cost or quality" (European Commission, 2003; Medda, 2006). Or, in other words, according to AbouRizk (2003), risk is defined as the possibility of suffering loss and the impact that the loss has on the project and party involved. Risk can be characterized in terms of its severity. Severity is defined as the likelihood of occurrence times the magnitude of the impact of the risk.

According to CII (1989) uncertainty can be defined as: "The gap between the information required to estimate an outcome and the information already possessed by the decision maker".

According to the Asian Development Bank (2002), risk and uncertainty present a spectrum of unknown situations within a project, ranging from perfect knowledge of the likelihood of all the possible outcomes at one end (i.e. risk) to no knowledge of the probabilities of the impacts at the other (i.e. uncertainty).

In short, risks can be empirically measured while uncertainties are non-quantifiable. Risks are events that can be quantified and also the probability that the risk event will occur can be estimated. An uncertainty describes a situation in which no statistical probability estimates are possible.

The definitions of risk suppose that all risks have a negative impact (threat) on the project. However, also positive impacts of special events might influence the outcome of a project. Such a positive impact is generally considered as an opportunity and not as a risk.

Generally, risks have the following characteristics (Abourizk, 2003):

- Magnitude dependent: the risk is generally more acceptable when the payoff is greater
- Value based: Everyone views risk differently and everyone has a different tolerance level of risk
- Time dependent: Risk is always a future event and time has an effect on the perception of risk. What is considered as a risk today may not be tomorrow.
- Possibility: risks itself and their outcome are associated with a certain degree of uncertainty.
- Management: risk can be reduced or transferred with mitigation measures like contracts, (financial) agreements, concessions, and insurance policies.

Besides, the Australian Government (2008) adds to this that risks might be strategic or operational. Strategic risks are related to broader business environment, strategic goals and long-term sustainability of the operation. Operational risks are affected to the systematic aspects of the processes or operation.

Risk assessment is the process of identifying risk factors and the quantification of these factors by estimating the likelihood and the magnitude of the impacts of the risks.

## 2.2 Risk Assessment

Risk assessment is critical for evaluating a large (port) investment. By applying risk assessment, events are identified which are the key determinants for the project outcome and this minimizes the formation of surprises in project execution and the emergence of unforeseen problems. Risk assessment can be applied for determining the likelihood of an individual project's result being unacceptable because of the effects of the identified key factors. Costs and schedules can be better handled because contingencies are properly estimated. Following the risk assessment, measures can be designed to mitigate the risk arising from the identified key factors.

According to the Asian Development Bank (2002), risk assessment is essential to complement sensitivity analysis and to demonstrate project robustness. Generally the risk analysis is applied to demonstrate that the risks have been identified and mitigated as far as possible and that the size of the other risks without measures assigned are quantified (i.e. known) and its existence is considered as 'acceptable'.

Risk management comprises the structuring of the project tasks, the identification of the project risks and the control of these most important project risks. Risk management usually consist of the following steps (Figure 2-1):

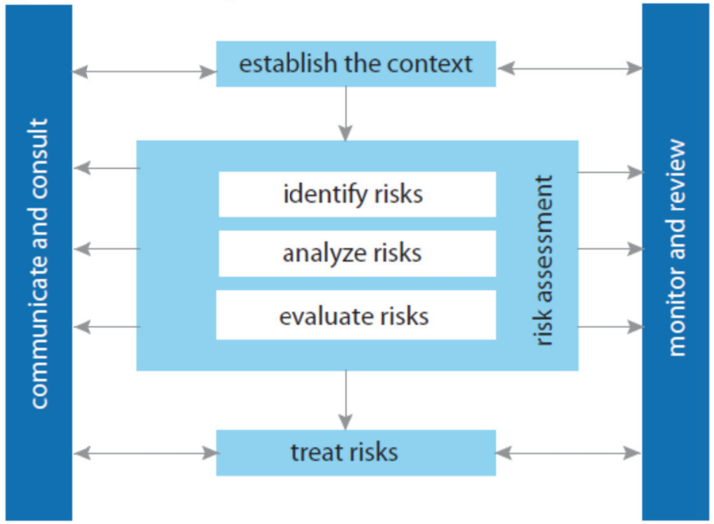
1. risk assessment
   a. risk identification: potential risks are determined
   b. analysis of the risks: the risks are identified, evaluated and ranked
2. risk mitigation and control
   a. formulate mitigating measures: identify the way how to deal with the risks
   b. implementation of mitigating measures
3. risk management evaluation
   a. evaluate measures
   b. update risk analysis

The characteristic of project risk management is that there exist a certain cycle and stratification in the analysis (Figure 2-1). At the start of a project the management is confronted with very high uncertainties and ambiguities. Risk management can assist in structuring the project and the identification of the bottlenecks of the project. As the project continues, the risks can be ranked and quantified. As time progresses, the uncertainties are being reduced and the remaining uncertainties and risks can be analysed in more detail. Therefore, a risk analysis is a snapshot during the project lifetime and is repeated over the whole duration of the project. The depth of the assessment depends on the phase of the project and the size of the risks. Risk assessment therefore is the basis of risk management.

In this thesis the focus is on the first step of the risk management cycle: the risk assessment including risk identification and analysis (refer Figure 2-2). Risk analysis and management will result in a clear understanding of the project objectives including all its alternatives and all other issues that needs to be considered during feasibility, design and construction of a project.

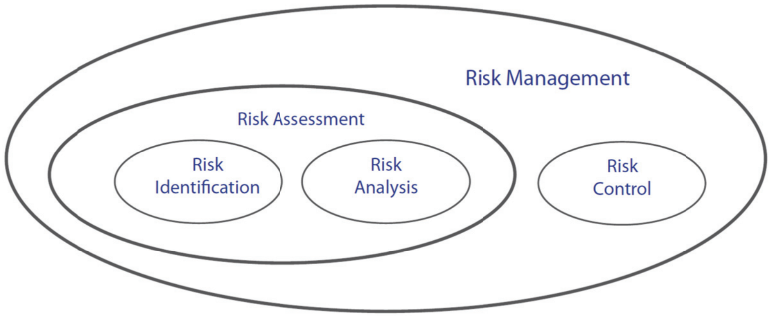
Several key stages are involved in the lifecycle of large-scale port projects. These stages include project initialisation, feasibility, design and implementation. Various forces act upon the project as it progresses from one phase to the next stage (Ho and Ho, 2006). This requires also different risk management responses dependent on the phase of the project. This is illustrated in Figure 2-3. The emphasis at the initial stages of the project should be on risk identification. Subsequently risk models can be developed for the analysis of the identified risks. Thereafter, risk control mechanisms can be structured in order to optimise the risk exposure (Ho and Ho, 2006). The risk control activities are intensified once a large project is finally implemented. Within this thesis the focus is on the first stages of a large port project. These phases require risk assessment which includes the risk identification and analysis.

**Figure 2-1 Risk Management Circle**




Source: Australian Government (2008), Author (2012)

**Figure 2-2 Key Aspects of Risk Management**



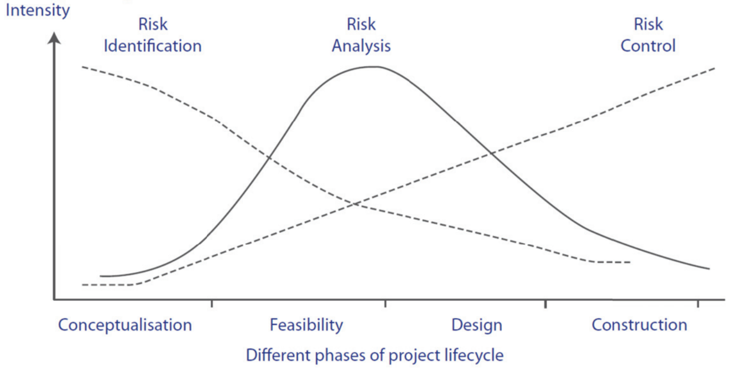

Source: Ho et al (1992)

As indicated in Figure 2-4, conceptual estimates are very difficult to produce for large investment projects. A large deviation in conceptual estimates can be noticed. Risk analysis can contribute to the process of estimating the costs of a project because the contingency allowance will be more thoroughly included.

According to Galway (2004) project management has the following three challenges: schedule, cost and performance. The questions are whether the project will go over schedule or overrun its budget and if the output of the project satisfies the goal(s) of the project. The uncertainty in these answers will probably decrease throughout the project's lifetime. Risk management is needed to control the complexity of the project and to take the complexity serious (CUR, 2010). The potential failure costs of the project can then be reduced. Further, innovation within the project can be stimulated because 'risk aversion is a barrier for the procurement of innovation' (Source EU Expert Group, 2010).

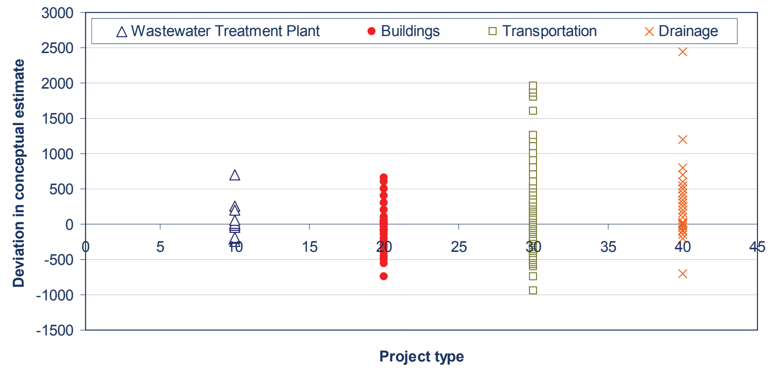
Performing a risk assessment for investment projects may result in several results and benefits. The project and accompanying investment will be continuously reconsidered through the project life cycle resulting in a greater chance on achieving the strategic project objectives, or as a last resort by rethinking the strategic project objectives itself. A more realistic planning can be prepared as possible delays in the projected schedule can be identified in early stages and as a result there will be a larger chance on achieving the business planning. Due to better planning in cost and time, resources can be more effectively used and services will be improved as a result of the stricter management.

**Figure 2-3 Changing Focus of Risk Management during the Cycle of a Large Project**




Source: Ho and Ho (2006)

**Figure 2-4 Deviation in Conceptual Cost Estimate**




Source: AbouRizk (2003) and Author (2012)

## 2.3 Risks of Infrastructural Investments

A definition of investments is provided by Hargitay and Yu (1993) and Ho and Ho (2006), indicating that investments can be seen as activities that require investment capital with the aim of receiving certain returns in the future. Because the future is not predictable, all investments include risk.

The challenge in project evaluation is to value the investment correctly and to continue with an investment that will add value (Bendall and Stent, 2007). To achieve this, project risks and strategies must be incorporated in the capital budgeting process. If the decision is made to proceed with the project, these risks and strategies must be monitored during the project.

*Flyvbjerg (2009): 'It is easier to be forgiven after an overshoot than now to get permission with a budget that is realistic'.*

Bent Flyvbjerg (University of Oxford) has written extensively about risk of infrastructural investments and megaprojects. Flyvbjerg et al (2009) mentions that infrastructure spending is the largest it has ever been as a share of world GDP and trillions of USD investments are to be expected over the next decade. Flyvbjerg et al (2009) states that cost overrun and benefit shortfalls of infrastructural projects of 50% are common and cost overruns of above 100% not uncommon. Flyvbjerg et al (2003) found that 9 out of 10 major projects in 20 countries had cost overruns. The under estimation of the costs and the overestimation of the benefits of projects result in an artificially high cost-benefit ratio and this leads to two problems according to Flyvbjerg et al (2009). First, the project may start despite the fact that it is not economically viable. Second, the project may start instead of another project that may have received higher returns if the actual costs and benefits of both projects were known.

Since the construction of very large infrastructural projects, budget overruns are well-known to these projects, for example (source: CROW 2010 & PAO course, TU Delft):

- Nieuwe Waterweg (1858) + 620%
- Stormvloedkering Oosterschelde (1986) +28%
- Average railway project + 45%

But also in very recent proejcts cost overruns are still occurring regularly. The numbers presented in Table 2-1 show increasing costs in the course of the process.

Also according to Wyman (2012) many infrastructure projects suffer from cost overruns and delays. According to Wyman (2012), companies that include risk management in their large projects can significantly reduce delays and cost overruns. Wyman (2012) advises to investors to select the project with the highest potential profit or more stable revenues to prevent questions from stakeholders and to investigate the implications of a variety of risks. Further flexibility need to be built in a plan to steer and mitigate risks and the operational and financial performance should be monitored closely by selecting key milestones and making people responsible for monitoring them.

Infrastructural projects still account for a large number of investments. According to Wyman (2012), the world needs 54 trillion USD of infrastructure to support its economic recovery. This is divided over different kind of projects as indicated in Table 2-2.

Rosenberg (2006) indicates a number of reasons for the cost overrun of large projects. First, change in scope due to increasing quality standards like safety standards, environmental requirements and integration measures cause cost overrun. Second, delays in the project implementation and third, inflation and interest increase costs of the project. Finally, lower revenues because of underutilisation of the project will have a negative impact on the project result.

Other reasons that can be indicated are for example project land status complications and replacement of some of the contractors of the project (Zaini et al 2011). Also the escalation of building material prices (25%) and shortage of workers contribute to cost overrun in projects (Zaini et al 2011). Zaini et al (2011) showed that risk assessment could improve the project performance in time, cost and quality and reduce the negative consequences in the construction project (risk assessment needs to be implemented to reduce the loss). Weaknesses of risk assessment indicated by Zaini et al (2011) are that it requires more training, it is time consuming and may also increase project cost.

**Table 2-1 Overview of Cost Estimates over Time of Large Infrastructural Projects (Rosenberg, 2006)**

| Project | 1st estimate | 2nd estimate | 3rd estimate |
|---|---|---|---|
| Betuwelijn | 1.1 (1990) | 4.7 (1995) | 10.3 (2005) |
| Maasvlakte 2 (phase 1) | 0.6 (2001) | 1 (2003) | 1.4 (2005) |
| Zuiderzeelaan (zweeflaan) | 6 (2000) | | 9 (2006) |

Source: Rosenberg (2006)

**Table 2-2 53.5 Trillion Worth of Infrastructure to Support its Economic Recovery**

| Infrastructure facilities | Aggregate investment 2009 – 2030 [trillion USD] |
|---|---|
| Water | 17.7 |
| Telecom | 10.9 |
| Roads | 7.5 |
| Electricity (transmission & distribution) | 6.1 |
| Rail 'new construction' | 5.0 |
| Oil and Gas (transport & distribution) | 3.3 |
| Airports | 2.2 |
| Ports | 0.8 |
| **Total** | **53.5** |

Source: Wyman (2012)

Vrijling and Van Gelder (2009) mention that uncertainty regarding the budget and time-planning scheme is not constant during the project. In the early stages of the project little is known about the project and it is of no use to make detailed estimates for phases to come. The uncertainty during the project decreases over the project duration and then more detailed estimates can be provided. Vrijling and Van Gelder (2009) indicate the following cost estimates variations in infrastructural projects as indicated in Table 2-3. This table presents the difference in accuracy between an estimate of the budget in an early stage of the project and the final estimate at the start of the engineering phase. Vrijling and Van Gelder (2009) indicate that the management and control of costs result from uncertainties in quantities and production times (like unit prices and wages), uncertainties involving economics and changes in the design of the project, difficulties in modelling and budgeting and time-planning caused by the long time period over which super investments like civil engineering projects are stretched.

The financial risk for most large engineering projects is highly time-dependent (Duffy and Van Dorp, 2003). Long completion times for the project may induce increased direct labour costs, delays in delivery time tying up facility resources, large cash disbursements for equipment and material deliveries. The investment may have complex scheduling interdependencies which greatly affect the time-dependent cost uncertainty. According to Duffy and Van Dorp (2003), an integrated risk analysis method that includes schedule and cost information would seem desirable.

**Table 2-3 Cost Estimate Variations**

| Project | Difference in % of the final costs | |
|---|---|---|
| | Estimate in study-of-plan phase | Estimate in Builder's specification phase |
| Haringvliet locks | 77% | 22% |
| Grevelingen dam | -19% | 22% |
| Volkerak dam | 56% | 23% |
| Brouwers dam | -39% | -18% |

Source: Vrijling and Van Gelder (2009)

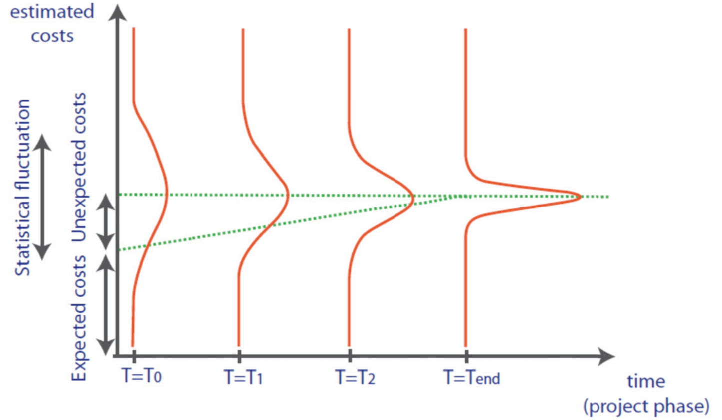
The impact of these large investments particular in infrastructural projects on the economy is generally considered to be significant. The politicians or shareholders deciding whether or not a project should be build are considerably influenced by the cost estimations. However, cost estimation of several projects has shown a tendency to increase during the development of those projects (Boschloo et al 2001). The rise in cost estimation is mainly caused by unexpected events and extra demands arising during the project. These unexpected costs are presented in Figure 2-5.

When the correct costs and project duration would be known immediately from the start of the project, the actual final project costs could also be exactly determined. However generally this is not the case and therefore a statistical fluctuation is shown in the cost estimates. This bandwidth shows the uncertainty in the cost estimation. The uncertainty decreases if the project proceeds because research adds information about for instance soil conditions and detailed engineering calculations. More detailed costs estimations can then be presented with reduced uncertainty.

HM Treasury (2011) also shows a demonstrated and systematic tendency for cost estimates to be optimistic. This is observed in both the public and private sectors. Benefits, timing and cost (capital and operational) are affected by optimism. HM Treasury (2011) advices that in order to redress this tendency, adjustments should be made for this bias.

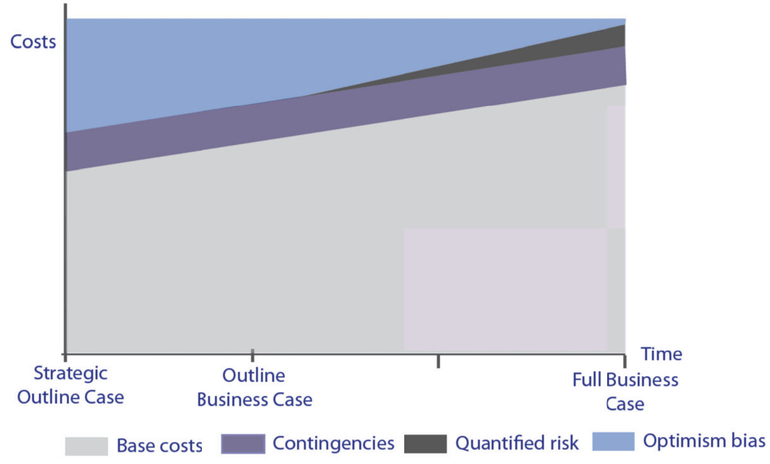
HM Treasury (2011) mentions that optimism bias, contingencies and risk are all types of risk analysis however in different stages of the project. Optimism bias relates mainly to changes in the scope of projects. HM Treasury (2011) argues that the risks covered by optimism bias can not be quantified or valued individually (or in case they can be quantified, there is a lack of an evidence basis). The optimism bias should therefore indicate the upper boundary of the cost estimates. Figure 2-6 shows that optimism bias is most relevant to stages prior to the Full Business Case. Note that contingencies are taken into account for uncertainty in the unit rates, local prices and changes in design.

**Figure 2-5 Cost Estimations as a Function of Time**




Source: Boschloo et al (2001) and Author (2012)

**Figure 2-6 Optimism Bias within Cost Estimate**




Source: HM Treasury (2011) and Author (2012)

The optimism bias is expressed as the percentage difference between the estimate at the project start and the final project result (Mott MacDonald, 2002). Mott MacDonald (2002) states that for non-standard civil engineering projects like ports, the upper and lower band optimism bias levels for the CAPEX estimates is 66% and 6% respectively. Mott MacDonald (2002) mentioned that optimism bias is caused by a failure to effectively identify and manage project risks, resulting in cost and time overruns and benefit shortfalls. Mott MacDonald (2002) recommends the upper bound optimism bias estimate for projects without effective risk management and bad scope definition. The lower bound value for optimism bias can be applied for projects with effective risk management by the start of the project.

According to HM Treasury (2011) the main causes for the application of an optimism bias in the capital cost estimates are 1) the definition of the scope and objectives of the project are not sufficient, possibly caused by poor identification of stakeholder requirements resulting in additional costs and 2) poor management of the project during implementation: schedules and deadlines are not reached and risks are not mitigated.

Nijkamp and Ubbels (1998) indicate in their study to infrastructural projects a cost overrun of 15% to 760% for the projects included in their discussion. Nijkamp and Ubbels (1998) indicate three main reasons for underestimation of the costs in infrastructural projects namely 1) price rises, 2) incompleteness of (or poor) estimations and 3) adjustments to the project. Nijkamp and Ubbels (1998) conclude also that the longer the project duration, the larger the cost underestimation. This relates in particular to the price rises, as the longer the course of time for the project, the higher the chance prices will rise influence the cost estimations. Nijkamp and Ubbels (1998) mention also that on the other hand there might be a decreasing influence to the final costs due to significant rise in productivity in the course of the project.

Walewski et al (2005) state that projects with the following characteristics are significant more likely to need a comprehensive and detailed risk assessment:

- Substantial resources
- Significant novelty (like a greenfield site)
- Long planning horizons
- Large size
- Complexity
- Several organizations (stakeholders)
- New jurisdiction for one or more project participants
- Significant political issues

Walewski et al (2005) indicate that many international construction projects have several of these factors. Most of these characteristics also apply to port investment projects. This is further elaborated in the next section.

## 2.4 Port Investment Projects

The focus area of this study is the risks assessment of investments specifically within the port industry. The core business of ports no longer only consists of loading and unloading of cargo but also ports perform now a more central role in the total transport chain (Chlomoudis and Pallis, 2008). Increasing the port productivity does not only depend on upgrading the maritime transport facilities, but the total transport chain should be improved. Subsequently, ports are one of the primary participants in a group of transportation stakeholders and therefore ports play a significant role in the economy of a country (Chlomoudis and Pallis, 2008).

Port investment projects are large-scale and their success, failure or negative impacts will have long-term implications for the economy of a country (Ho and Ho, 2006). Furthermore, maritime industry acts in a dynamic global environment subject to a great number of variables (Bendall and Stent, 2007).

Risk assessment in port investment projects is more complicated than other infrastructural projects due to the different nature of ports:

- There are more and different players within ports and players in ports are more diffuse
- The seaport has an impact on the economic development it serves and this goes beyond the regional impact of the port. The development of a seaport will therefore also be of interest to governments owing to the externalities that are spilling over to the hinterland's economy
- Demand for port services is related to the regional and global trade and market, increase in ship sizes, hinterland connection, competition between ports, political climate.
- Large cash flows: potential for large gains or losses. Unbalanced cash flow, front-loaded with initial (large capital) spending before generating revenues. This increases the payback period and reduce the NPV. Also relatively low operational cost during project lifetime in combination with a significant economic life of port infrastructure result in large cash flows.

The Asian Development Bank (2002) recommends the application of quantitative risk analysis techniques for very large projects from a national point of view, marginal projects (i.e. where the economic internal rate of return may be just over 10% - 12%) and projects with considerable uncertainty over the values of key variables. Port investments projects generally have all of these characteristics and therefore a quantitative risk analysis within a port investment project is certainly required.

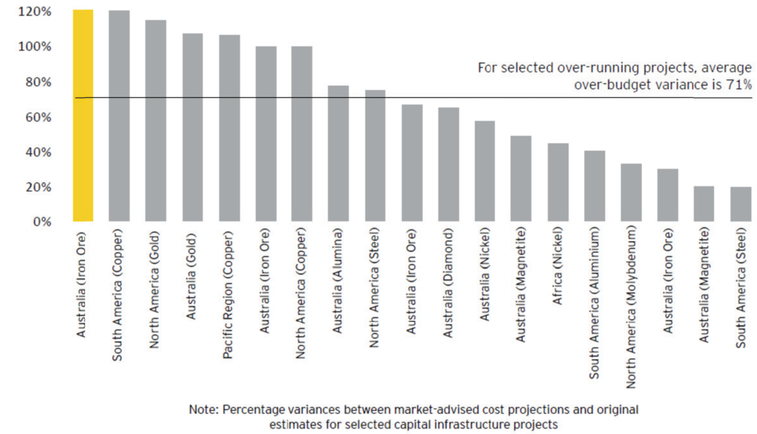
Besides, Asian Development Bank (2002) indicates some factors that might affect the economic outcomes of ports and shipping projects. These factors are implementation delays, cost overruns, traffic volumes, extent of maintenance, operating costs and benefit estimation methodologies and all of these factors should be subject to risk analysis.

The nature of the port and its industrial area presents a large range of uncertainties in the field of environmental impacts, economic benefits and costs, social effects, geotechnical conditions and political influences. Furthermore stakeholders will have different perceptions of risks and uncertainty.

Risk assessment is considered to contribute to a positive project outcome especially for complex projects like port developments. The use of a risk assessment may result in investors preparing for existing and potential risk and organisations to have increased confidence in achieving the desired outcome of the investment. Investors will be able to take informed decisions about investments and constrain the impact of risk events by taking mitigating measures.

The mining and metals business make amongst others large investments in their own ports. According to Ernst & Young (2011), many companies have encountered cost escalations that have forced them to defer, cancel or revise projects and strategies. The average cost overrun was about 71% of the original cost estimate for companies that reported their overruns publicly between October 2010 and March 2011 (Ernst & Young, 2011) (refer Figure 2-7).

**Figure 2-7 Projected Cost Variances for Selected Over-Running Capital Infrastructure Projects**




Source: Ernst & Young (2011)

Ernst & Young (2011) state that these mining and metals companies face a growing level of project execution complexity and risk and are struggling with cost and schedule pressure in their investment projects. The mining and metals companies are responding to these challenges by focusing on stage-gate delivery in combination with robust project (risk) management (Ernst & Young, 2011).

Within public port investments, risks can be allocated to the government or to private parties by initiating Public Private Partnership (PPP) arrangements. These PPP structures can be used to fulfil the budgetary cash flow requirements as well as for transferring risk and increasing efficiencies (Cooper 2003). Through PPP structures risks will be shared between the government and private sector. The more risk the private sector takes the lower the government provision and the higher the privatisation.

The above shows that the benefits of performing a risk assessment might have effect on several different parties. For the port authority the cost and benefits of possible port investment projects will be more clear, investors are more willing to invest and more efficient port management might be possible resulting in stable and secure financial results. The government will gain good value for public money and is better prepared for unexpected results. Risk assessment will help private investors in presenting the expected project results and risks to their shareholders or other decision makers.

## 2.5 Stage Gate Model

According to Ernst & Young (2011), the best opportunity to make a positive impact on the lifecycle of major investment projects is during early planning, before the outlay occurs and by using a stage gate model for evaluating the processes.

As the project moves through its lifecycle from concept to operation, well advised decisions can be enabled by using the information derived from the stage gate model. As presented in Figure 2-8, opportunities and challenges in the planning process must be proactively considered. Then the investors have the ability to influence the total costs over the project lifecycle by reducing the risk over the subsequent phases from design to execution of the project.

Stage gates are embedded in large investment projects including minimum stage gate acceptance criteria for the projects. Furthermore, funding decisions are related to successful stage gate completion. The stage gate model was introduced by Robert R. Cooper (Cooper, 1986).

According to Ernst & Young (2011), stage gates reinforce a discipline of reflection on the project progress and to respond to planning difficulties. Risk assessment is frequently used in combination with the stage gate model to be able to provide recommendations for the investors at the important decision moments.

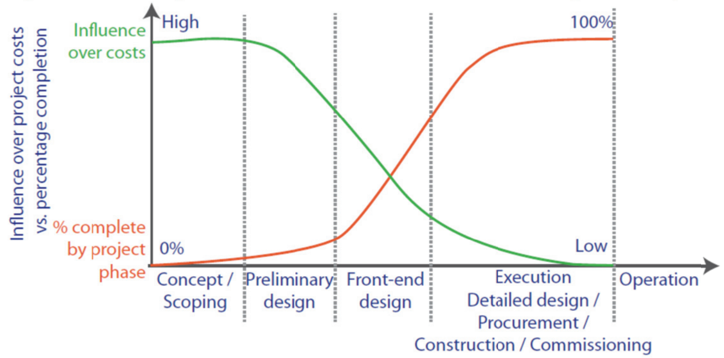
Early intervention with respect to risks is needed within large investment projects. An on-going process of risk identification and review is required to control the investment. By using the stage gate model during the entire project realisation and operation phase, the stakeholders have the opportunity to make decisions based upon solid information derived from the stage gate model. Actively involving stakeholders in the process can be realised with the clear intervals for the assessment of current-stage performance derived from the stage-gate model. According to Ernst & Young (2011), effective planning and early intervention will induce a switch from reactive to proactive portfolio and strategic planning.

Figure 2-9 presents an example of a stage gate model for port investment projects. Other models can have different stages and labels but share the same principles.

The stage gate model describes the process from identification to operation of the port project by using different stages of the project in the project lifecycle.

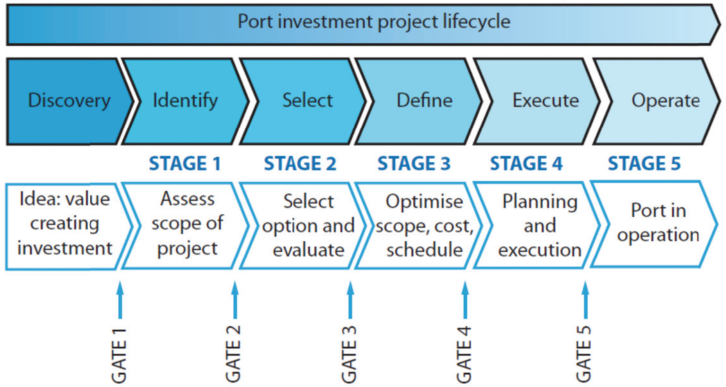
Figure 2-9 shows five stages plus the discovery stage. Each stage is proceeded by a gate, where a team of 'gatekeepers' make decisions on the progress of the projects (Cooper et al, 2001). A gate meeting generally can lead to the decision go, kill, hold or recycle.

**Figure 2-8 Ability to influence Total Cost over the Project Lifecycle**




Source: Ernst & Young (2011)

**Figure 2-9 Stage Gates within a Port Investment Project**




Source: Author (2012)

A port project starts with the discovery phase in which the idea is created. Then the following gates might be included in the project:

- Gate 1: The idea of the value creating investment is raised. The decision here is simply whether or not to explore the project a bit further.
- Gate 2: Identify the investment and assess the scope of the project with a feasibility study. A survey can be used to explore the possibilities for port development further.
- Gate 3: Assess all reasonable alternatives and select the optimal investment alternative based on Net Present Value, payback period, risk and uncertainty.
- Gate 4: Detailed design; decision has to be made whether or not to proceed with full scale implementation of the project
- Gate 5: From execution to start of operations.

# 3 RISK ASSESSMENT

The methodology for risk assessment within port projects that is set up in the following sections consists of the following parts:

- Risk identification: contains risk checklist, risk register and risk ranking
- Risk assessment:
    - Qualitative: includes an impact and likelihood table
    - Semi-quantitative: includes a risk matrix and risk map
    - Quantitative: entails assessing the costs, cash flows (costs, revenues and schedule) or advanced analysis (tax and accounting). In this thesis the focus is on costs assessment.

## 3.1 Risk Identification

Risk identification is the first step of the risk assessment process. The aim of the risk identification process is to understand all the key risk events that are relevant to the port investment project. Furthermore all potential consequences should be defined and their likelihood of occurring needs to be indicated. All currently known risks that could have an impact during the course of the project should be documented. This includes threats and opportunities. An event or issue should be identified as a risk factor if it may cause harm to the project.

In order to ensure or maintain a healthy project process, risk identification is an important step to undertake at the beginning and during the project. If the risk identification is not sufficient not all risks will be evaluated and included in the analysis. This can have immediate or future impact on the project progress.

### 3.1.1 Techniques for Risk Identification

A number of approaches can be used to identify risks. AbouRizk (2003) focuses on comparison lists, brainstorming and (expert) interviews. Rio Tinto (2005) has a more extensive list with tools and techniques including SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) and assumptions and constraints analysis. Furthermore Rio Tinto (2005) mentions the importance of post-project review analysis and the use of historical data and lessons learned.

Other additional tools and techniques for risk identification are included in a consolidated list by Raz and Hillson (2005). Raz and Hillson (2005) underline the use of (influence) diagram techniques and schematic trees or flow charts to indicate risks. In addition, specific engineering techniques and modelling and testing are suggested.

The risk identification techniques as suggested in literature are summarized in Appendix B. The advantages and disadvantages are listed for each technique.

A combination of methods will provide the most complete list of risks events within a port investment project. The risk identification technique suitable for port projects should stimulate out of the box thinking because of the complex environment in which ports usually are included. Further the method should not be too time-consuming as project planning might be tight and it is important to generate a risk list in the early stages of the project.

The risk identification techniques as indicated in Table 3-1 are recommended during the risk identification process for port investment projects.

As shown in Table 3-1 the risk identification process for port investment projects preferably consists of two phases, namely a desk study and a consultation phase. It is recommended to start with a desk study to stimulate thinking about the project and to create a basis for further analysis. The basis of the risk identification process will be the risk checklist that can be used during the whole project. A setup for a risk checklist for project investment projects is presented in Appendix C.

Information for the risk identification process also needs to be obtained from experts of the project and experienced operators. These specialists fully understand the project and can be consulted for example on specific convened workshops. The expertise of external stakeholders will be needed for the risk identification in case the project has broader consequences.

Another risk identification technique recommended for the consultation phase are brainstorm sessions with all the relevant parties. The findings of the first phase desk study can then also be verified with this stakeholder workshop or brainstorm session. New findings will be included to the list of risk events and the risk identification process can be updated.

**Table 3-1 Recommended Risk Identification Process for Port Projects**

| Phase 1<br>Desk study | Phase 2:<br>Consultation |
|---|---|
| Standard checklist | (Expert) interviews |
| Scenario analysis | (Stakeholder) workshop |
| Flow Chart / Critical path method | |

Source: Author (2012)

### 3.1.2 Risk Check List

The aim of the risk list is to identify the primary resources of risk that will affect the port investment projects worldwide. Within literature, the input for a risk list is generally categorized to differentiate the various sources of the risks.

Hitchings and Wilson (2002) indicate risks at a project level while Hastak and Shaked (2000) state that risks should be analysed at a higher level. Next to the risks associated with the project they distinguish between macro or country risks and market risks.

Nijkamp and Ubbels (1998) specifically select a way of identifying risks in transportation projects. They further elaborate the project risks into a construction and operational level and create a separate category for the financial risks. Walewski (2005) goes one step further for risks in construction projects and makes an additional subdivision on all levels. Both Nijkamp and Ubbels (1998) and

Walewski (2005) indicate next to the project risks a category for political (or country) and commercial risks.

Rio Tinto (2005) distinguishes downside risks (threats) and upside risks (opportunities). Rio Tinto (2005) recognizes that managing the threats and maximizing the opportunities will ensure that business objectives will be met in the most effective way. This will result in increased value to the business and their stakeholders. Further, Rio Tinto (2005) considers risk with and without economic consequence. The risks with economic consequence have a direct effect on NPV.

The World Bank (2007) has a risk list primarily focusing on port projects and projects in developing countries. Next to country, commercial and project risks the World Bank (2007) also focuses on regulatory and contractual risks.

Chlomoudis and Pallis (2009) introduce an extensive list that should be taken under consideration for investments in the port industry. The list includes a high level distinction between risks related to project scope, social, environmental, safety and natural issues.

Based on the above data a Risk List is created specifically for port investment projects. Five main categories of risk are identified which have been indicated as the main risks categories for port investment projects.

Country Risks describe the risks resulting from the (inter)national framework in which the port operates. The country risks can be further subdivided into political/government risks, risks related to cultural diversification and economic/currency risks.

Market Risks are the risk associated with the international construction and transport market. This includes risks related to traffic and competition, obligations and guarantees.

The risks associated with the investment are the Project Risks. The project risks are further subdivided over the different stages of the project: project scope and start-up, design, construction, operation and management.

The fourth category contains the Environmental Risks. These risks are related to the port environment and are subdivided into natural, safety and social risks.

The last category describes the regulatory risks. This includes risks related to regulation and contractual issues. In addition, legal and taxation risks are part of the regulatory risks.

This extensive Risk List is presented in Appendix C. The risk list presented here is composed out of numerous sources and in particular based upon information related to potential risks mentioned by The World Bank (2007) and Chlomoudis and Pallis (2009). The other resources that have been applied for completion of the list are (Walewski et al (2005), Mott MacDonald (2002) and Hastak and Shaked (2000)).

It should be noted that the list is not considered to be comprehensive. In the process of risk identification the project team should always be critical to specific and unique project related risks.

### 3.1.3 Risk Register

The risk register is a central repository generally applied for collating risk information and documenting the output of the risk identification process. Patterson and Neailey (2002) performed a study to the development of a risk register database system to aid the management of project risk. Patterson and Neailey (2002) state that the risk register should take track of the risks of a project and has the role as a repository of knowledge and initiate the risk analysis process. According to Patterson and Neailey (2002), the risk register should be able to clearly identify and prioritize the (key) risks within the project. Risk registers can be very simple documents presenting the key risks and prioritize them and once established, it is strongly recommended to regularly review and update the risk register.

Patterson and Neailey (2002) concluded that the risk register should contain at least a description of the risk, its impact, probability value (probability or likelihood), reduction and mitigation (contingency) plans. Patterson and Neailey (2002) further state that the Risk register consists of three main entities namely the risk register itself, which is the main focus of the register, and two supporting documents which specifies the risk owner and includes information on risk reduction and/or mitigation plans.

Australian Government (2008) describes similar typical contents of risk registers and further recommends retaining the information on all closed risks in order to provide an audit trial and to assist in learning for future risk analyses.

HM Treasury (2011) indicates additional information that can be included in the risk register which is not included in the list of Patterson and Neailey (2002). HM Treasure (2011) proposes also to include information related to the risk type or category and the date (on which the risk is identified and/or last updated), the risk owner (who raised it) and interdependencies with other sources of risk.

The above analysis about the risk register has resulted in the following risk register setup for port investment projects as presented in Table 3-2.

As shown in Table 3-2 an additional item is included to create the link with the stage gate model. The stage in the project life cycle should be mentioned in which the risk might occur: concept phase, pre-feasibility, feasibility, construction, commissioning, operations and closure.

### 3.1.4 Risk Ranking

As shown in Table 3-2 the probability, impact and severity of all risks need to be included in the risk register. Not all risks events can be indicated with monetary values. Several risk consequences can be identified divided in economic and non-economic. Economic risks are mainly risks related to the capital expenditure, project schedule and production volumes and the operating costs and revenues. Non-economic risks are risks associated with health and safety, environmental and community issues and compliance and reputation.

The economic risks can be identified with a certain cost impact. The non-economic risks can be described but not a direct cost impact can be allocated. However the non-economic risks can still be presented in terms of their likelihood, impact and severity. The way to describe the economic and non-economic risks in a similar way is presented hereafter. Thereafter all risks can be ranked which will provide a first indication of importance.

The approach for evaluating the risk factors is as follows (AbouRizk, 2003):

- Assess each factor and the impact of each factor if the risk will occur
- Determine the likelihood that the risk will occur and classify the risk probability accordingly
- Determine the magnitude of the impact if the factor is encountered. Possible impact might be in cost, time, and / or requirements (scope, performance, acceptance, quality)
- Determine the impact of the factor by multiplying the likelihood by the magnitude. This is the severity value of the factor.
- Interpret the score and rank the risk events. Prioritize the identified risks on the basis of the above
- Classify the risk events

Patterson and Neailey (2002) use descriptive names (very) low to medium to (very) high for allocating a non-numeric value to the risks.

**Table 3-2 Risk Register for Port Investment Projects**

| Name | Description |
|---|---|
| Risk ID | Risk Identification Number |
| Risk title | Brief title of the risk |
| Description of the risk | Brief description of the risk |
| Risk category | legal, financial, environmental, market, political, technical, organizational, cultural, socio-economic |
| Project stage | Stage in project life cycle the risk might occur |
| Probability value | Probability of the likelihood of the risk occurring |
| Impact value time | Impact of the risk in time |
| Impact value cost | Impact of the risk in costs |
| Total impact | Combination of the impact values in time and cost |
| Severity value | Combination of the probability and total impact values |
| Rank | Indicate active risk and its severity within the project. |
| Track of risk | Has the risk increased, remained the same or decreased in severity since the previous check |
| Phase / time span | Phase or time by which the risk must have been evaluated |
| Risk owner | Owner / bearer of the risk |
| Mitigation plans | Brief description of the reduction / mitigation plans which have been developed |
| Interdependencies | Interdependencies with other sources of risk |
| Risk author | Who raised the risk event |
| Risk active | Whether the risk is active on the register |
| Risk solved | Whether the risk has been solved |
| Date identified | Date when the risk was introduced for the first time in the register |
| Date last updated | Latest date at which the specific risk has been updated |

Source: Author (2012)

For the context of this thesis it is decided to present the likelihood and the impact level with different descriptions as is shown in Table 3-3 (presented from top to bottom from very high to very low value). Per project it can be indicated what is exactly meant by rare or possible, i.e. one in the 2 years or 50 years event.

The severity values can be calculated by multiplying the likelihood and impact values. The severity values or risk rating can be described as follows:

- Extreme: Very significant impact on project baselines
- High: Significant impact on project baselines
- Moderate: Moderate impact on cost, schedule, performance
- Low: Minor impact on cost, schedule, performance

Figure 3-1 presents the resulted figure for the severity values as proposed by Bowden et al (2001). The severity value is determined by multiplying the probability level with the consequence level. This results in the risk rating as indicated with the colours in the figure. The likelihood and consequence are assessed against the five-point scales and the risk acceptance threshold is shown in the figure as the yellow zone (occupied with the 'moderate' risks). The risk ranking matrix is asymmetric and gives more weight to consequence than to likelihood. In case a risk has more than one type of consequence (like environmental, technical, political) its position in the matrix need to be determined by its highest scoring in the consequence (impact) level.

**Table 3-3 Description for Likelihood and Impact Levels**

| Likelihood | Impact |
|---|---|
| Almost certain | Catastrophic |
| Likely | Major |
| Possible | Moderate |
| Unlikely | Minor |
| Rare | Insignificant |

Source: Author (2012)

**Figure 3-1 Risk Ranking**

| | | Consequence level | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Likelihood level | Descriptor | Insignificant | Minor | Moderate | Major | Catastrophic |
| A | Almost certain | A1 | A2 | A3 | A4 | A5 |
| B | Likely | B1 | B2 | B3 | B4 | B5 |
| C | Possible | C1 | C2 | C3 | C4 | C5 |
| D | Unlikely | D1 | D2 | D3 | D4 | D5 |
| E | Rare | E1 | E2 | E3 | E4 | E5 |

| Risk rating |
|---|
| Extreme |
| High |
| Moderate |
| Low |

Source: Bowden et al (2001)

The risk rating can be applied to prioritize the risk events for the port investment project.

For the specific case of port projects it is proposed to slightly adjust the risk ranking as shown in Figure 3-1. The risk rating is adjusted in contrast to Bowden et al (2001) to make a more clear distinction between the final risk ratings for port investment projects. This is further discussed in section 3.3.1. The 5-level final risk rating classifies the risk into low, marginal, moderate, high or extreme importance for the project. This is presented in Figure 3-2. With the use of Figure 3-2 risks can be classified into one of these five classes. The classes have been identified as follows (Rio Tinto (2005), Author (2012)):

- Class I: Low Risk. Risks that are below the risk acceptance threshold and do not require active management
- Class II: Marginal Risk. Risks that are heading towards the risk acceptance threshold and do require management to some extent
- Class III: Moderate Risks. Risks that lie on the risk acceptance threshold and require active monitoring
- Class IV: High Risks. Risks that exceed the risk acceptance threshold and require proactive management
- Class V: Extreme Risks. Risks that significantly exceed the risk acceptance threshold and need urgent and immediate attention

**Figure 3-2 Risk Ranking Port Projects**

| | | | Consequence level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | |
| | | | Insignificant | Minor | Moderate | Major | Catastrophic | | Risk Rating |
| Likelihood level | E | Almost certain | E1 | E2 | E3 | E4 | E5 | | Low |
| | D | Likely | D1 | D2 | D3 | D4 | D5 | | Marginal |
| | C | Possible | C1 | C2 | C3 | C4 | C5 | | Moderate |
| | B | Unlikely | B1 | B2 | B3 | B4 | B5 | | High |
| | A | Rare | A1 | A2 | A3 | A4 | A5 | | Extreme |

Source: Author (2012)

## 3.2 Risk Analysis

Within the risk analysis process the likelihood and possible impact of the risks are evaluated. Risk analysis arises through the whole project life cycle. Risk analysis therefore is an iterative process and the risk assessment input and outcome should be updated during all project stages. Ideally, a risk analysis should be performed on all strategic points in the project (Walewski et al, 2005).

The objective of risk analysis is to generate outcomes that can be used to evaluate the risk events and their characteristics and distribution. Further the risk analysis is used to develop adequate strategies to manage the risk. Risk assessment methods can be performed qualitative or quantitative.

Qualitative tools use subjective designation like 'low', 'medium', 'high' or colour codes to indicate the various risk factors. Descriptive terms are used to define the likelihood and consequences of risk events. Qualitative risk analysis can provide a general understanding of the risk factors and compare risk between various risk events. A limitation of qualitative risk analysis is that no detailed information is provided for project costing and budgeting.

Semi-qualitative risk assessment allocates values or multipliers to the likelihood of the risk events.
Quantitative methods assign probabilities or likelihood to the various factors including an estimation of the impact of the risk. Quantitative risk analysis attempts to assign certain numeric values to the indicated risks. Subsequently the severity of the various risk factors can be identified.

Results need to be presented in such as way to demonstrate the variability in the outcomes and to provide as much information to the decision makers (board of management, shareholders) as possible. The aim is to present the result in a way that can be understood easily, without ignoring important points.

## 3.3 Qualitative Risk Analysis

Qualitative risk assessment methods are fast and relatively easy to apply. The general understanding of the risk events can be presented and the likelihood and impacts can be identified. The method can also be used to subdivide the different risk events into classes. A qualitative method estimates the risks and describes a situation by using instinct or expert judgment.

The results can be presented in a semi-quantitative way as presented in Figure 3-3. These probability-impact risk rating tables assign the risk ratings based on combining probability and impact qualitative scales.

As port investment projects may have different kind of risk impacts, it is recommended to subdivide the consequences into impacts for socio-economic, financial, environmental, and technical levels. The highest score determines then the consequence level.

### 3.3.1 Qualitative Risk Analysis for Port Projects

Qualitative risk assessment or semi-quantitative risk assessment can be very useful for port investment studies because there might be many diverse environmental and social issues that need to be evaluated. Risk events need to be communicated to the country and various stakeholders and the use of qualitative methods are than very suitable to prevent putting a cost value on probably intangible discussions.

Hereafter, a qualitative risk assessment methodology is setup specifically applicable for port investment projects.

A description of the likelihood as composed for port investment projects is presented in Table 3-4.

A consequence (severity) description for port projects is created for this research. It is based on the classification applied in the risk list as presented in Appendix C. The severity description is included per main risk category and the impacts are described from very low (1) to very high (5) in Appendix D.

**Figure 3-3 Basic semi-quantitative Risk Rating Matrix (example)**

| | | Consequence level | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Likelihood level | Descriptor | Insignificant | Minor | Moderate | Major | Catastrophic |
| 5 | Almost certain | 5 | 10 | 15 | 20 | 25 |
| 4 | Likely | 4 | 8 | 12 | 16 | 20 |
| 3 | Possible | 3 | 6 | 9 | 12 | 15 |
| 2 | Unlikely | 2 | 4 | 6 | 8 | 10 |
| 1 | Rare | 1 | 2 | 3 | 4 | 5 |

| Risk rating |
|---|
| Extreme |
| High |
| Moderate |
| Low |

Source: Bowden et al (2001)

**Table 3-4 Likelihood Table Port Projects**

| Level | Description | Timeframe |
|---|---|---|
| Almost certain | Highly probable, highly likely | Once or more during next year |
| Likely | Possible | Could be within 1 to 2 years |
| Possible | Chances about even | Possible within 5 years |
| Unlikely | Doubtful, almost certainly not | Could be between 5-10 years |
| Rare | Highly doubtful, seems impossible | Chance only 1/10 – 1/50 |

Source: Author (2012)

The risk rating is adjusted in contrast to Bowden et al (2001) to make a more clear distinction between the final risk ratings for port investment projects. This is shown in Table 3-5. This results in an asymmetric risk matrix as more weight is assigned to the risk consequence level. Each risk indicated for the port project can be rated by using the risk rating matrix as presented in Figure 3-4. Also, a 5-level final risk rating is selected to classify the risks into low, marginal, moderate, high or extreme importance for the project. Note that the exact risk tolerance boundaries should be discussed with the investors as every company has a difference tolerance for risk.

Figure 3-5 shows the risk map presenting the relationship between the likelihood (vertical axis) and consequence level (horizontal axis) for each event. The figure shows how all risks can be rated from low to extreme risks. The diagonal lines show points of equal risk.

Special attention should be paid to risk with a major consequence and with a very low likelihood. These risks may result in severe environmental, social or project results or are potential show stoppers for the business. These risks might be related to other events and this should be investigated carefully. It is recommended to indicate these risks in the Risk Register as exceptional risk and urgently evaluate them.

**Table 3-5 Consequences Indicators Port Projects**

| Level | Likelihood ranking | | Consequence ranking | |
|---|---|---|---|---|
| 5 | Almost certain | 10 | Catastrophic | 625 |
| 4 | Likely | 3 | Major | 125 |
| 3 | Possible | 1 | Moderate | 25 |
| 2 | Unlikely | 0.3 | Minor | 5 |
| 1 | Rare | 0.1 | Insignificant | 1 |

Source: Author (2012)

**Figure 3-4 Risk Rating Matrix Port Projects**

| | | | Consequence level and ranking | | | | |
|---|---|---|---|---|---|---|---|
| | | level | 1 | 2 | 3 | 4 | 5 |
| | | rank | 1 | 5 | 25 | 125 | 625 |
| Likelihood level and ranking: level | rank | | Insignificant | Minor | Moderate | Major | Catastrophic |
| 5 | 10 | Almost certain | 10 | 50 | 250 | 1250 | 6250 |
| 4 | 3 | Likely | 3 | 15 | 75 | 375 | 1875 |
| 3 | 1 | Possible | 1 | 5 | 25 | 125 | 625 |
| 2 | 0.3 | Unlikely | 0.3 | 1.5 | 7.5 | 37.5 | 187.5 |
| 1 | 0.1 | Rare | 0.1 | 0.5 | 2.5 | 12.5 | 62.5 |

| Low | Marginal | Moderate | High | Extreme |
|---|---|---|---|---|

Source: Author (2012)

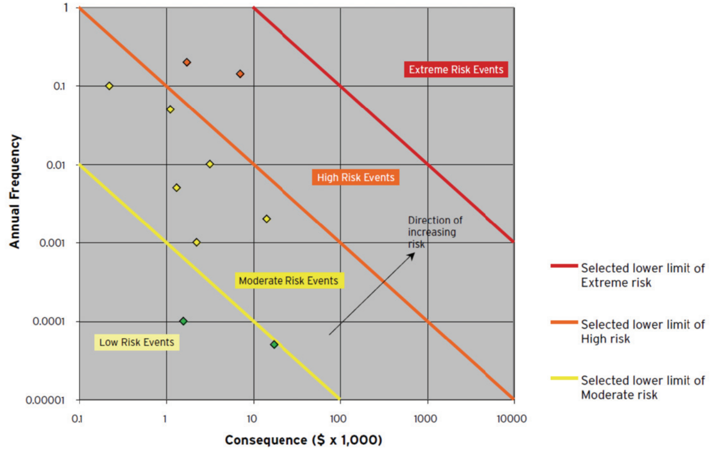
Summarizing, the method for the quantitative risk analysis for port projects is suggested as follows:

- Indicate per risk event the likelihood level
- Indicate per consequence the category (country, traffic, project, environmental, regulatory) and its severity
- The maximum severity is included as value for the risk consequence level
- Calculate the risk rating by multiplying the likelihood with the maximum severity level
- The final risk ranking can be indicated by using the colours as indicated in Figure 3-5: extreme, high, moderate, marginal and low.
- Present all indicated risks in a risk map (Figure 3-5)

The qualitative risk analysis presents the impact of the risks of all the categories: country, market, project, environmental, regulatory. Hitchings and Wilson (2002) stated that these five areas are joined by a corresponding cost that influences the decision taking about the project and the amount of budget and time that should be used for mitigating the risk (refer Figure 3-6).

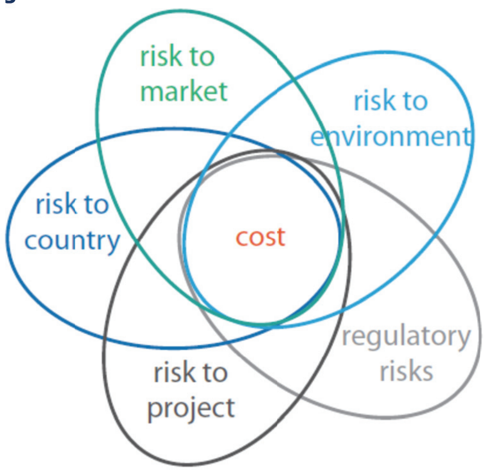
As shown in Figure 3-6, not all risks can be directly transferred into costs. This should be kept in mind by evaluating the risks and quantitatively assessing them.

**Figure 3-5 Risk Map (Example)**




Source: Bowden et al (2001)

**Figure 3-6 Relation between Risk Areas and Cost**




Source: Author (2012)

## 3.4 Quantitative Risk Analysis

In case sufficient and reliable data is available a quantitative risk assessment method can be added to the risk analysis process. Within quantitative risk assessment methods a certain cost value is added in the risk register for each risk. Next to a qualitative description of the risks a quantitative method is needed to value the risks for the investors in time and financial value. Quantitative methods generally can create probabilistic based project estimates dependent on the behaviour of the indicated key risk events. The quantitative methods applied to generate these rather sophisticated estimates are generally data intensive techniques. In a quantitative method, the risks are being quantified in measurable criteria by assigning numerical values to the risks and also often the financial result is indicated. Within the risk assessment framework of port projects the impact on capital costs is described.

Ho and Ho (2006) present a list of common tools for risk analysis. The quantitative risk analysis methods from this list are summarized in Appendix E and for all methods the advantages and disadvantages are briefly illustrated.

A number of criteria have been developed for the selection of the best quantitative method for port investment projects. First, the method needs to be generally acceptable, commonly used and not under discussion to be suitable for the decision making process within port projects. The results presented by the method need to provide a sound indication for a board of management or shareholders meeting. Further it is favourable if the method can be used for time and cost analysis. Preferable, the method is compatible with Microsoft Excel as this is widely used by international consultants. Further it is favourable if the method produced 'hard numbers' and includes probability of risk events. Finally, the method availability and ease of use are important factors.

From the above and the list presented in Appendix E it is concluded that the Monte Carlo method best fits to the criteria above and that Monte Carlo method is therefore the best method available for the creation of the risk assessment methodology for port projects. The second best method is the Latin Hypercube method. The Monte Carlo Method is preferred above the Latin Hypercube method because of the ease of use, the general application and familiarity and the availability of multiple programs as for example, @RISK, Risk Solver, Risk AMP and Crystal Ball.

### 3.4.1 Quantitative Risk Analysis for Port Projects

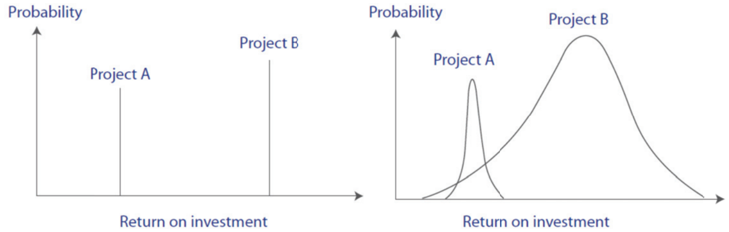
Risk analysis using Monte Carlo simulation is recommended to quantify the risks in port investment projects. The risks are expressed in statistical form and ranges and probabilities are indicated. As Ho and Ho (2006) states, instead of applying discrete numbers to select risky variables, risks are made explicit instead of implicit in qualitative appraisals. Ranges and probabilities are included as probability distributions. This is illustrated in the Figure 3-7. The left figure shows the single point (or deterministic) estimates for Project A and Project B. In this figure Project B seems to be superior. In the right plot the estimates of return are included as probability distributions showing the uncertainties surrounding the results of each proposal (stochastic approach). This makes Project A be preferable to Project B (Ho and Ho, 2006).

Numbers are a very powerful tool to substantiate the qualitative assessment. For example the success rate for meeting a certain planning or the chance of exceeding the budget provides valuable information concerning the project. A Monte Carlo analysis provides the margin of error for an activity within a project. Furthermore, the Monte Carlo method is very suitable for illustrating the consequences of different decisions over the project duration.

Monte Carlo randomly generates values for individual variables according to their distribution functions. Combined with the other randomly generated values for the other variables these figures can be used to calculate the project costs. After repeating the process numerous times the average or expected project costs is produced together with the probability distribution of the result.

Within the Monte Carlo analysis the existence of covariance between different risk factor should be carefully considered. When risk factors are statistically independent of one another no problems will occur during simulation. However when variables are expected to relate to each other in some way this should be taken into account in the risk analysis.

**Figure 3-7 Single Point versus Probability Distribution to Describe Returns of Investment**




Source: Ho and Ho (2006)

Monte Carlo analysis replaces single entries with probability distributions of possible values for key inputs. The calculation is simulated a large number of times (using a computer program). In every model simulation a random value for each variable from its probability density function is chosen. The results consist of a set of probability distributions showing how uncertainties in key inputs might impact key outcomes. The outcome of the simulation is thus a probability distribution of the overall value of the model.

Within the quantitative risk analysis two sources of risks can be identified. First the general contingencies, which are taken into account for uncertainty in the unit rates, local prices and changes in the design. These general contingencies have a 100% probability in the quantitative analysis and are allocated to all elements of the capital cost estimate of the project.

The second source of risks contains the special events which have a probability of less than 50%. These special events have a relative small probability and are therefore not included in the deterministic cost estimate. In the probabilistic estimate the probability distribution of these risks are included. The probabilities proposed to apply in the quantitative analysis are presented in Table 3-6.

**Table 3-6 Likelihood Table Port Projects**

| Level | Description | Probability |
|---|---|---|
| Almost certain | Highly probable, highly likely | 45% - 50% |
| Likely | Possible | 30% - 45% |
| Possible | Chances about even | 15% - 30% |
| Unlikely | Doubtful, almost certainly not | 5% - 15% |
| Rare | Highly doubtful, seems impossible | 0% - 5% |

Source: Author (2012)

Summarizing, for the Monte Carlo analysis for port projects the following approach for data handling in risk analysis is proposed (Asian Development Bank, 2002):

- Indicate any correlation that exist between the risk factors
- Indicate the likelihood and expected scale of impact of the key events
- Construct probability distributions of the key risk events
- Explain the statistic nature of the variables that have probability distributions (why are these distributions triangular, normal, uniform, etc.)
- Perform probabilistic Monte Carlo analysis to generate expected values and minimum and maximum values
- Present the results
- Sensitivity analysis is recommended, to discover the critical value of various project parameters

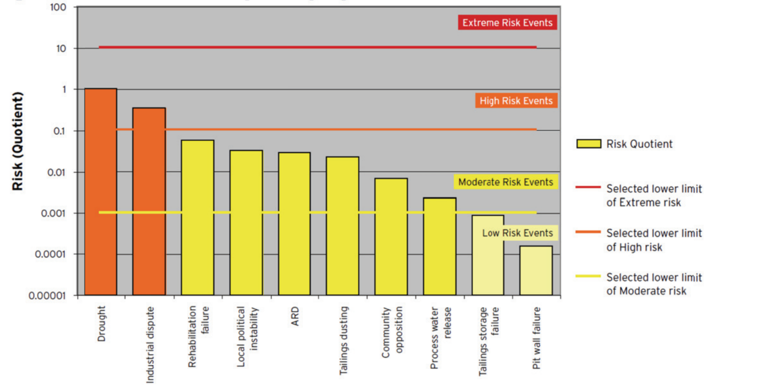
The qualitative and quantitative risk analysis methods are not mutually exclusive. They can be well complementarily to each other. The qualitative method with the risk matrix as a result can indicate the most serious risks. These risks with a high or extreme ranking can then be further investigated with a quantitative technique.

Figure 3-8 shows the risk profile to express the outputs of all individual risks. The risk quotient of the different indicated risks is shown on the vertical axis and is calculated by multiplying the likelihood with the costs impact if the event is occurred. All selected limits of the risks are indicated in the figure with the horizontal lines.

Figure 3-9 shows an example of an exposure profile. This figure shows on the left vertical axis the estimated costs (simulated with Monte Carlo) if the risk event where to occur. The right vertical axis shows again the risk quotient as the product of the likelihood and the costs if the event occurred. This figure provides insight into the range of uncertainty combined with the consequences of all risk events.

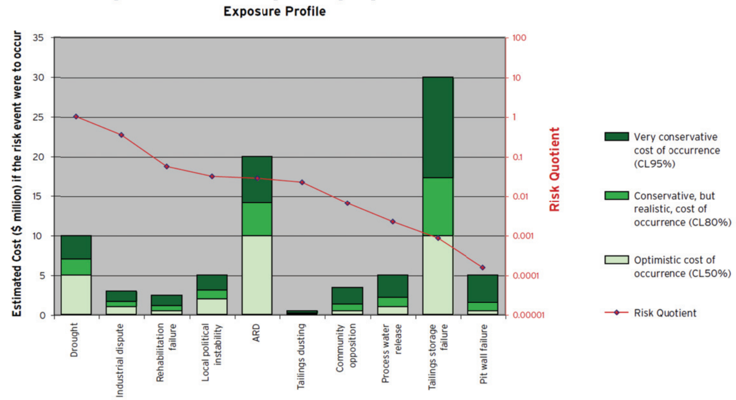
As presented by the Asian Development Bank (2002) two project alternatives can be compared by using the probability-based risk analysis technique and contribute to investment decision making.

**Figure 3-8 Risk Profile (example)**




Source: Bowden et al (2001)

**Figure 3-9 Exposure Profile (example)**

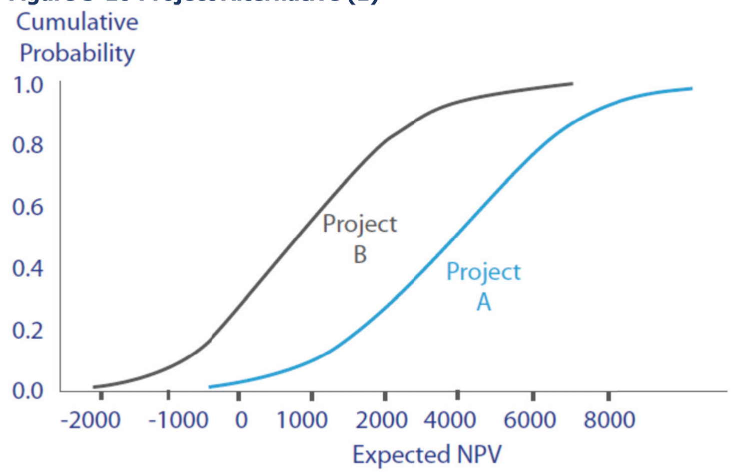



Source: Bowden et al (2001)

Figure 3-10 shows the cumulative distribution functions of two project alternatives. The figure shows that project A is preferable to project B. Project A is said to be stochastically dominant. The figure shows stochastic dominance to the first degree, because the distribution of project A lies entirely to the right of the distribution of project B (i.e. at any level of probability the Net Present Value of project A is higher). Figure 3-10 also shows the likelihood of both projects producing negative or low outcomes, namely project A does not generate negative outcomes however project B does. The figure clearly shows the higher risk of project B.

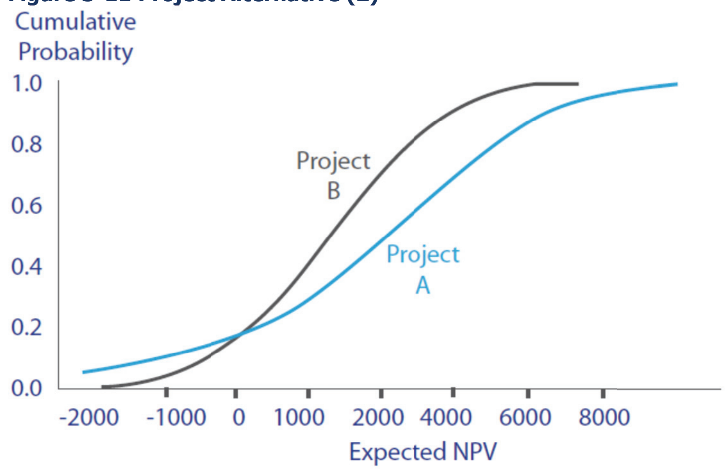
Figure 3-11 shows a more complex situation. Project A may again be concluded as stochastically dominant to project B. Namely Project A lies for the largest part to the right of the figure of project B. However the situation in Figure 3-11 now only shows second degree stochastic dominance of Project A, because despite the higher expected Net Present Value of A, project A has a greater probability of negative outcomes than project B. This is shown with the cumulative distribution function of B that crosses the one of A.

**Figure 3-10 Project Alternative (1)**




Source: Asian Development Bank (2002)

**Figure 3-11 Project Alternative (2)**




Source: Asian Development Bank (2002)

# 4 CASE STUDY

This chapter presents the case study that is applied to verify and present the risk assessment methodology as set up in Chapter 3. The case study provides a better understanding of how the risk assessment methodology can be applied in practice. The aim of the case study is to present the results in a sound and substantiated way.

The goals of the case study are as follows:

- Verify the qualitative and quantitative analysis as proposed for port development projects
- Interpretation of the results of the risk assessment
- Present the results of a stress test and sensitivity analysis
- Show the number of input parameters required for a solid analysis

As the project applied for the case study is an existing consultancy project and partly confidential, the names and location of the project are not mentioned. This project is selected for the case study as it includes a clear stage gate approach and because it was stated to be a high risk project. This is verified and elaborated further hereafter.

In the case study the focus is on the risks within the capital cost estimate. The impact on the revenues or Net Present Value of the project is not considered here.

## 4.1 Case Description

The project concerns the development of a port by a mining company. The mining operator is planning to export iron ore from an inland mountain region. The port will therefore be a dedicated port to accommodate the loading of bulk carriers to export the ore. The throughput capacity of the port will be between 5 and 50 million tonnes per annum, depending on the strategy and phasing. A mix of bulk carriers is expected to call at the port, ranging in size from 60,000 deadweight tonnage (DWT, Panamax) to 250,000 DWT (Capesize), with an average size of 180,000 DWT. This case study considers the port development as part of the transport chain of the entire project (i.e. from pit to port).

A greenfield site was identified to have the greatest port development potential. It provides close proximity to deep waters, access to hinterland infrastructure and an abundance of land. Moreover, the site has an absence of environmentally protected areas, although the potential of rock in the area requires further investigation as this will be a key issue for the dredging and hence the cost of the port.

A sheltered port is necessary to achieve the required throughput under the operational boundary conditions of the vessels calling at the port. The cost estimate is made on the basis of the conceptual design of the main port structures. The port infrastructure includes the trestle, loading platform, breakwater, and nautical manoeuvring areas.

The entire project is defined in five main stages:

- Stage 1: Identification Phase Study
- Stage 2a: Interim Options Study
- Stage 2: Selection Phase Study
- Stage 3: Definition Phase Study
- Stage 4: Execution

Currently, the project is approaching the completion of the Interim Options Study, and hence Gate 2 of the project.

## 4.2 Risk Identification

A Risk Register has been setup for the case and is presented in Appendix F. For each risk the category is indicated: country, market, project, environmental or regulatory risk.

The different types of risks as indicated in the study are as follows: 8 Country Risks, 1 Market Risk, 10 Project Risks, 7 Environmental Risks and 2 Regulatory Risks. The risks have been identified based on the study reports provided for the interim options study in which a number of major risks were mentioned. Further own assumptions have been made on the potential risks of the project.

The Country Risks are related to government and cultural issues. The management of the different cultures and diversity within the project can provide a risk as well as the expectations of the community. Government risks include the agreements about the port, managing corruption, stakeholder engagement, stakeholder support and regional instability. Further the railway (between mine and port) will need to cross borders which might be sensitive at a political level.

The Market Risk identified for this project is the uncertainty of emerging competitors for the transport or port location which may influence the development of the port.

Project Risks related to the project start-up are the land availability for the port which might be a timely and costly process. Furthermore a number of design risks have been indicated. These consist of the need for detailed bathymetric survey and data on coastal morphology and dredging. Further the scarcity of geotechnical and geological data and uncertainty about the condition of the subsoil result in significant risk factors as the geotechnical and geophysical conditions at the port site are of importance for the design of the piling of the trestle, the breakwater, the dredging operations and all other structure designs. For operations the current and wave conditions are most important and will define the port layout and the mooring and navigation requirements. The risks identified are related to the lack of specific site data (wind and wave measurements). Further operational project risks are the labour construction costs and productivity. Project construction risks are the availability of regionally located quarries to produce the rock volume required and the availability of suitable disposal areas for dredged material. Further Project Risks are the possible requirement of new inland infrastructure (roads, bridges) to serve the marine works and the market interrogation with regard to the availability and securing of steel tubular piles.

The Environmental Risks indicated are related to natural, social and safety issues. The possibility of environmental accidents and loss is identified as a risk. Further the environmental standards may not be met. With regards to safety, a risk is the compliance to the standards. Social risks are indicated in that the medical first aid response may be insufficient and the occurrence of malaria. Also problems may arise due to the quality of the road and transport infrastructure around the port resulting in fatalities, delays, or damage.

Regulatory risks are contractual in the way that permits need to be acquired. Legal risks are identified because of the uncertain legal framework in the country.

Note that only the risks over the study and construction period are included, not the risks during the operational period.

## 4.3 Qualitative Analysis

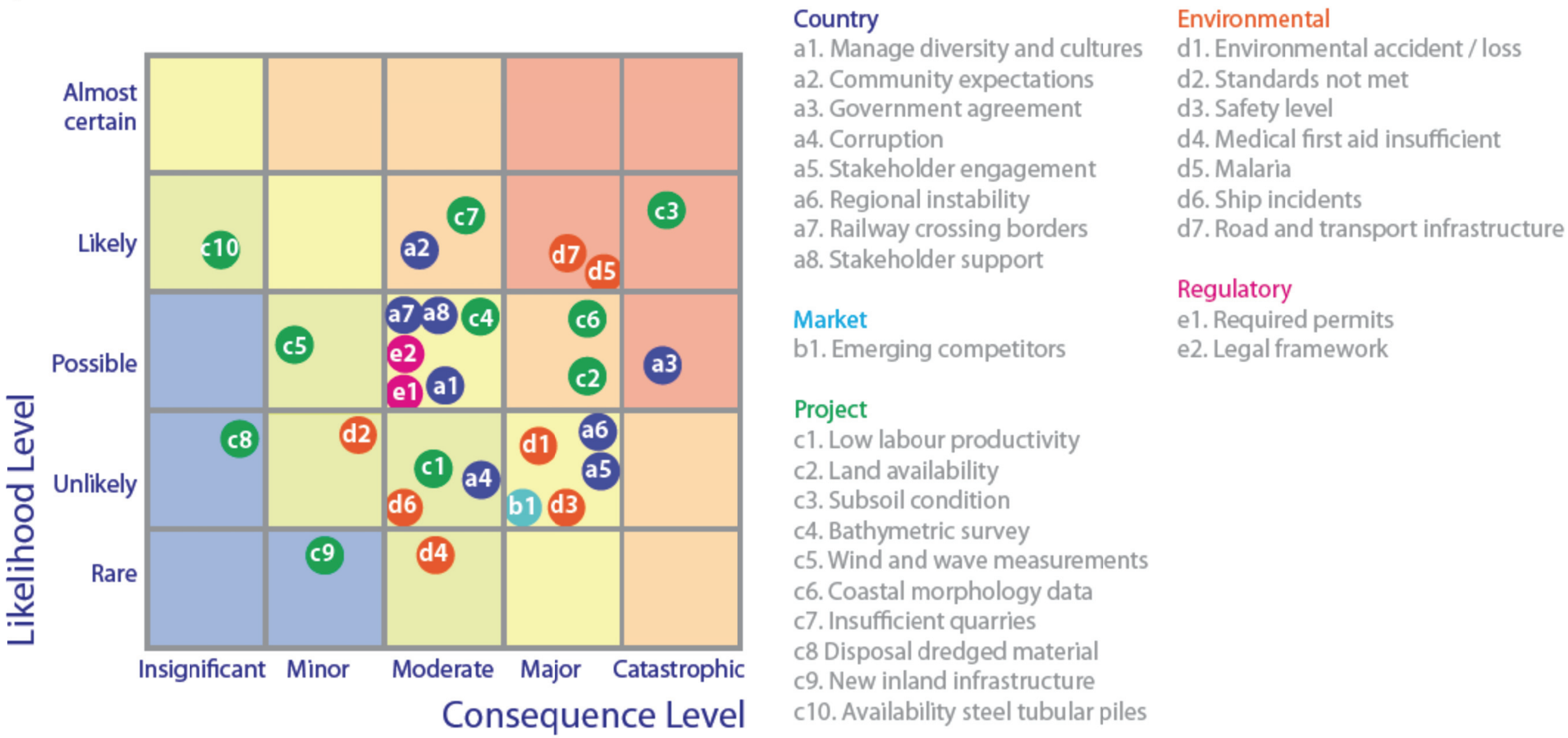
The likelihood and impact values are estimated for each risk (Table 6-10 Appendix F). The rank (or consequence) of the risks is calculated my multiplying the likelihood with the impact value.

A high level breakdown of the risks is provided hereafter:

- A total of 28 risks were identified. Of these:
  - 4 were identified as Extreme Risks
  - 4 were identified as High Risks
  - 11 were identified as Moderate Risks
  - 7 were identified as Marginal Risks
  - 2 were identified as Low Risks

The risks are presented in the Risk Matrix shown in Figure 4-1. The different colours indicate the five risk categories. As shown, the most extreme risks are one country risk, a project risk and two environmental risks.

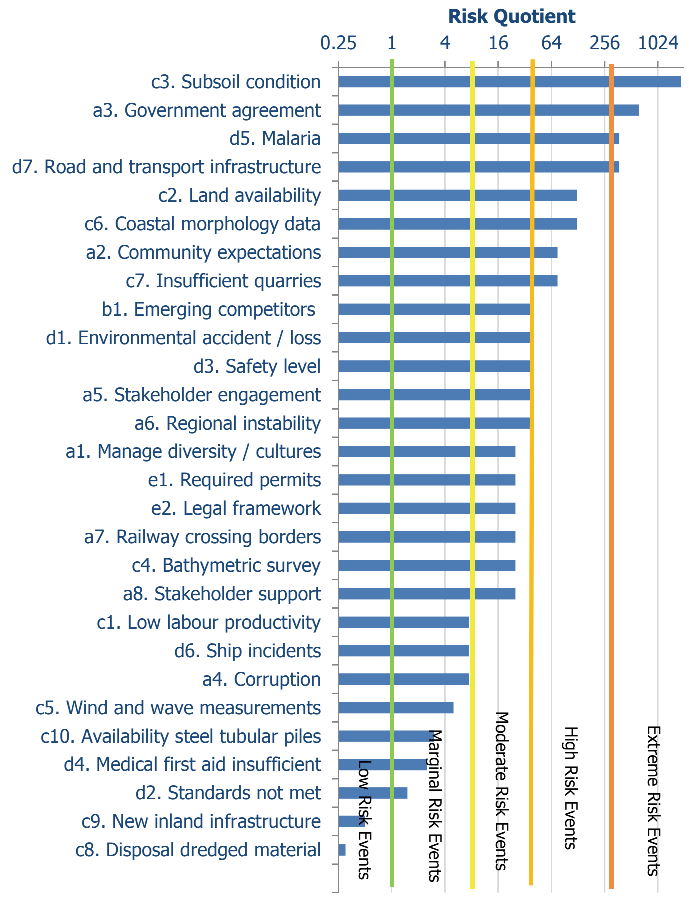
**Figure 4-1 Risk Matrix**




Source: Author (2012)

Figure 4-2 shows the risk profile of the project. The figure presents the risk quotient for all risks. The risk quotient is the risk ranking based on the product of the likelihood and the impact of the risk. The highest risks in this ranking are the government agreement, the subsoil condition, malaria and the road and transport infrastructure.

**Figure 4-2 Risk Profile**




Source: Author (2012)

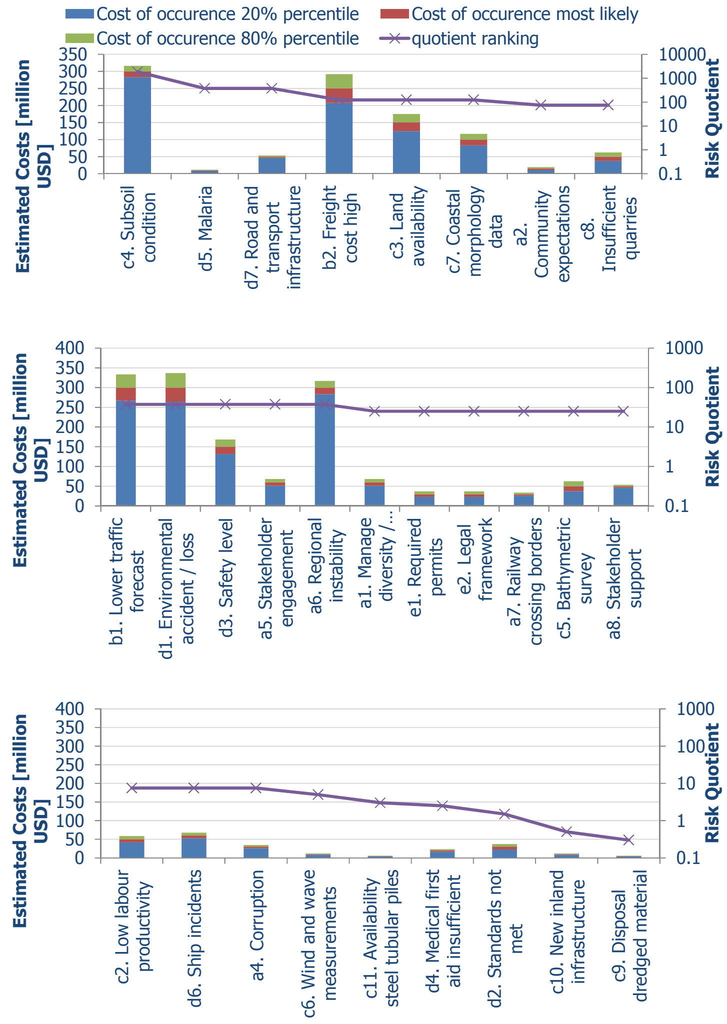
## 4.4 Quantitative Analysis

In the quantitative risk assessment process the cost impact of the various risk events is assessed. The calculation model data for generating output and figures for the quantitative analysis is included in Appendix G.

The highest risks can be further subdivided based on the risk ranking and estimated costs. For all risks the probability values are identified based on the likelihood value (Table 3-4) Also for each risk the cost impact is estimated. This is shown in Appendix F.

The risk exposure profile is indicated in the three figures in Figure 4-3. The risks are sorted from a high to low risk quotient. The figures show the estimated cost of the risk events on the left vertical axis. The figure clearly indicates both the risk of each event and the estimated cost impact if the event would occur. The high-risk high-cost events can be indicated from the figure. The risk that can be indicated as high-risk high-cost and should be prioritized based on Figure 4-3 are the subsoil condition, government agreement, freight cost, lower traffic forecast, environmental accident and regional instability.

**Figure 4-3 Risk Exposure Profile**

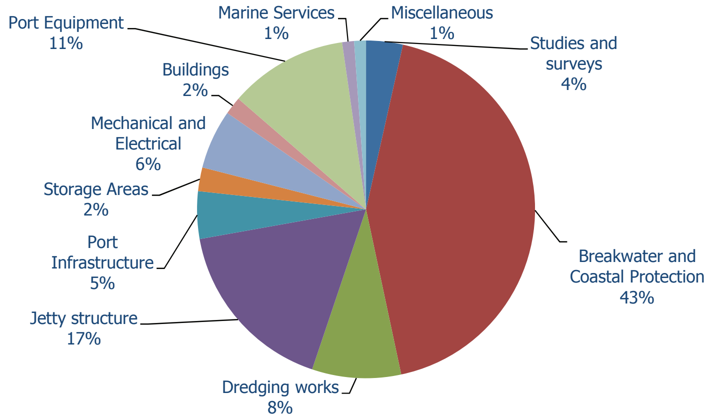



Source: Author (2012)

For each risk the estimated bandwidth in cost is indicated in Figure 6-1 in Appendix G. The red bars show the 20th and 80th percentile of the risk events. The vertical line in the middle shows the mean estimate of the cost impact of the risk events. As shown the risks with a higher cost impact show also a higher bandwidth in the estimate.

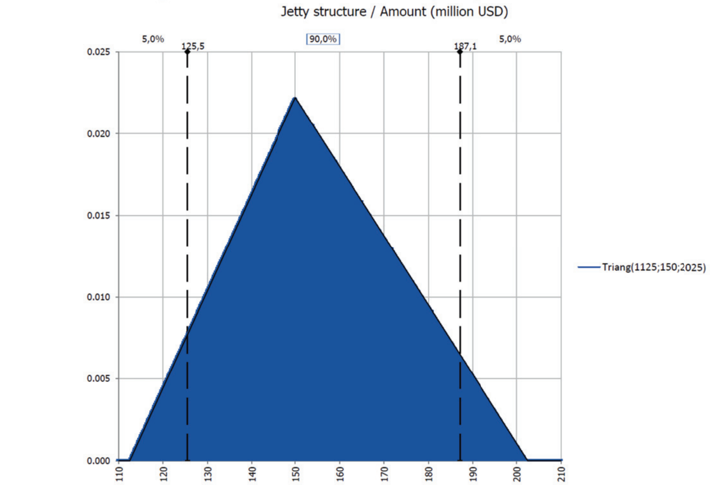
To determine the impact of the risk events on the total capital cost estimates of the port, first the capital cost expenditures (CAPEX) of the port are determined. The investments in the port are divided over the subsequent stages. The share in CAPEX of the different investment categories is illustrated in Figure 4-4. The total capital cost estimates for the port project are about 910 million USD including contingencies. The largest share of the costs is related to the breakwater and coastal protection works. Also the jetty structure, port equipment and dredging works account to a large part of the capital costs of the port. For each CAPEX category the contingencies are included by adding a triangular distribution to the estimate. A triangular distribution has fixed upper and lower limits. Next to the most likely cost estimate, for every category also the minimum and maximum values are used to describe a complete distribution. At this stage of the project the accuracy of the cost estimate is in the range of -25% to +35%. This range is illustrated in the maximum and minimum value of the triangular distribution for each CAPEX category. The triangular distribution for the jetty capital costs as included in the quantitative analysis is shown in Figure 4-5.

**Figure 4-4 CAPEX Estimates Port**




Source: Author (2012)

**Figure 4-5 Triangular Distribution for Jetty Capital Costs**



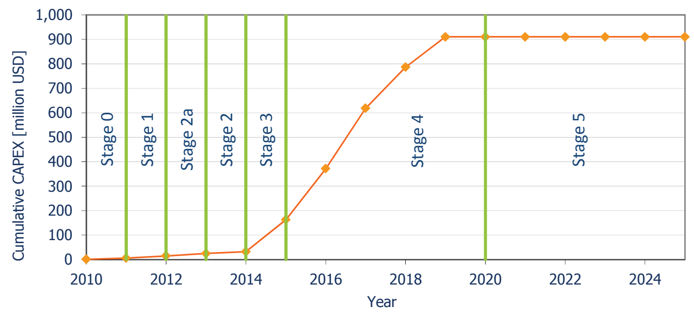

Source: Author (2012)

The phasing of the project is indicated in Figure 4-6. The vertical green lines indicate the stages of the project. Stage 0 was started in 2010, stage 1 in 2011 and stage 2a in 2012. Stage 2 is planned for 2013, stage 4 for 2015 and stage 5, the operation of the port, for 2020. The figure shows that the phase between stage 4 and 5 account for the largest part of the cost of the port (construction phase). Note that the total costs of 910 million USD are without reservations for quantified risk.

For each risk a probability density function of the cost impact is estimated. This is shown in Figure 4-7 and Figure 4-8. Figure 4-7 shows a normal distribution for the risk ‘government agreement’. Figure 4-8 shows the same risk however then with the probability of occurrence included. This is the cost of the risk as it is added to the model simulations to calculate the total risk impact for this risk specifically. The figure shows the 40% probability of the risk and the calculated mean value and standard deviation.

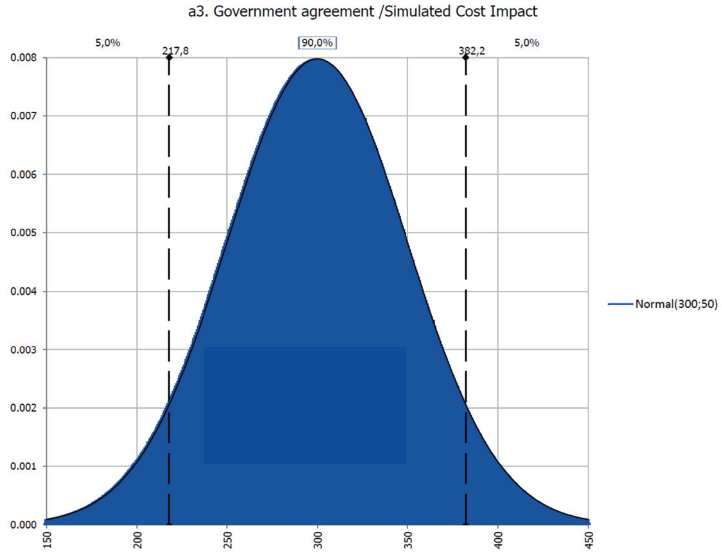
For the cost and time impact of the risks, different distribution have been used. Normal distributions are applied for the simulated cost impact of all risks (refer Figure 4-7). Uniform distributions are selected for the time impact of the risks. Each parameter is assumed to be uncorrelated with the other parameters. Because it is not exactly known how the risks are distributed, the simpler distributions are applied to the analysis namely uniform, triangular and normal distributions (Palisade, 2010). The simple distribution functions can be very powerful as the risks can be described with only a few arguments. For example, uniform distributions use only two values to describe the full range of the distribution and assign probabilities for all the values in the range. For the normal distributions a mean and standard deviations should be given.

**Figure 4-6 CAPEX Without Special Events**




Source: Author (2012)

**Figure 4-7 Risk Simulated Cost Impact Probability Density Function**

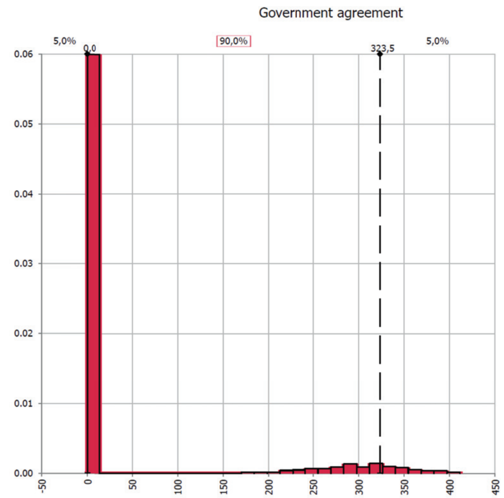



Source: Author (2012)

For each risk the time impact is estimated in which the risk will materialize. For this time impact a minimum and maximum date is estimated and a uniform distribution between these dates is assumed. The year that the risk expires is also included in the modelling. For example, after stage 2 several surveys have been performed resulting in additional data and a reduction of the risks. The risks corresponding with this lack of data are then expired after the surveys, as the risk is mitigated by gathering additional data.

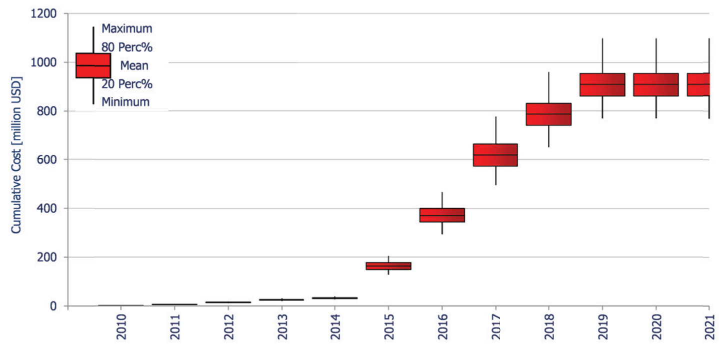
Figure 4-9 shows the bandwidth of the CAPEX estimates including contingencies over time (excluding special events). The figure shows the stages 1 to 3 with relatively low costs and from stage 4 (2015) increasing costs and bandwidth. The spreading in the cost estimates are the result of the triangular distributions assumed for each cost category. The upper and lower bound of the red rectangle present the $20^{th}$ and $80^{th}$ percentile. The vertical error bars on top and below the box represent the maximum and minimum value respectively. As the project progresses, the cumulative costs will increase as well as the bandwidth, because each additional costs includes a certain contingency.

**Figure 4-8 Risk Impact Distribution Function of Cost Added to Model**




Source: Author (2012)

**Figure 4-9 CAPEX Estimates Including Contingencies**



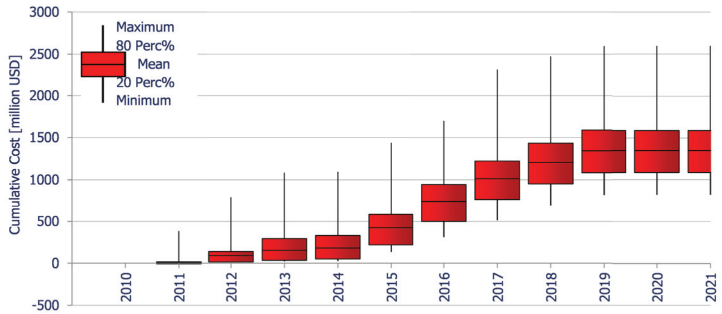

Source: Author (2012)

The impact of all risk events on the total capital costs of the port is shown in Figure 4-10. The results in this figure contain the CAPEX estimates including contingencies and the impact of the special events. Because now the impact of the special events is included, Figure 4-10 shows a higher mean value than Figure 4-9 (1260 million USD compared to 910 million USD). The figure presents the total cumulative costs over the model period and shows the increasing bandwidth over the project duration. Most of the special events, if they occur, materialize in the construction period (from 2015 to 2019). In this period therefore the maximum bandwidth in the results is reached. The error bar at the top of the band is higher than the negative error bar below the red bandwidth; this indicates the skewness of the results.

Figure 4-10 shows the risks to the project capital costs considered from the perspective of the current year 2012. It is interesting to know how the bandwidth changes over the different stage of the project. This shows the impact of decisions made over the project duration. For example if certain surveys are done this reduces the risks in certain cost estimates. In the current year 2012 (stage 2a) the bandwidth is maximal as a large number of risks are identified. In stage 2 some surveys are planned that will reduce the risks on certain cost estimations. This results in a decreasing bandwidth for the cost estimate from stage 3.

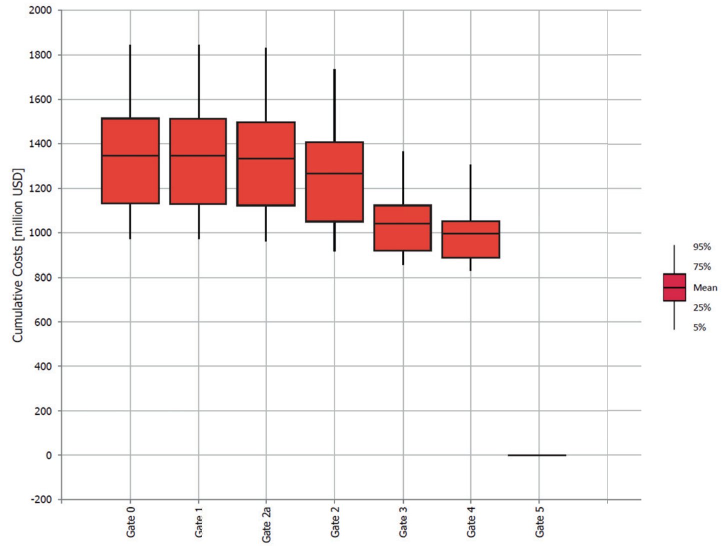
The risk results per stage gate for the case study are shown in Figure 4-11. A stage gate precedes a certain stage, implying that for example Gate 2a precedes Stage 2a.

**Figure 4-10 CAPEX Estimates Including Contingencies and Special Events**




Source: Author (2012)

**Figure 4-11 Risk Result per Project Stage Gate**



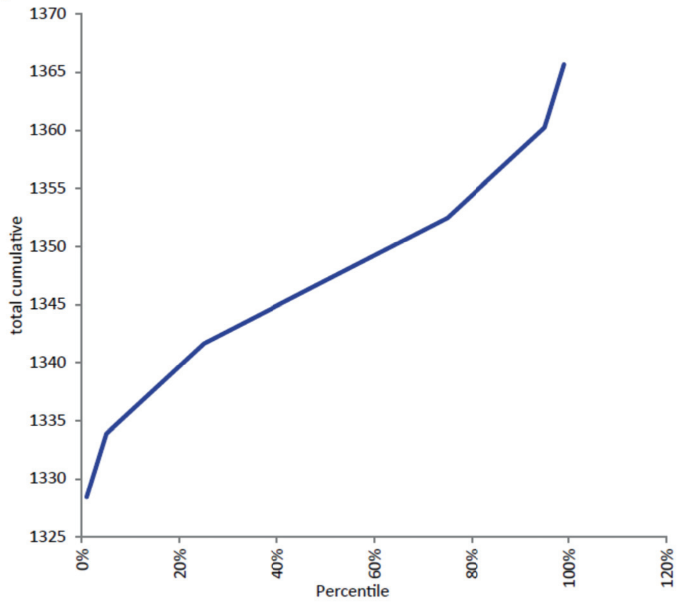

Source: Author (2012)

Figure 4-11 shows a decreasing bandwidth from Gate 2a. Gate 5 is just before the start of the operational phase Stage 5. As the bandwidth on Gate 5 has disappeared this indicates that all risk events have a time impact between stage 0 and stage 4. Next to the bandwidth of the total costs, Figure 4-11 also shows the total cost that needs to be spend from the specific stage gate onward. The figure clearly shows the study, survey and construction phases. The study phase from gate 0 to gate 2a only shows minor expenditures. From gate 2 the costs drop because of two major reasons. Firstly, the expenditures from gate 2 onwards have been reduced because already some expenditures are made in the preceding stages. Secondly, the risks have been reduced resulting in a lower cost estimate because some risks have been mitigating by performing surveys or because the risk has expired. From gate 4 the operational phase starts. This phase includes the highest expenditures, shown in the drop in required budget from gate 4 to gate 5.

## 4.5 Sensitivity Analysis

A sensitivity analysis is performed to check the impact of a single input on the output of the quantitative analysis. The total cumulative cost including contingencies and special events are verified by variations in the input risk event c3 condition of subsoil.
Figure 4-12 shows the percentile variation in input on the horizontal axis, and the impact on the mean of the total cumulative results on the vertical axis. The results of the sensitivity analysis show that the variation of the risk event c3 condition of subsoil, between 0% and 120%, changes the output by 1% to 2%.

**Figure 4-12 Sensitivity Analysis on Risk Subsoil Condition**




Source: Author (2012)

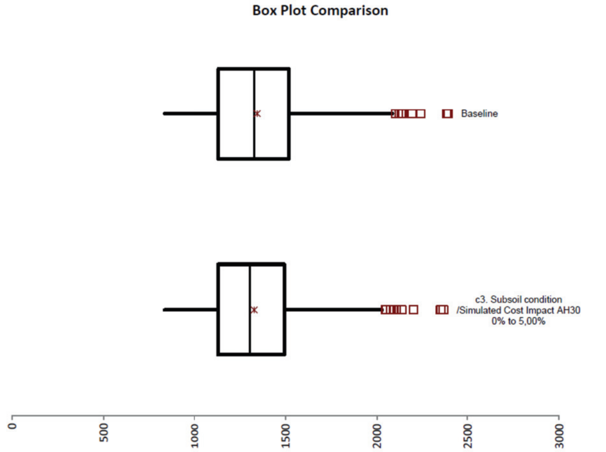
### 4.5.1 Stress test

A stress test is performed to analyse the effects of stressing the input distributions. Stressing a distribution restricts samples drawing from the distribution to values between a specified pair of percentiles. The aim of the stress test is to show the impact on the total costs if one of the input values (risk events) is allocated with an odd value. The input c3 condition of subsoil is selected for the stress analysis. This is one of the risk events with the larges impact on the total costs. The results of the stress test show the impact on the total cumulative cost including contingencies and special events.

Figure 4-13 show the stress test with low values of the input parameter subsoil condition. Figure 4-13 shows a box-whisker plot. The left and right of both boxes are indicators of the first and third quartiles. The vertical line inside the box represents the median and the X indicates the location of the mean. The horizontal lines indicate the first/last data point that is less than 1.5 times the 75th percentile minus the 25th percentile below/above the low/high edge of the box. Mild outliers are shown as hollow squares (Palisade, 2010). The upper box plot in the figure shows the baseline value of the risk input. The lower box plot in the figure shows the simulated cost impact with a stress test between the 0% and 5% percentile.

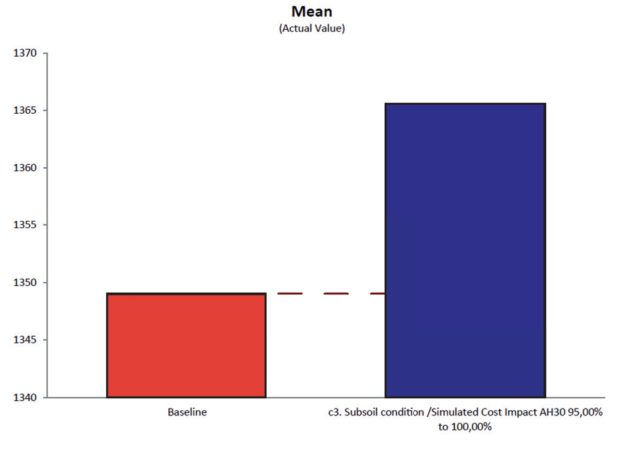
Figure 4-14 shows the stress test with high values of the input parameter subsoil condition in a bar chart layout. The red bar shows the baseline value of the risk input and the blue bar shows the simulated cost impact with a stress test between the 95% and 100% percentile. Both the low value and the high value stress test show a minor impact on the results with only 1% to 2% variation in total costs.

**Figure 4-13 Stress Test (Low Values) on Risk Subsoil Condition**




Source: Author (2012)

**Figure 4-14 Stress Test (High Values) on Risk Subsoil Condition**




Source: Author (2012)

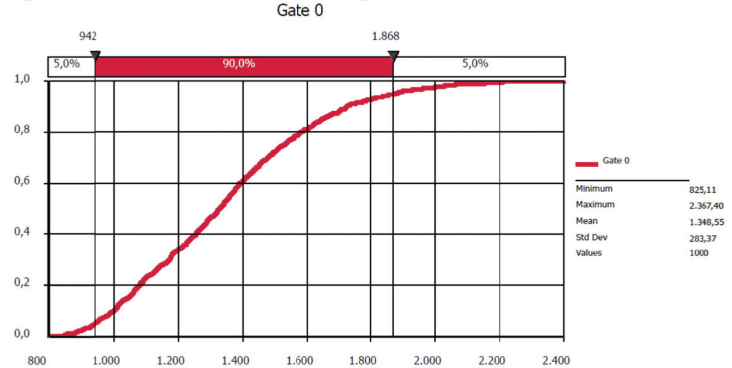
### 4.5.2 Varying number of inputs

A sensitivity test is carried out to check the sensitivity of the model results to the number of risk events included in the analysis. If the model is run with all 28 risks included, there is a 5% chance that the total costs will be larger than 1868 USD. This is shown in the cumulative distribution as presented in Figure 4-15. The mean value for the total costs if all risk events are included in the analysis is 1349 USD.

Another simulation is run without all the 28 risk events. Therefore this simulation only includes the contingency in the CAPEX. The total costs without all the special events will have a 90% confidence not higher than 1001 USD. This is illustrated in the cumulative distribution in Figure 4-16. The mean value of the CAPEX including contingencies and excluding special events is 911 USD. The difference between the results including and excluding the special events show that the CAPEX including contingencies account for approximately 54% of the total costs as estimated with the special events included.

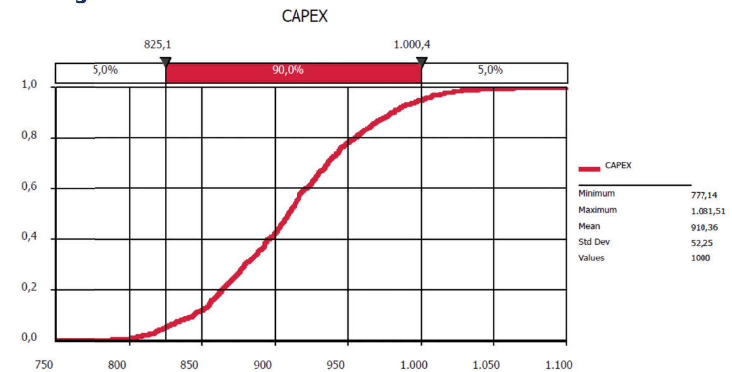
Two other simulations were run with respectively the 7 and 13 main risks included in the analysis instead of all 28 risks. The cumulative ascending costs for these runs are included in Appendix G. The results show that for the simulations with the 7 major risks included, the maximum costs that can occur within a 90% probability interval is 1537 USD. This is 82% of the total costs as estimated with all 28 risks included. In case the 13 main risks are included in the analysis, the 90% confidence is on 1763 USD. This is 94% of the total costs as estimated with all 28 risks included.

**Figure 4-15 Cumulative Ascending Costs for All Risks Included**




Source: Author (2012)

**Figure 4-16 Cumulative Ascending Costs for CAPEX Including Contingencies**




Source: Author (2012)

The quantitative risk analysis includes for all risks additional costs to the CAPEX estimates. The higher the impact of the risks, the more this risk will contribute to the estimated total costs of the project. It may be that the 28 risks as identified for the analysis are not the complete list and some small additional risks may not have been incoporated. Assuming that the 28 risks as selected for the analysis are an almost complete list, the above analysis shows that if only the 13 major risks were identified the cost estimate would only be 5% less. If only the major 7 risks were identified than the total cost estimate would be 18% underestimated. It must be noted that all projects are different and that all projects have a different number of major risks. This case study shows that the 13 key identified risks would give a reasonable accurate estimate of the total costs of the projects including contingencies and special events.

## 4.6 Key Messages from Case Study

The main risks identified in the port development project are the government agreement, the subsoil condition, malaria and the road and transport infrastructure.

The lack of knowledge on the geotechnical conditions at the site represents the greatest risk to the feasibility and cost estimate for the port. Geophysical/geotechnical and metocean data should be obtained as soon as possible in order to confirm the optimum location and allow further optimisation of the layout and conceptual designs. This data may show that the location and/or layout of the port should be adjusted to avoid costly dredging works.

Next to the project risk, the risk assessment also shows high country and environmental risk. These are more external risks and most likely cannot be controlled by the parties involved in the project. However, these risks should still be closely monitored as they can have a direct influence on the project.

The project described above is a high risk project with significant country (political), market, environmental, project and regulatory risks. It will be critical for the project to introduce a risk control action plan and monitor and mitigate the risks identified. The risk register should be kept up to date during the project.

The sensitivity analysis of the project shows that if only the 13 major risks are included in the analysis the total cost estimation will be 94% of the total costs as estimated with all risks included.

The decision on the risks and whether or not to go ahead with the project is not only determined by the outcome of the risk assessment. The decision about the project is a management decision and is also influenced by commercial considerations. The cost estimation including risk assessment will not provide a direct way forward but may support the decision makers.

# 5 CONCLUSIONS AND RECOMMENDATIONS

The main research question of this thesis is: 'Is risk assessment for port investment projects needed and what would be a solid methodology?'

The following sub-questions were considered:

- What are the major risk factors involved in port investment projects?
- How do we present the risks within port projects and identify additional possible cost?
- How do we prioritize issues in time and provide insight into the critical path of the project?

The input for a systematic methodology has been developed to identify and assess risk specific for port development projects and to qualify, quantify and prioritize the relative importance of the identified risks. The main conclusions of the assessment are summarized hereafter.

## 5.1 Conclusions

The nature of port projects shows the need for a risk analysis as these are generally large projects with large cash flows, having many different and diffuse players, containing various types of risk events and the impact of these projects goes beyond the regional boundaries of the port. The increasing size of investments in port development projects result in risks having a growing impact on the project's performance. Risk assessment is considered to contribute to a positive project outcome especially for complex projects like port developments. The use of a risk assessment may result in investors preparing for existing and potential risk and organisations to have increased confidence in achieving the desired outcome of the investment. Investors will be able to take informed decisions regarding investments and constrain the impact of risk events by taking mitigating measures. Risk assessment takes into account what might occur and will save time, money and stress today and in the future.

The proposed risk assessment methodology as discussed in this writing consists of risk identification, qualitative and quantitative risk assessment. The risk identification categories to be considered are Country, Market, Project, Environmental and Regulatory risks. Methods to be used for risk identification are: standard checklist, scenario analysis, flow chart or critical path. In a second phase also expert interviews and stakeholder workshops are recommended. The risk identification process has a major impact on the outcome of the risk assessment.

***The major risk factors involved in port investment projects can be subdivided into country, market, project, environmental and regulatory risk.***

A risk register needs to be setup to keep track of the risks of the project and act as a repository of knowledge and initiate the risk analysis process. By ranking the risks the importance of the risks with regard to likelihood and impact is indicated.

It is advised to apply both qualitative and quantitative methods in the risk assessment. Not all risks can be transferred into monetary values and/or time impact. The five risk areas are joined by a corresponding cost that influences the decision taking about the project and the amount of budget and time that should be used for mitigating the risk.

A (semi) qualitative risk analysis is recommended for presenting the likelihood and impacts of the risk events. A risk rating matrix and risk map should be applied to visualize the risk events. Special attention should be paid to risk with a major consequence and with a very low likelihood. These risks may result in severe environmental, social or project results or are potential show stoppers for the business. Furthermore, these risks might be related to other events and this should be investigated carefully. It is recommended to indicate these risks in the Risk Register as exceptional risk and urgently evaluate them.

***Risks within port projects should be qualitatively presented by showing a risk rating matrix and risk map.***

In case sufficient and reliable data is available a quantitative risk analysis can be added to the risk assessment. The Monte Carlo method is selected as the best method available for the creation of the risk assessment methodology for port projects. Two sources of risks need to be identified, namely general contingencies and special events. General contingencies are taken into account for uncertainty in the unit rates, local prices and changes in the design. These general contingencies have a 100% probability in the quantitative analysis and are allocated to all elements of the capital cost estimate of the project. The special events have a probability of less than 50%. These special events have a relative small probability and are therefore not included in the deterministic cost estimate. In the probabilistic estimate the probability distributions of these risks are included. It is recommended to perform a sensitivity analysis and stress test on the results of the quantitative analysis.

***Additional possible costs can be identified by quantitatively analysing the risks with the Monte Carlo analysis. Two sources of risks need to be identified namely the general contingencies and special events.***

Being risk aware does not mean being risk averse. Project or risk managers should stay focused, up-to-date and aware of the internal and external influences on the investment. Risk analysis is required through the whole project lifecycle and it is therefore an iterative process. Additionally, the risk assessment input and outcome should be updated through all process stages.

***Risks can be prioritized by constructing a risk ranking and by analysing the results of the qualitative and quantitative assessment. The activities in a project that have the highest influence on the result of the project can be indicated by assessing the impact of the main risk events in terms of likelihood and impact, resulting in the critical path of the project.***

The risk assessment methodology for port investment projects as set up in this thesis will contribute to providing investors strategic advice for their investments. International maritime consultants can apply the methodology for making carefully considered recommendations to their clients on the progress of the projects. The methodology for risk assessment provides engineering consultants a standard method statement that can contribute to a uniform way of working for strategic planning advisory projects.

***Risk assessment for port investment projects is certainly highly recommended. The methodology to be applied consists of 1) risk identification by setting up a risk register and by using a risk checklist and risk ranking, 2) risk qualification by constructing a risk matrix and risk map and 3) risk quantification by applying the Monte Carlo analysis on the risk events to model impact of the general contingencies and special events.***

It is encountered that little is written in scientific literature regarding risk assessment within port projects specifically. This thesis introduced a methodology for risk assessment for port investment projects that can be added to the existing practice of literature on risks management. Distinctive in this thesis is the focus on risks within the dynamic projects in the port sector that are generally significantly influencing the economy of a country. Characteristic of this thesis is the structured representation of a risk assessment methodology for port investment projects. Several ways have been proposed to identify and assess the risks within these projects and to gain insight into port project performance and indicate the risks that have the highest impact. The methodology setup in this thesis contributes to improve the decision making process for port investments. An extensive risk checklist has been setup that provides a strong basis for the risk identification process. Further the various risk identification and assessment methods, both qualitative and quantitative, have been weighted and the most suitable methods for port projects have been selected. The resulting risk assessment methodology provides a solid basis for engineering consultants to offer dynamic strategic planning advice to their clients and gains insight into the critical path of a project.

The risk assessment methodology contributes to improving the capabilities of the project manager of the investment project. It assists in maintaining the focus and prevents tunnel vision. It forces the project team to reflect on the project. The risk assessment methodology as proposed in this thesis supports the exploration of the possible impacts on an investment in a structured way.

## 5.2 Recommendations

Recommendations for further research are represented hereafter.

- The identification of the risk impact on the payback period, IRR or NPV needs to be further analysed.
- The drawback of the identification process is the identification of the risks itself. This has a significant impact on the outcome of the risk assessment. It is recommended to further research the risk identification methodology with the aim to create a format for generating accurate input.
- A methodology for investigating causes and consequences of risks should be developed. The focus in this thesis is on the identification and assessing of risks only, however reviewing, reporting, communicating, mitigating and evaluating should not be neglected. The risk management method statement needs to be completed by developing a risk control framework.
- It is recommended to further investigate the time value of risk and consequences of project delays and any resulting loss of income or additional costs.

- This thesis does not further develop the analysis of the possible correlations between risks. It is recommended to perform e.g. two risk simulations: one reproducing that a risk may individually occur and another simulation in which if a risk event occurs, all other risks will happen simultaneously. The actual costs will be somewhere in between these two simulations.
- For applying the Monte Carlo analysis the probability distributions need to be selected for the different risk events. In this thesis the normal, triangular and uniform distributions were applied but it is advised to investigate the impact of different distributions and determine the best approach of selecting appropriate distributions.
- Further investigate the understanding of the decision-makers' attitude towards risk and to enable them to make sound choices. It is recommended to create a better understanding of the trade-off between projects with higher expected returns but more variability of returns compared to less attractive but more stable opportunities. By doing this, the risk assessment methodology can be upgraded and adjusted to the needs of the decision makers to further improve and support the decision making process.
- Within the thesis some information is provided on applying stochastic dominance to select the best alternative for a project development, for example two alternatives on different locations. It is suggested to further investigate this and add guidelines on how to deal with the decision which alternative is preferable.
- It is recommended to apply more case studies and evaluate projects afterwards to assess the results of the risk assessment. By assessing completed projects the effects of the risk assessment methodology can be better determined and adjusted if needed. Further the number of risks to be identified can then be verified more accurately.

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# Appendix A
# Literature Review

**Table 6-1 Literature review**

| Literature short name | Brief description | Relevance | Journal MEL or MPM* |
|---|---|---|---|
| **A** | | | |
| Abourizk 2003 - Risk and uncertainty in construction | Construction risk | yes | |
| Asian Development Bank 2002 - Handbook for Integrating risk analysis in economic analysis of projects | Risk in all kind of projects | yes | |
| Australian Government 2008 - Risk assessment and Management | Risk general | yes | |
| Aven 2008 - Risk analysis methods | Some methods on risk management | low | |
| **B** | | | |
| Barbaro and Bagajewicz 2004 - Managing financial risk in planning under uncertainty | Mathematical formulations; probabilistic formulation of financial risk; two stage stochastic programming methods | no | |
| Bendall and Stent 2003 - Investment strategies in market uncertainty | Shipping market; real options analysis (ROA) | yes | MPM |
| Bendall et al 2007 - Maritime investment strategies with a portfolio of real options | Shipping market; real options analysis (ROA) | yes | MPM |
| Bichou 2008 - Security and Risk-Based Models in Shipping and Ports | Risk assessment and security | no | |
| Bichou et al 2008 - Risk management in port operations logistics and supply chain security | Security and risk management | no | MEL |
| Baker et al 1998 - Techniques for the analysis of risks in major projects | Risk management - interviews and results | no | MEL |
| Boschloo et al 2001 - Evaluation of uncertainties in cost estimation | Uncertainties and costs | partly | |
| Bu-Qammaz 2007 - Risk assessment of international construction projects | Risk in construction | partly | |
| **C** | | | |
| Chlomoudis and Pallis 2008 - Defining factors for the undertaking of risk for investments in the port industry | Risks in ports, safety | yes | |
| Chlomoudis and Lampridis - Quality assurance providing tools for managing risk in ports | Quality management in ports and risks in ports | no | |
| Chaplin 2003 - Calculating the adjustment for bias | Bias adjustment in cost estimates | partly | |
| Chapman and Cooper 1983 - Risk Engineerng - Basic Controlled Modelling and Memory Models | Formulas, little CPM and Perth, but no explanation on methods | no | |
| Cooper 2003 - Implementing Risk Management in Large Projects | Large projects risk assessment | yes | |
| **D** | | | |
| Dekker and Verhaeghe 2008 - Development of a strategy for port expansion | Optimal control theory; optimal expansion strategy | no | |

| Literature short name | Brief description | Relevance | Journal MEL or MPM* |
|---|---|---|---|
| Dewar 2002 - Assumption-based planning a planning tool for very uncertain times | Assumption-based-planning | no | |
| Dewar 2002 - Assumption-based planning a tool for reducing avoidable surprises | Assumption-based-planning - book - only contents | no | |
| Duffy and Van Dorp 2003 - Risk analysis for large engineering projects | Simulation based risk analysis; monte carlo based risk analysis | possible | |
| Dillon et al 2002 - Assessment of cost uncertainties for large techn projects | Tritium study cost uncertainties in cost estimates | no | |
| Desai 2005 - Risk analysis in port finance | Risk assessment framework development combined with port finance | yes | |
| **E** | | | |
| Eisenhardt 1989 - Making fast strategic decisions in high velocity environments | Making decisions in microcomputer industry | no | |
| Eden 2006 - Risk Assessment Tunnel Project | General background information | partly | |
| Ernst & Young 2011 - Business Risks facing Mining and Metal | General information on business risks | no | |
| **F** | | | |
| Flyvbjerg et al 2003 - How common and how large are cost overruns in transport infrastructure projects | Misinformation, forecasts compared to actual costs, consequences for policy making, statistical analysis | partly | |
| Flyvbjerg et al 2003 - Megaprojects and risk - an anatomy of ambition | Risks and megaprojects | book: yes | |
| Flyvbjerg et al 2004 - What causes cost overrun in transport infrastructure projects | Focuses on what causes cost escalation | partly | |
| Floricel and Miller 2001 - Strategizing for anticipated risks and turbulence in large-scale engineering projects | Strategic robustness and flexibility; strategies used in conditions of turbulence | no | |
| Ford et al 2002 - A real options approach to valuing strategic flexibility in uncertain construction projects | Real options | yes | |
| **G** | | | |
| Garving and Cheah 2004 - Valuation techniques for infrastructure investment decisions | Methods for valuing investments; option valuation techniques: continuous and discrete time models | partly | |
| Galway 2004 - Quantitative risk analysis for project management | Quantitative project risk assessment | yes | |
| Guo 2004 - Preliminary Framework risk analysis transportation projects | Risk in transportation projects | partly | |
| **H** | | | |
| Ho and Ho 2006 - Risk management in large physical infrastructure investments | Port case; strategic risk management | yes | MEL |
| Hastak and Shaked 2000 - Model for international construction risk assessment | Risk list included macro market project | partly | |
| Hertogh 2006 - Presentatie Management of large infrastructure projects Dynamiqs | not relevant | no | |

| Literature short name | Brief description | Relevance | Journal MEL or MPM* |
|---|---|---|---|
| HM Treasury 2004 - The Orange Book - Management of Risk | Focused on risk management | yes | |
| HM Treasury 2011 - The Green Book | Applied optimism bias, risk register | yes | |
| **K** | | | |
| Koh 2001 - Optimal investment priority in container port development | Investment planning models inland container transportation; mathematical model | no | MPM |
| Kavussanos 2003 - Time varying risks among segments of the tanker freight markets | Risks in shipping market | no | MEL |
| Kwak and Ingall 2007 - Exploring Monte Carlo simulation application | Monte carlo method description for project management | partly | |
| **L** | | | |
| Li and Cullinane 2003 - An economic approach to maritime risk management and safety regulation | Safety; maritime risk management | no | MEL |
| Lessard and Miller 2001 - Understanding and managing risks in large engineering projects | Recognizing, shaping and realizing the real options | no | |
| **M** | | | |
| Miller and Waller 2003 - Scenarios real options and integrated risk management | Scenario planning; qualitative assessment of real options; integrated risk management process; combining scenario pl and real option | yes | |
| Mott MacDonald 2002 - Review of Large Public Procurement in the UK | Optimism bias | partly | |
| **N** | | | |
| Neufville de 2000 - Dynamic strategic planning for technology policy | Dynamic strategic planning; decision analysis | no | |
| Nijkamp 1998 - How reliable are estimates of infrastructure costs | Cost overrun literature | yes | |
| **O** | | | |
| Outline Business Case - BC_Guide_3 | interesting for OBC, but not that well on risk analysis | no | |
| **P** | | | |
| Patterson and Neailey 2002 - A risk register database system | Particular on text on risk database | yes | |
| Port Finance International - Global investments in ports and terminals | General text on risk and procurement within ports | partly | |
| Projectrisico - from delta-pi | General on risk management | partly | |
| **R** | | | |
| Rahman et al 1999 - Onzekerheidsanalyse van de ruimtevraag in de Haven van Rotterdam | Uncertainty to demand | no | |

| Literature short name | Brief description | Relevance | Journal MEL or MPM* |
|---|---|---|---|
| Ranasinghe and Russell 1992 - Analytical approach for economic risk quantification of large engineering projects | PNET versus Monte Carlo | no | |
| Raz and Hillson 2005 - A comparative review of risk management standards | Risk identification tools list | partly | |
| Rio Tinto 2005 - Risk assessment and management guidance | Risks assessment within projects | yes | |
| Risicoanalyse voor projectplanning | Risk analysis | partly | |
| Risk Assessment and Management Process RAMP | Risks assessment method | yes | |
| Roman 1962 - The PERT system | Text on PERT method, however from 1962 | partly | |
| **T** | | | |
| Taneja et al 2010 - Implications of an uncertain future for port planning | Framework for managing uncertainty in port planning; adaptive planning | no | MPM |
| Touran and Lopez 2006 - Modelling cost escalation in large infrastructure projects | Escalation factor | yes | |
| **U** | | | |
| UNCTAD 2011 - Review of maritime transport 2011 | Maritime transport developments | yes | |
| **V** | | | |
| Vastert en Van Gelder - Effectivity of risk management for design and construct projects for large contractors | Risk management formulas in construction projects | partly | |
| Vrijling and Van Gelder 2009 - probabilistic budgetting and time planning | Analytical / probabilistic planning | partly | |
| **W** | | | |
| Walewski 2005 - Risk identification and assessment for construction projects | Risk in construction projects | yes | |
| Wee 2004 - Grote infrastructuurprojecten - de kwaliteit van kostenschattingen - literatuuroverzicht | Cost estimates in infrastructure projects | partly | |
| World Bank - Port Reform Toolkit | Port development projects | partly | |
| Wyman 2012 - Maximizing returns on large investment projects | General info on large projects | partly | |
| **Z** | | | |
| Zaini et al 2011 - Strategic Approaches to risk assessment techniques | Research under contractors about RA | partly | |
| Zavadskas et al 2009 - Risk assessment of construction projects | Risk assessment construction | no | |

Source: Author (2012)

* MEL = Maritime Economics & Logistics
MPM = Maritime Policy & Management

# Appendix B
# Risk Identification Techniques

**Table 6-2 Risk Identification Techniques including Advantages and Disadvantages**

| Name of technique | Advantages | Disadvantages |
|---|---|---|
| Standard checklists | Not time consuming, list can be readily available, major risks can be identified and stimulates thinking about different risk categories. Provides strong basis for risk identification. | List may not be complete so new or unique risks might be overlooked. Lists need to be regularly updated. |
| Comparison to other projects / benchmarking | Important to check the outcome of the cost estimates and to verify if the risks and project methods make sense. | Projects are not identical and this method might prevent out of the box thinking. |
| Expert interviews | Experienced people can use their knowledge to indicate their major concerns to the project. High chance of indicating the major risk events of the project. | Can be time consuming to consult all kind of experts with various fields of expertise. |
| Brainstorm/workshop sessions or Nominal group technique | Offset the threat of group dominance by individuals. Gain insight into the project risk as indicated by different (expert) people. Provides increased number of solutions and inputs and unique ideas | Time consuming and not much spontaneity involved. Facilities must be arranged and planned. |
| Delphi technique | Structured communication technique relying on a panel of experts. Is conducted in writing so no meetings required, keeps attention on the issue, independent thinking of participants. | Time consuming process, skills in written communication, time and commitment required from participants, tendency to eliminate extreme outcomes. |
| Interviews (individual or group) / Questionnaires | Direct commitment of participants, interviewed people is not influenced by others and might speak open. Systematic way of questioning. | Time consuming to prepare and process. The interviewer can affect the data or asks closed questions. |
| Post-project review analysis, historical data, lessons learned | Useful tool as a first step for identification of the possible risks within a project. | Every port project is unique and different circumstances play a role. When looking at other projects it is easy to overlook other important risks that play a role for the current project. |
| SWOT analysis | Helps in summarizing and indicating the issues facing a certain project. Not very much time and cost involved. Used for evaluating operations and indicate forces that work on the project. | The list might not generate sufficient depth into the project. SWOT can be simple and straightforward; more research will probably be needed to present a comprehensive picture. |
| Assumptions analysis and constraints analysis | Identifies the risks that exist as a result of each assumption made during the project / testing of recorded constraints for stability. Systematically analysis of the project. | Only part of the risks of the port investment might be identified. Within port projects also external risks may play a role and these are not always related to assumptions / constraints. |
| Cause and effect diagram | Graphically illustrates the relationship between a possible outcome and the factors influencing the outcome with the aim to identify and sort causes of a specific problem. | Large focus on outcomes and problems, but risks can also be hidden and not be directly visible. |

| Name of technique | Advantages | Disadvantages |
|---|---|---|
| Flow charts / Critical Path Method | Organize the data, analyses where the flow/path is and how certain controls are needed | For complicated projects like ports the flow charts might become complex |
| Event tree analysis / Fault tree analysis | Structured, methodical approach, computerized method, visual model, easy to implement | Only one initiating event, so multiple trees will be required to evaluate the impact of multiple events. Small dependencies and unique individual events can be overlooked. |
| Hazard and operability studies (HAZOP) | Detailed examination of possible situations that can occur. Their impact is examined and adjustments to the process are predefined to mitigate large risks. HAZOP is more specifically for chemical processes and software development. | Very detailed analysis and thus time consuming. |
| Incident investigation | Focused on identifying safety problems and take corrective actions. | Also events that are not related to safety can include risks. Method does not stimulate out of the box thinking. |
| Influence diagrams | Influence diagrams are very suitable for decision making processes. | Does not stimulate risk identification specifically. Risk can also be individual discrete events. |
| Prototyping | Indicate major problems to a (small) project in real time | Port projects are usually very complex and it will be very time consuming to create a prototype. |
| Root cause analysis | Root cause analysis is a structured approach to identify factors that resulted in a specific noticed undesired consequence. This considers the analysis of one or more past events and indicates what need to change to prevent recurrence of the outcomes. | This method does not take into account new events. |
| Scenario analysis | The scenario analysis can be very useful in the decision making process as it does not show one possible picture but presents several alternative future developments. This can be applicable for port investment projects to show the outcome of certain possible developments. | It will not provide a full list of possible risks that may occur, chance of only focusing on the most important scenarios (and correlated events instead of all possible events. |
| System engineering techniques | This technique focuses on the managing and design of complex engineering projects. | Method is more suitable for projects with work processes and automatic control of machinery (physical systems). |
| Technology readiness levels / Testing and modelling | The technology readiness methodology is suitable for technologies before incorporating in a system. It focuses on the experimentation and refining phase including testing. | Method is useful for materials and components but not for infrastructural projects like ports. Testing and modelling also focuses on the testing and optimisation and this cannot be used for infrastructural projects. |

Source: Author (2012)

# Appendix C
# Risk Checklist

References applied for the tables below:

- Ref. [1] World Bank (2007)
- Ref. [2] Chlomoudis and Pallis (2009)
- Ref. [3] Walewski et al (2005)
- Ref. [4] Mott MacDonald (2002)
- Ref. [5] Hastak and Shaked (2000)

Risks are subdivided into:

- Country Risk (Table 6-3)
- Market Risk (Table 6-4)
- Project Risk (Table 6-5)
- Environmental Risk (Table 6-6)
- Regulatory Risk (Table 6-7)

**Table 6-3 Country Risk**

| **I. Country risk** | **Source** |
|---|---|
| **A. Political/ Government Policy / Cultural Diversification** | |
| ▪ Stability | Ref. [1] |
| ▪ Reputation (negotiations, administrative inefficiency) | Ref. [2] |
| ▪ Links established | Ref. [3] |
| ▪ Concessioning authority | Ref. [4] |
| ▪ Cultural obstacles / religious differences | Ref. [5] |
| ▪ Poor public decision making process | |
| ▪ In corruption | |
| ▪ Flexibility and adaptability risk | |
| ▪ Lacks support from key political stakeholders | |
| ▪ Bureaucratic delays | |
| **B. Economic / Currency** | |
| ▪ Poor financial market | Ref. [1] |
| ▪ Inflation rate volatility | Ref. [2] |
| ▪ Interest rate volatility | Ref. [3] |
| ▪ Influential economic events | Ref. [4] |
| ▪ Exchange rate | Ref. [5] |
| ▪ Credit risk | |
| ▪ GDP growth | |
| ▪ Balancing of national saving and debt | |
| ▪ Revenue in foreign country? | |
| ▪ Revenue in local currency? | |
| ▪ Stability of local currency over last few years | |
| ▪ Convertibility of local currency | |

Source: Author (2012)

**Table 6-4 Market Risk**

| **II. Market Risk** | **Source** |
|---|---|
| A. Traffic and Competition | |
| ▪ Activity | Ref. [1] |
| ○ Traffic established? (stable, sharp fluctuations, or steady growth) | Ref. [2]<br>Ref. [5] |
| ○ New traffic | |
| ▪ Growth factor | |
| ○ General economic activity | |
| ○ Sector/domain activity | |
| ○ Acquisition of market share | |
| ▪ Previous quality of service/reliability | |
| ○ Non-existent/Poor/fair/good | |

| II. Market Risk | Source |
|---|---|
| ▪ Customers | |
| o Identified major customers | |
| o “Atomized” market | |
| o Competition/captive traffic | |
| o Present situation | |
| ▪ Competitor terminal in port? | |
| ▪ Competitor terminal in country? | |
| ▪ Competitor corridors? | |
| o Traffic volatile or stable? | |
| o Future situation | |
| o Contractual guarantee of exclusivity? | |
| o Entry barriers? | |
| o Risk of changes: low, medium, high | |
| o Risk of competition: low, medium, high | |
| **B. Obligations** | |
| ▪ Public service obligations | Ref. [1] |
| o Technical | |
| o Minimum capacity | |
| o Performance standards | |
| ▪ Tariffs | |
| o Free rates | |
| o Price cap | |
| o Escalation formulas | |
| o Exemptions? | |
| ▪ Fee payable to concessioning authority | |
| o Up-front fee? | |
| o Fixed annual part: fixed amount, judgment criterion? | |
| o Variable annual part: fixed amount, judgment criterion? | |

| II. Market Risk | Source |
|---|---|
| o Concessioning authority subsidy | |
| o Investment | |
| o Fixed annual part: fixed amount, judgment criterion? | |
| o Guaranteed traffic? Cost + fee? | |
| **C. Guarantees** | |
| ▪ Extra franchise port services | Ref. [1] |
| o What port services do my customers require? | |
| o Who is in charge? (me, public or private port authority, potential problem) | |
| o Level of service guaranteed? | |
| o Level of service satisfactory? | |
| o Price levels satisfactory? | |
| ▪ Pilot service | |
| ▪ Berthing services | |
| ▪ Haulage | |
| ▪ Buoying | |
| ▪ Maintenance of access | |
| ▪ Maintenance of basins | |
| ▪ Maintenance of protection structures | |
| ▪ Other | |
| o Operating hours for these services | |
| o Degree of sensitivity to inspection | |
| ▪ Customs | |
| ▪ Veterinary and phytosanitary | |
| ▪ Other | |
| ▪ Vessel waiting time | |
| o Priorities granted | |
| ▪ Land transport | |
| o What modes of transport are used for my | |

| II. Market Risk | Source |
|---|---|
| traffic? | |
| ○ For each mode: | |
| ▪ Capacity of operators | |
| ▪ Quality of service of operator(s) (time taken, security, and so forth) | |
| ▪ Obstacles to the work of these operators (regulatory, political, and so forth) | |

Source: Author (2012)

**Table 6-5 Project Risk**

| III. Project Risks | Source |
|---|---|
| **A. Project scope and start-up** | |
| ▪ Clear scope of work | Ref. [2] |
| ▪ Land acquisition (site availability) | Ref. [3] |
| ▪ Level of demand for project | |
| ▪ Approvals, permits, licensing | |
| **B. Design** | |
| ▪ Investment amount | Ref. [1] |
| ○ Dredging | Ref. [2] |
| ○ Infrastructures | Ref. [3] |
| ○ Buildings | Ref. [4] |
| ○ Facilities | Ref. [5] |
| ▪ Missions | |
| ○ Design | |
| ○ Construction/installation | |
| ○ Rehabilitation/repair | |
| ○ Maintenance (infrastructure, superstructure, and | |

| III. Project Risks | Source |
|---|---|
| dredging) | |
| ○ Operation | |
| ○ Security | |
| ▪ Obligations relating to investments | |
| ○ Functional specifications | |
| ○ Technical specifications | |
| ○ Functional specifications related to a threshold (future subject) | |
| ▪ Information supplied and technical specifications imposed | |
| ○ Investigation campaigns | |
| ○ Contractual information? | |
| ○ Preliminary design | |
| ○ Detailed design | |
| ▪ Work and supply contracts | |
| ○ Concessionaire-employer | |
| ○ Approval of concessioning authority required? | |
| ○ Call for tenders obligatory? Thresholds? | |
| ▪ Maintenance standards imposed? | |
| ▪ Construction period/commissioning date (Underestimated, Reasonable, Comfortable) | |
| ○ Penalty level | |
| ○ Operation | |
| ○ Public suppliers (water, electricity, and so forth) | |
| ○ Safety rules | |
| ○ Subcontracting authorized/approval | |
| ○ Delay in project approvals and permits | |
| ○ Design deficiency | |
| ○ Unproven engineering techniques | |
| ▪ Design complexity | |
| **C. Construction** | |

| III. Project Risks | Source |
|---|---|
| ▪ Construction time delay | Ref. [2] |
| ▪ Material / labour availability | Ref. [3] |
| ▪ Late design changes | Ref. [5] |
| ▪ Poor quality workmanship | |
| ▪ Insolvency / default of sub-contractors or suppliers | |
| ▪ Climate | |
| ▪ Workforce availability and skills | |
| **D. Operation** | |
| ▪ Operation cost overrun | Ref. [1] |
| ▪ Operational revenues below expectation | Ref. [2] |
| ▪ Low operating productivity | Ref. [3] |
| ▪ Maintenance cost higher than expected | |
| ▪ Lack of training | |
| ▪ Language | |
| ▪ Infrastructure and technical support | |
| ▪ Operational shut downs and start up | |
| ▪ Quality assurance and control | |
| **E. Management** | |
| ▪ Organisation and co-ordination risk | Ref. [1] |
| ▪ Inadequate experience in projects | Ref. [2] |
| ▪ Inadequate distribution of responsibilities and risks | Ref. [3] |
| ▪ Inadequate distribution of authorities | Ref. [4] |
| ▪ Differences in working method and know-how between investors | Ref. [5] |
| ▪ Inadequate review before construction | |
| ▪ Franchise period | |
| ▪ Project IRR over this period | |
| ▪ Payback period | |
| ▪ Availability of finance | |
| ▪ | |
| ▪ Financial attraction of project to investors | |
| ▪ High finance costs | |
| ▪ Insurance | |

Source: Author (2012)

**Table 6-6 Environmental Risk**

| IV. Environmental Risks | Source |
|---|---|
| **A. Natural** | |
| ▪ Water pollution | Ref. [2] |
| ▪ Archaeological risk | Ref. [4] |
| ▪ Force majeure | Ref. [5] |
| ▪ Geotechnical conditions | |
| ▪ Weather | |
| **B. Safety** | |
| ▪ Quality management | Ref. [2] |
| ▪ Accidents prevention | |
| ▪ War | |
| **C. Social** | |
| ▪ Does the operation induce a major reduction in personnel? | Ref. [1] |
| ▪ If so, is a redundancy scheme planned? | Ref. [2] |
| ▪ Funded? By whom? | Ref. [3] |
| ▪ Must a proportion of local personnel be taken on? | Ref. [5] |
| ▪ Qualification of local labour? | |
| ▪ Level of public opposition to project | |
| ▪ Lack of tradition of private provision of public services | |

Source: Author (2012)

Table 6-7 Regulatory Risk

| IV. Regulatory Risks | Source |
|---|---|
| **A. Contractual** | |
| ▪ Status of project company | Ref. [1] |
| o State or concessioning authority has blocking minority interest? | Ref. [5] |
| o Proportion of capital reserved for local investors? | |
| ▪ Contracts with third parties | |
| o What contracts taken over by concessionaire? | |
| o Concessioning authority's approval required for signature of new contracts? | |
| ▪ Bonds | |
| o Nature of bonds | |
| o Amount | |
| o Call conditions | |
| ▪ Consequences of legislative regulatory changes | |
| o Borne by concessioning authority | |
| o Borne by concessionaire or not specified | |
| o Possibilities for recourse | |
| ▪ Contract revision | |
| o Instigation of concessioning authority | |
| o Instigation of concessionaire | |
| o No provision | |
| ▪ Force majeure | |
| o Causes | |
| o Procedures | |
| ▪ Early termination | |
| o Concessioning authority's request: causes, procedures | |
| o Concessionaire's request: causes, procedures | |
| ▪ Disputes | |
| o Possibilities for claim | |
| o Contract law | |
| o Arbitration clause | |
| **B. Legal and Taxation** | |
| ▪ Level of knowledge | Ref. [1] |
| ▪ Profits tax? | Ref. [2] |
| ▪ Sales tax? | Ref. [3] |
| ▪ Personal income tax? | Ref. [4] |
| ▪ Corporate income tax? | Ref. [5] |
| ▪ Miscellaneous taxes? | |
| ▪ Withholding on dividends or intragroup transactions? | |
| ▪ Stability of fiscal system | |
| ▪ Legislation change | |
| ▪ Change in tax regulation | |
| ▪ Industrial legislation change | |
| ▪ Liberalisation degree | |
| ▪ Trade restrictions | |

Source: Author (2012

# Appendix D
# Qualitative Risk Description

## Risk Impact Description

Severity (impact) description for port investment risks (described from very low (1) to very high (5)):

### Country / Social / Cultural

1. Limited impact on local population
2. Minor medium-term consequences for regional population
3. Moderate and on-going social issues
4. Serious impact and damage to country items
5. Very serious impact and damage to country, social and/or cultural items

### Commercial / Traffic

1. Low level impact to commercial issues and expected traffic
2. Minor short-term consequences to project schedule and cost
3. Moderate impact with medium-term consequences to project
4. Serious impact on project schedule and result
5. Very significant issues with very serious impact on project feasibility

### Project / Technical

1. Insignificant technical issues
2. Minor issues with short-term impact on project schedule and costs
3. Moderate issues with medium-term schedule and cost consequences
4. Major schedule and cost impacts
5. Very serious issues with very significant impact on the project

### Environmental

1. Limited damage to minimal area of low significance
2. Minor consequences for small environmental area
3. Moderate short-term impacts not permanent effecting the ecosystem
4. Major medium-term effects on environment
5. Very significant long-term impact on high-valued ecosystem

### Regulatory / Contractual

1. Low-level regulatory issues
2. Minor issues with short-term impact on schedule
3. Moderate issues resulting in possible prosecution and fine
4. Serious issues with significant prosecution result and fines
5. Very significant prosecution and fines

# Appendix E
# Quantitative Risk Assessment Methods

**Table 6-8 Quantitative Risk Assessment Methods including Advantages and Disadvantages**

| Method name | Advantages | Disadvantages |
|---|---|---|
| The Process Evaluation and Review Technique (PERT) | Calculates the minimal required time to complete each task within a certain project. It is an event-oriented technique and can especially be used in projects where time is the important factor over costs (Roman (1962)). PERT focuses on importance of planning and control and the coordination of these functions within a project. PERT indicates every event that is critical for the program performance and shows the related activity time before the next events can take place (Roman, 1962). | Not suitable for time and cost risk assessment. Partly applicable for risk assessment within port projects<br>A problem area of the PERT method is the human element, lack of correlation between progress and expenditure and some questions on scheduling practices (Roman, 1962). |
| Monte Carlo Simulation | Suitable for time and costs analysis. Applicable for risk assessment within port projects. A useful method when there are many variables with significant uncertainties. Ease of implementation. Information on distribution is provided. Based on continuous distribution of key variables. Classical risk analysis method. | Expert advice is required in particular when risks are not independent. For all data probability density functions should be generated regardless of the data available. Interdependencies and relations between input variables are difficult to determine and include in the analysis. Demanding in data requirements and model running time. |
| The Analytic Hierarchy Process (AHP) | Suitable for time and costs analysis. AHP is a multi-criteria decision analysis methodology that allows subjective as well as objective factors in the process. The framework offers a systematic thinking environment and will give a rational basis on which to make decisions (Mustafa and Al-Bahar, 1991). | Medium applicable for risk assessment within port projects. The form of comparisons can be seen as a limitation. Scales need to be formed without the intervention of instruments or measurements. |
| Latin Hypercube sampling | Suitable for time and costs analysis. Method for generating input vectors into computer models for the use of sensitivity analysis studies. Effects of distributional assumptions on key inputs can be included and multidimensional distributions can be applied. Reduced number of model calculations compared to Monte Carlo by using stratified sampling technique (Quelch and Cameron, 1994) | Undesired correlations between input variables may be induced due to nature of sampling. Requires large amounts of computer processing time (Quelch and Cameron, 1994). |
| Game theory | Strategic decision making method, strategically thinking based on rationality. Payoffs can represent money or costs. | Requires strong assumptions about the availability of mutual information and about rationality. |
| Utility theory | Risk assessment based on utility theory quantifies the risk consequences by using a loss function. This function is derived from an equivalent lottery where the probability of getting the worst possible risk outcome is taken as the value representing the risk consequences (Ben-Asher, 2008). Ben-Asher (2008) describes that the prioritization of the risks is based on their expected loss. | Difficulties in specifying a utility function or to derive a consistent one for a group of events. |

| Method name | Advantages | Disadvantages |
|---|---|---|
| Systems thinking | Illustrates that events are interrelated and that an improvement in one area can adversely affect another, holistic approach. | Complicated method to implement and difficult to learn. More suited for developing innovative solutions instead of risk assessment; does not provide a direct cost or time result as is typically asked for by port projects. |
| Catastrophic theory | Examines the risk events as mathematical catastrophes. Concerned with sudden changes by smooth alterations in the situation. Suited to study events that are caused by non-linear system behaviour (Bier et al, 1999). | More qualitative then quantitative method. Not probabilistic. |
| Fuzzy-set theory | Allows vague concepts to be defined in a mathematical sense (Quelch and Cameron, 1994). Partial membership can be allowed as a kind of possibility distribution. Less computation required than with stochastic calculation. | Difficult validating results. Subjectivity in specifying fuzzy-set membership functions. Does indicate 'how much' a variable is in a set instead of 'how probable' it is that a variable is in a set. Some experts indicate that fuzzy set might be unnecessary because only one mathematical uncertainty would be needed. |
| Multi-criteria decision-making models / Analytic hierarchy process | Specific for making choices among alternatives with conflicting demands. Risk ranking, prioritization possible. Analytic hierarchy process can be used for multi-criteria selection among different risk responses, mixing qualitative and quantitative criteria. | Rank reversal may occur easily when new risks are added to model. No probability distribution possible to include. |

Source: Author (2012)

# Appendix F
# Case Study Risk Register

**Table 6-9 Case Study Risk Register**

| Risk ID | Risk title | Brief description of the risk | Risk category | Project stage |
|---|---|---|---|---|
| 1 | b1. Emerging competitors | Competitors for transport or port location | Market Risk | Stage 4-5 |
| 2 | c1. Low labour productivity | Labour construction cost and labour productivity lower than estimated | Project Risk | Stage 4 |
| 3 | a1. Manage diversity / cultures | Manage the diversity of people and different cultures within the project. | Country Risk | Stage 1-5 |
| 4 | a2. Community expectations | Community expectations too high | Country Risk | Stage 1-3 |
| 5 | c2. Land availability | Land availability time consuming and costly | Project Risk | Stage 1-3 |
| 6 | d1. Environmental accident / loss | Environmental accidents / loss | Environmental Risk | Stage 4-5 |
| 7 | e1. Required permits | Required permits not achieved | Regulatory Risk | Stage 1-4 |
| 8 | d2. Standards not met | Environmental quality standards not met | Environmental Risk | Stage 1-4 |
| 9 | d3. Safety level | Safety level during project below level | Environmental Risk | Stage 1-4 |
| 10 | d4. Medical first aid insufficient | Insufficient medical first aid response | Environmental Risk | Stage 1-4 |
| 11 | d5. Malaria | Malaria | Environmental Risk | Stage 1-4 |
| 12 | d6. Ship incidents | Ship incidents with smaller local (fishing) vessels | Environmental Risk | Stage 1-4 |
| 13 | d7. Road and transport infrastructure | Problems with road and transport infrastructure | Environmental Risk | Stage 1-4 |
| 14 | a3. Government agreement | No agreement with government regarding port | Country Risk | Stage 1-3 |
| 15 | a4. Corruption | Corruption not managed | Country Risk | Stage 1-4 |
| 16 | a5. Stakeholder engagement | Lack of stakeholder engagement | Country Risk | Stage 1-3 |
| 17 | a6. Regional instability | Regional instability (political) | Country Risk | Stage 1-5 |
| 18 | e2. Legal framework | Uncertain legal framework | Regulatory Risk | Stage 1-3 |
| 19 | c3. Subsoil condition | Scarcity of geological and geotechnical data / condition of subsoil | Project Risk | Stage 4 |
| 20 | a7. Railway crossing borders | Railway crossing borders: politically sensitive | Country Risk | Stage 1-4 |
| 21 | c4. Bathymetric survey | Detailed bathymetric survey | Project Risk | Stage 4 |
| 22 | c5. Wind and wave measurements | Wind and wave measurements | Project Risk | Stage 4 |
| 23 | c6. Coastal morphology data | Insufficient data on coastal morphology (f.e. dredging) | Project Risk | Stage 1-3 |
| 24 | a8. Stakeholder support | Lack of support from international / political stakeholders | Country Risk | Stage 1-4 |
| 25 | c7. Insufficient quarries | Insufficient quarries available to produce the volumes rock required | Project Risk | Stage 3-4 |
| 26 | c8. Disposal dredged material | Availibility of suitable disposal areas for dredged material | Project Risk | Stage 4 |
| 27 | c9. New inland infrastructure | New inland infrastructure (e.g. roads, bridges, rail) required to serve the marine works | Project Risk | Stage 4 |
| 28 | c10. Availability steel tubular piles | Market interrogation with regards availability and securing steel tubular piles. | Project Risk | Stage 4 |

**Table 6-10 Case Study Risk Register Likelihood and Impact**

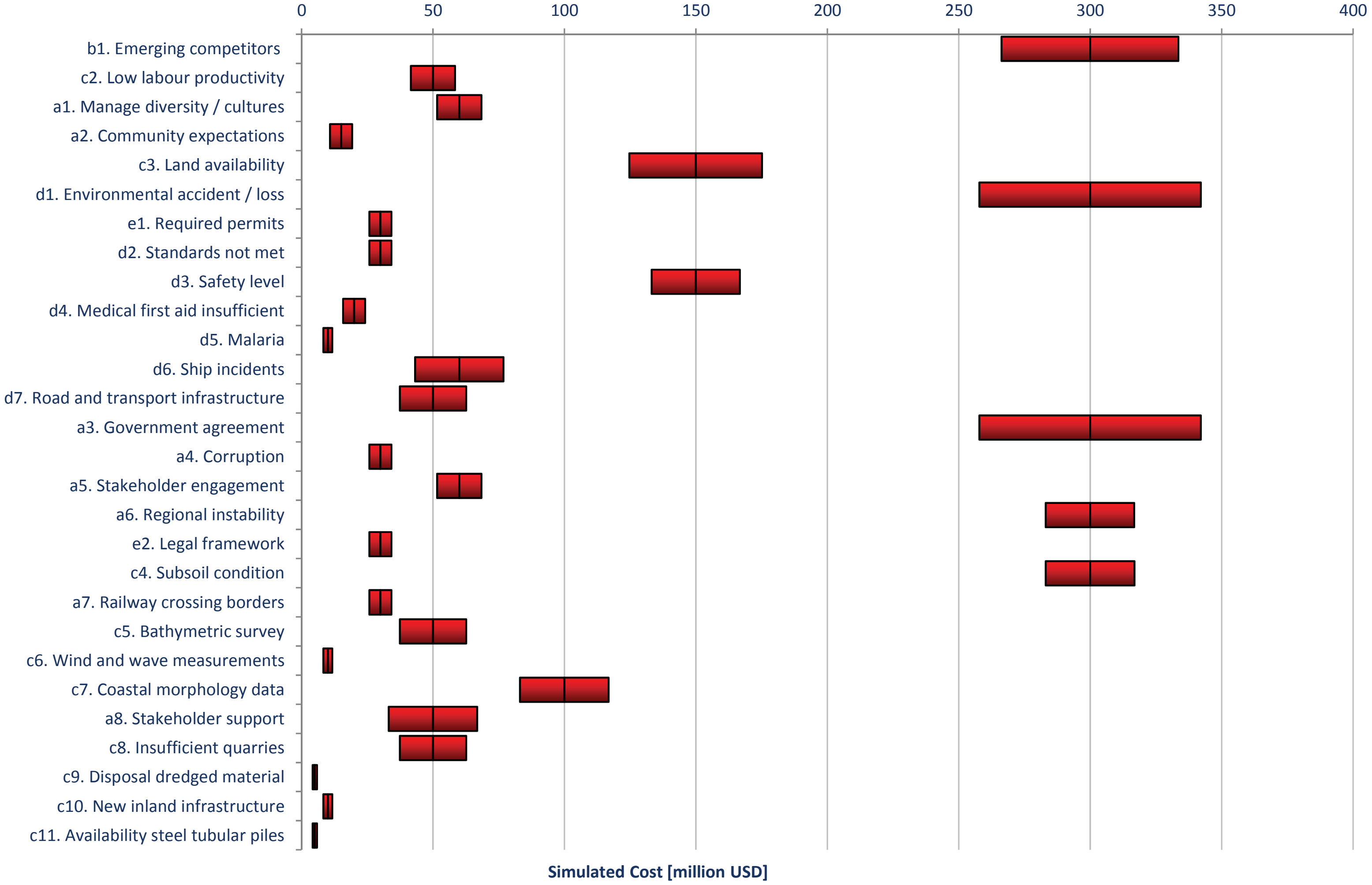
| Risk ID | Risk title | Likelihood value | Impact value | Rank | Probability value | Impact [million USD] |
|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 0.3 | 125 | 37.5 | 35% | 300 |
| 2 | c1. Low labour productivity | 0.3 | 25 | 7.5 | 15% | 50 |
| 3 | a1. Manage diversity / cultures | 1 | 25 | 25 | 40% | 60 |
| 4 | a2. Community expectations | 3 | 25 | 75 | 70% | 15 |
| 5 | c2. Land availability | 1 | 125 | 125 | 35% | 150 |
| 6 | d1. Environmental accident / loss | 0.3 | 125 | 37.5 | 12% | 300 |
| 7 | e1. Required permits | 1 | 25 | 25 | 40% | 30 |
| 8 | d2. Standards not met | 0.3 | 5 | 1.5 | 20% | 30 |
| 9 | d3. Safety level | 0.3 | 125 | 37.5 | 15% | 150 |
| 10 | d4. Medical first aid insufficient | 0.1 | 25 | 2.5 | 5% | 20 |
| 11 | d5. Malaria | 3 | 125 | 375 | 70% | 10 |
| 12 | d6. Ship incidents | 0.3 | 25 | 7.5 | 15% | 60 |
| 13 | d7. Road and transport infrastructure | 3 | 125 | 375 | 65% | 50 |
| 14 | a3. Government agreement | 1 | 625 | 625 | 40% | 300 |
| 15 | a4. Corruption | 0.3 | 25 | 7.5 | 20% | 30 |
| 16 | a5. Stakeholder engagement | 0.3 | 125 | 37.5 | 25% | 60 |
| 17 | a6. Regional instability | 0.3 | 125 | 37.5 | 30% | 300 |
| 18 | e2. Legal framework | 1 | 25 | 25 | 60% | 30 |
| 19 | c3. Subsoil condition | 3 | 625 | 1875 | 75% | 300 |
| 20 | a7. Railway crossing borders | 1 | 25 | 25 | 60% | 30 |
| 21 | c4. Bathymetric survey | 1 | 25 | 25 | 35% | 50 |
| 22 | c5. Wind and wave measurements | 1 | 5 | 5 | 40% | 10 |
| 23 | c6. Coastal morphology data | 1 | 125 | 125 | 50% | 100 |
| 24 | a8. Stakeholder support | 1 | 25 | 25 | 40% | 50 |
| 25 | c7. Insufficient quarries | 3 | 25 | 75 | 65% | 50 |
| 26 | c8. Disposal dredged material | 0.3 | 1 | 0.3 | 10% | 5 |
| 27 | c9. New inland infrastructure | 0.1 | 5 | 0.5 | 5% | 10 |
| 28 | c10. Availability steel tubular piles | 3 | 1 | 3 | 70% | 5 |

**Table 6-11 Case Study Risk Register Expire and Impact Dates**

| Risk ID | Risk title | Mu [million USD] | Sigma [million USD] | Expire date | Min Date occurs | Max date occurs |
|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 300 | 40 | 2019 | 2012 | 2020 |
| 2 | c1. Low labour productivity | 50 | 10 | 2019 | 2015 | 2019 |
| 3 | a1. Manage diversity / cultures | 60 | 10 | 2019 | 2012 | 2019 |
| 4 | a2. Community expectations | 15 | 5 | 2019 | 2012 | 2014 |
| 5 | c2. Land availability | 150 | 30 | 2015 | 2012 | 2014 |
| 6 | d1. Environmental accident / loss | 300 | 50 | 2019 | 2015 | 2020 |
| 7 | e1. Required permits | 30 | 5 | 2014 | 2012 | 2014 |
| 8 | d2. Standards not met | 30 | 5 | 2019 | 2012 | 2020 |
| 9 | d3. Safety level | 150 | 20 | 2019 | 2015 | 2019 |
| 10 | d4. Medical first aid insufficient | 20 | 5 | 2019 | 2015 | 2019 |
| 11 | d5. Malaria | 10 | 2 | 2019 | 2012 | 2019 |
| 12 | d6. Ship incidents | 60 | 20 | 2019 | 2015 | 2019 |
| 13 | d7. Road and transport infrastructure | 50 | 15 | 2019 | 2015 | 2019 |
| 14 | a3. Government agreement | 300 | 50 | 2014 | 2012 | 2014 |
| 15 | a4. Corruption | 30 | 5 | 2019 | 2012 | 2020 |
| 16 | a5. Stakeholder engagement | 60 | 10 | 2015 | 2011 | 2014 |
| 17 | a6. Regional instability | 300 | 20 | 2019 | 2011 | 2020 |
| 18 | e2. Legal framework | 30 | 5 | 2015 | 2011 | 2019 |
| 19 | c3. Subsoil condition | 300 | 20 | 2014 | 2015 | 2017 |
| 20 | a7. Railway crossing borders | 30 | 5 | 2019 | 2011 | 2019 |
| 21 | c4. Bathymetric survey | 50 | 15 | 2014 | 2015 | 2017 |
| 22 | c5. Wind and wave measurements | 10 | 2 | 2014 | 2015 | 2017 |
| 23 | c6. Coastal morphology data | 100 | 20 | 2014 | 2015 | 2017 |
| 24 | a8. Stakeholder support | 50 | 20 | 2015 | 2012 | 2015 |
| 25 | c7. Insufficient quarries | 50 | 15 | 2015 | 2015 | 2017 |
| 26 | c8. Disposal dredged material | 5 | 1 | 2017 | 2017 | 2018 |
| 27 | c9. New inland infrastructure | 10 | 2 | 2015 | 2015 | 2017 |
| 28 | c10. Availability steel tubular piles | 5 | 1 | 2016 | 2016 | 2017 |

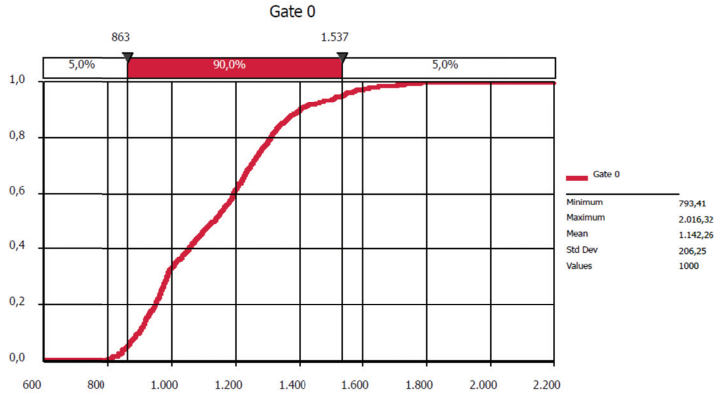
# Appendix G
# Case Study Model and Results

**Figure 6-1 Risk Bandwidths**



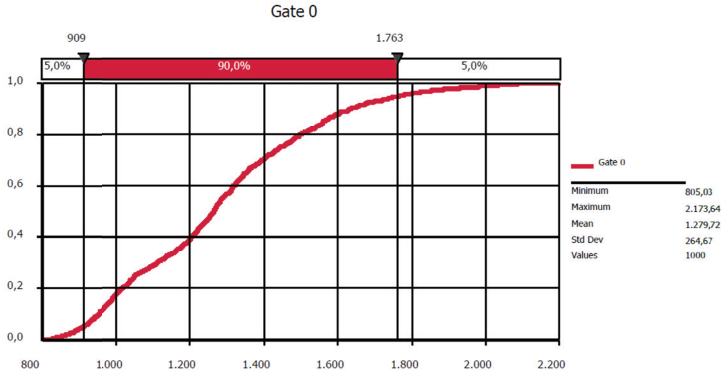

Source: Author (2012)

**Figure 6-2 Cumulative Ascending Costs for the 7 Main Risks Included**




Source: Author (2012)

**Figure 6-3 Cumulative Ascending Costs for the 13 Main Risks Included**




Source: Author (2012)

**Risk Assessment**

| no. Test | | Risk category | Setting |
|---|---|---|---|
| | | Country risk | 1 |
| | | Market Risk | 1 |
| 0 | no test | Project Risk | 1 |
| 1 | yes test with 7 | Environmental Risk | 1 |
| 2 | yes test with 13 | Regulatory Risk | 1 |
| 0 | | | |

| | | | |
|---|---|---|---|
| 10 | | 45-50% | 90 |
| 3 | # | 30-45% | 65-90 |
| 1 | | 15-30% | 35-65 |
| 0.3 | | 5-15% | 10-35 |
| 0.1 | | 0-5% | 0-10 |

Cost impacts: Risk Triangle (Min, Most Likely, Max); Cost impacts: Risk Normal (Mu, Sigma)

| | Risk Identification Number | Brief title of the risk | Risk category | Included | Likelihood | Severity | no test | | Probability [%] | Simulated Occurrence [-] | Simulated Occurrence (2) [-] | Occurs? [-] | Min [million USD] | Most Likely [million USD] | Max [million USD] | Mu [million USD] | Sigma [million USD] | Mean [million USD] | Simulated Cost Impact [million USD] | Cost Added to Plan [million USD] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | b1. Emerging competitors | Market Risk | 1 | 0.3 | 125 | 1 | 15% | 15% | - | - | No | 200 | 300 | 400 | 300 | 40 | 45 | 300 | - |
| | 2 | c1. Low labour productivity | Project Risk | 1 | 0.3 | 25 | 1 | 5% | 5% | - | - | No | 20 | 50 | 80 | 50 | 10 | 3 | 50 | - |
| | 3 | a1. Manage diversity / cultures | Country Risk | 1 | 1 | 25 | 1 | 20% | 20% | - | - | No | 40 | 60 | 80 | 60 | 10 | 12 | 60 | - |
| 2 | 4 | a2. Community expectations | Country Risk | 1 | 3 | 25 | 1 | 30% | 30% | - | - | No | 10 | 15 | 20 | 15 | 5 | 5 | 15 | - |
| 1 | 5 | c2. Land availability | Project Risk | 1 | 1 | 125 | 1 | 15% | 15% | - | - | No | 100 | 150 | 200 | 150 | 30 | 23 | 150 | - |
| 2 | 6 | d1. Environmental accident / loss | Environmental Risk | 1 | 0.3 | 125 | 1 | 5% | 5% | - | - | No | 200 | 300 | 400 | 300 | 50 | 15 | 300 | - |
| | 7 | e1. Required permits | Regulatory Risk | 1 | 1 | 25 | 1 | 20% | 20% | - | - | No | 10 | 30 | 50 | 30 | 5 | 6 | 30 | - |
| | 8 | d2. Standards not met | Environmental Risk | 1 | 0.3 | 5 | 1 | 10% | 10% | - | - | No | 10 | 30 | 50 | 30 | 5 | 3 | 30 | - |
| 2 | 9 | d3. Safety level | Environmental Risk | 1 | 0.3 | 125 | 1 | 5% | 5% | - | - | No | 100 | 150 | 200 | 150 | 20 | 8 | 150 | - |
| | 10 | d4. Medical first aid insufficient | Environmental Risk | 1 | 0.1 | 25 | 1 | 1% | 1% | - | - | No | 10 | 20 | 30 | 20 | 5 | 0 | 20 | - |
| 1 | 11 | d5. Malaria | Environmental Risk | 1 | 3 | 125 | 1 | 35% | 35% | - | - | No | 5 | 10 | 15 | 10 | 2 | 4 | 10 | - |
| | 12 | d6. Ship incidents | Environmental Risk | 1 | 0.3 | 25 | 1 | 10% | 10% | - | - | No | 40 | 60 | 80 | 60 | 20 | 6 | 60 | - |
| 1 | 13 | d7. Road and transport infrastructure | Environmental Risk | 1 | 3 | 125 | 1 | 30% | 30% | - | - | No | 40 | 50 | 60 | 50 | 15 | 15 | 50 | - |
| 1 | 14 | a3. Government agreement | Country Risk | 1 | 1 | 625 | 1 | 15% | 15% | - | - | No | 200 | 300 | 400 | 300 | 50 | 45 | 300 | - |
| | 15 | a4. Corruption | Country Risk | 1 | 0.3 | 25 | 1 | 10% | 10% | - | - | No | 10 | 30 | 50 | 30 | 5 | 3 | 30 | - |
| 2 | 16 | a5. Stakeholder engagement | Country Risk | 1 | 0.3 | 125 | 1 | 10% | 10% | - | - | No | 20 | 60 | 100 | 60 | 10 | 6 | 60 | - |
| 2 | 17 | a6. Regional instability | Country Risk | 1 | 0.3 | 125 | 1 | 15% | 15% | - | - | No | 200 | 300 | 400 | 300 | 20 | 45 | 300 | - |
| | 18 | e2. Legal framework | Regulatory Risk | 1 | 1 | 25 | 1 | 30% | 30% | - | - | No | 10 | 30 | 50 | 30 | 5 | 9 | 30 | - |
| 1 | 19 | c3. Subsoil condition | Project Risk | 1 | 3 | 625 | 1 | 40% | 40% | - | - | No | 250 | 300 | 350 | 300 | 20 | 120 | 300 | - |
| | 20 | a7. Railway crossing borders | Country Risk | 1 | 1 | 25 | 1 | 25% | 25% | - | - | No | 10 | 30 | 50 | 30 | 5 | 8 | 30 | - |
| | 21 | c4. Bathymetric survey | Project Risk | 1 | 1 | 25 | 1 | 15% | 15% | - | - | No | 40 | 50 | 60 | 50 | 15 | 8 | 50 | - |
| | 22 | c5. Wind and wave measurements | Project Risk | 1 | 1 | 5 | 1 | 20% | 20% | - | - | No | 5 | 10 | 15 | 10 | 2 | 2 | 10 | - |
| 1 | 23 | c6. Coastal morphology data | Project Risk | 1 | 1 | 125 | 1 | 25% | 25% | - | - | No | 50 | 100 | 150 | 100 | 20 | 25 | 100 | - |
| | 24 | a8. Stakeholder support | Country Risk | 1 | 1 | 25 | 1 | 15% | 15% | - | - | No | 40 | 50 | 60 | 50 | 20 | 8 | 50 | - |
| 2 | 25 | c7. Insufficient quarries | Project Risk | 1 | 3 | 25 | 1 | 30% | 30% | - | - | No | 40 | 50 | 60 | 50 | 15 | 15 | 50 | - |
| | 26 | c8. Disposal dredged material | Project Risk | 1 | 0.3 | 1 | 1 | 5% | 5% | - | - | No | 2 | 5 | 8 | 5 | 1 | 0 | 5 | - |
| | 27 | c9. New inland infrastructure | Project Risk | 1 | 0.1 | 5 | 1 | 2% | 2% | - | - | No | 5 | 10 | 15 | 10 | 2 | 0 | 10 | - |
| | 28 | c10. Availability steel tubular piles | Project Risk | 1 | 3 | 1 | 1 | 30% | 30% | - | - | No | 2 | 5 | 8 | 5 | 1 | 2 | 5 | - |

## Risk Assessment

| no. Test | | Risk category |
|---|---|---|
| | | Country risk |
| | | Market Risk |
| 0 | no test | Project Risk |
| 1 | yes test with 7 | Environmental Risk |
| 2 | yes test with 13 | Regulatory Risk |
| 0 | | |

date when risk materialize

| | Risk Identification Number | Brief title of the risk | Risk category | Expire date [-] | Minimum date [-] | Maximum date [-] | Data when cost added to plan [-] | Deterministic costs [million USD] | Deterministic data [-] | Risk Min [million USD] | Risk 20% Percentile | Risk Most Likely [million USD] | Risk 80% Percentile [million USD] | Risk Max [million USD] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | b1. Emerging competitors | Market Risk | 2019 | 2012 | 2020 | 1-1-2016 | 45 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 2 | c1. Low labour productivity | Project Risk | 2019 | 2015 | 2019 | 31-12-2016 | 3 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 3 | a1. Manage diversity / cultures | Country Risk | 2019 | 2012 | 2019 | 2-7-2015 | 12 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 4 | a2. Community expectations | Country Risk | 2019 | 2012 | 2014 | 31-12-2012 | 5 | 2,013 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 5 | c2. Land availability | Project Risk | 2015 | 2012 | 2014 | 31-12-2012 | 23 | 2,013 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 6 | d1. Environmental accident / loss | Environmental Risk | 2019 | 2015 | 2020 | 2-7-2017 | 15 | 2,018 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 7 | e1. Required permits | Regulatory Risk | 2014 | 2012 | 2014 | 31-12-2012 | 6 | 2,013 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 8 | d2. Standards not met | Environmental Risk | 2019 | 2012 | 2020 | 1-1-2016 | 3 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 9 | d3. Safety level | Environmental Risk | 2019 | 2015 | 2019 | 31-12-2016 | 8 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 10 | d4. Medical first aid insufficient | Environmental Risk | 2019 | 2015 | 2019 | 31-12-2016 | 0 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 11 | d5. Malaria | Environmental Risk | 2019 | 2012 | 2019 | 2-7-2015 | 4 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 12 | d6. Ship incidents | Environmental Risk | 2019 | 2015 | 2019 | 31-12-2016 | 6 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 13 | d7. Road and transport infrastructure | Environmental Risk | 2019 | 2015 | 2019 | 31-12-2016 | 15 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 14 | a3. Government agreement | Country Risk | 2014 | 2012 | 2014 | 31-12-2012 | 45 | 2,013 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 15 | a4. Corruption | Country Risk | 2019 | 2012 | 2020 | 1-1-2016 | 3 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 16 | a5. Stakeholder engagement | Country Risk | 2015 | 2011 | 2014 | 2-7-2012 | 6 | 2,013 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 17 | a6. Regional instability | Country Risk | 2019 | 2011 | 2020 | 2-7-2015 | 45 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 18 | e2. Legal framework | Regulatory Risk | 2015 | 2011 | 2019 | 1-1-2015 | 9 | 2,015 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 19 | c3. Subsoil condition | Project Risk | 2014 | 2015 | 2017 | 1-1-2016 | 120 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 20 | a7. Railway crossing borders | Country Risk | 2019 | 2011 | 2019 | 1-1-2015 | 8 | 2,015 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 21 | c4. Bathymetric survey | Project Risk | 2014 | 2015 | 2017 | 1-1-2016 | 8 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 22 | c5. Wind and wave measurements | Project Risk | 2014 | 2015 | 2017 | 1-1-2016 | 2 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 1 | 23 | c6. Coastal morphology data | Project Risk | 2014 | 2015 | 2017 | 1-1-2016 | 25 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 24 | a8. Stakeholder support | Country Risk | 2015 | 2012 | 2015 | 2-7-2013 | 8 | 2,014 | #N/A | #N/A | #N/A | #N/A | #N/A |
| 2 | 25 | c7. Insufficient quarries | Project Risk | 2015 | 2015 | 2017 | 1-1-2016 | 15 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 26 | c8. Disposal dredged material | Project Risk | 2017 | 2017 | 2018 | 2-7-2017 | 0 | 2,018 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 27 | c9. New inland infrastructure | Project Risk | 2015 | 2015 | 2017 | 1-1-2016 | 0 | 2,016 | #N/A | #N/A | #N/A | #N/A | #N/A |
| | 28 | c10. Availability steel tubular piles | Project Risk | 2016 | 2016 | 2017 | 2-7-2016 | 2 | 2,017 | #N/A | #N/A | #N/A | #N/A | #N/A |

**CAPEX**

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model year | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |

**CAPEX Categories**

Note that contingencies are taken into account for uncertainty in the unit rates, local prices and changes in design.

| Unique ID | Category | Stage | Duration [year] | Start Year | End Year | min (-25%) | most likely | max (35%) | Amount (million USD) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Initial Plan Study | 0 | 1 | 2010 | 2010 | 0.75 | 1 | 1.35 | 1.03 |
| 2 | Concept Studies | 1 | 1 | 2011 | 2011 | 3.75 | 5 | 6.75 | 5.17 |
| 3 | Interim Options Study: pre-feasibility and initial surveys | 2a | 1 | 2012 | 2012 | 6 | 8 | 10.8 | 8.27 |
| 4 | Feasibility Studies and Surveys | 2 | 1 | 2013 | 2013 | 7.5 | 10 | 13.5 | 10.33 |
| 5 | Detailed Design Studies | 3 | 1 | 2014 | 2014 | 3.75 | 5 | 6.75 | 5.17 |
| 6 | Final scope, cost, commercial terms and approvals | 3 | 1 | 2014 | 2014 | 1.5 | 2 | 2.7 | 2.07 |
| 7 | Breakwater and Coastal Protection | 4 | 3 | 2015 | 2017 | 285 | 380 | 513 | 392.67 |
| 8 | Dredging works | 4 | 2 | 2017 | 2018 | 56.25 | 75 | 101.25 | 77.50 |
| 9 | Jetty structure | 4 | 2 | 2016 | 2017 | 112.5 | 150 | 202.5 | 155.00 |
| 10 | Port Infrastructure | 4 | 1 | 2018 | 2018 | 30 | 40 | 54 | 41.33 |
| 11 | Storage Areas | 4 | 1 | 2018 | 2018 | 15 | 20 | 27 | 20.67 |
| 12 | Mechanical and Electrical | 4 | 1 | 2019 | 2019 | 37.5 | 50 | 67.5 | 51.67 |
| 13 | Buildings | 4 | 1 | 2018 | 2018 | 11.25 | 15 | 20.25 | 15.50 |
| 14 | Port Equipment | 4 | 2 | 2018 | 2019 | 75 | 100 | 135 | 103.33 |
| 15 | Marine Services | 4 | 1 | 2019 | 2019 | 7.5 | 10 | 13.5 | 10.33 |
| 16 | Miscellaneous | 4 | 1 | 2019 | 2019 | 7.5 | 10 | 13.5 | 10.33 |
| 17 | Terminal startup | 5 | | 2020 | | | | | |
| | | | | | | | | | 910.37 |
| | **Total CAPEX** | | | | | **910.37** | | | |
| | **Cumulative CAPEX** | | | | | | | | |

*values in milion USD*

| Unique ID / Category | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Initial Plan Study | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 2 Concept Studies | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 3 Interim Options Study: pre-feasibility and initial surveys | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 4 Feasibility Studies and Surveys | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 5 Detailed Design Studies | - | - | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 6 Final scope, cost, commercial terms and approvals | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 7 Breakwater and Coastal Protection | - | - | - | - | - | 131 | 131 | 131 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 8 Dredging works | - | - | - | - | - | - | - | 39 | 39 | - | - | - | - | - | - | - | - | - | - | - | - | |
| 9 Jetty structure | - | - | - | - | - | - | 78 | 78 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 10 Port Infrastructure | - | - | - | - | - | - | - | - | 41 | - | - | - | - | - | - | - | - | - | - | - | - | |
| 11 Storage Areas | - | - | - | - | - | - | - | - | 21 | - | - | - | - | - | - | - | - | - | - | - | - | |
| 12 Mechanical and Electrical | - | - | - | - | - | - | - | - | - | 52 | - | - | - | - | - | - | - | - | - | - | - | |
| 13 Buildings | - | - | - | - | - | - | - | - | 16 | - | - | - | - | - | - | - | - | - | - | - | - | |
| 14 Port Equipment | - | - | - | - | - | - | - | - | 52 | 52 | - | - | - | - | - | - | - | - | - | - | - | |
| 15 Marine Services | - | - | - | - | - | - | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - | |
| 16 Miscellaneous | - | - | - | - | - | - | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - | |
| 17 Terminal startup | | | | | | | | | | | | | | | | | | | | | | |
| **Total CAPEX** | **1** | **5** | **8** | **10** | **7** | **131** | **208** | **247** | **168** | **124** | - | - | - | - | - | - | - | - | - | - | - | |
| **Cumulative CAPEX** | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | |

**Stage 0**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added (0) |
|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | - |
| 0 | 0 | | 1900 | 0-1-1900 | |

| Risk ID | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 11 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 18 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 20 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 21 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 24 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 26 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 28 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| **Total Additional Costs from Risks** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| **Total capex + Total Additional Costs from Risks** | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - | |
| **Total Cumulative CAPEX + Risks** | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | |

**Deterministic**

| Risk ID | | | | cost added |
|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2016 | 2016 | 45 |
| 2 | c1. Low labour productivity | 2017 | 2017 | 3 |
| 3 | a1. Manage diversity / cultures | 2016 | 2016 | 12 |
| 4 | a2. Community expectations | 2013 | 2013 | 5 |
| 5 | c2. Land availability | 2013 | 2013 | 23 |
| 6 | d1. Environmental accident / loss | 2018 | 2018 | 15 |
| 7 | e1. Required permits | 2013 | 2013 | 6 |
| 8 | d2. Standards not met | 2016 | 2016 | 3 |
| 9 | d3. Safety level | 2017 | 2017 | 8 |
| 10 | d4. Medical first aid insufficient | 2017 | 2017 | 0 |
| 11 | d5. Malaria | 2016 | 2016 | 4 |
| 12 | d6. Ship incidents | 2017 | 2017 | 6 |
| 13 | d7. Road and transport infrastructure | 2017 | 2017 | 15 |
| 14 | a3. Government agreement | 2013 | 2013 | 45 |
| 15 | a4. Corruption | 2016 | 2016 | 3 |
| 16 | a5. Stakeholder engagement | 2013 | 2013 | 6 |
| 17 | a6. Regional instability | 2016 | 2016 | 45 |
| 18 | e2. Legal framework | 2015 | 2015 | 9 |
| 19 | c3. Subsoil condition | 2016 | 2016 | 120 |
| 20 | a7. Railway crossing borders | 2015 | 2015 | 8 |
| 21 | c4. Bathymetric survey | 2016 | 2016 | 8 |
| 22 | c5. Wind and wave measurements | 2016 | 2016 | 2 |
| 23 | c6. Coastal morphology data | 2016 | 2016 | 25 |
| 24 | a8. Stakeholder support | 2014 | 2014 | 8 |
| 25 | c7. Insufficient quarries | 2016 | 2016 | 15 |
| 26 | c8. Disposal dredged material | 2018 | 2018 | 0 |
| 27 | c9. New inland infrastructure | 2016 | 2016 | 0 |
| 28 | c10. Availability steel tubular piles | 2017 | 2017 | 2 |

| Risk ID | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 2 | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 4 | - | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 5 | - | - | - | 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 7 | - | - | - | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 8 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 9 | - | - | - | - | - | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 10 | - | - | - | - | - | - | - | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 11 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 12 | - | - | - | - | - | - | - | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 13 | - | - | - | - | - | - | - | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 14 | - | - | - | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 15 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 18 | - | - | - | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 19 | - | - | - | - | - | - | 120 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 20 | - | - | - | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 21 | - | - | - | - | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 22 | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 23 | - | - | - | - | - | - | 25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 24 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 25 | - | - | - | - | - | - | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 26 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 27 | - | - | - | - | - | - | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| 28 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| **Deterministic: Total Additional Costs from Risks** | - | - | - | 78 | - | 17 | 221 | 31 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| **Deterministic: Total capex + Total Additional Costs from Risks** | 1 | 5 | 8 | 88 | 7 | 147 | 429 | 278 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - | |
| **Deterministic: Total Cumulative CAPEX + Risks** | **1** | **6** | **14** | **103** | **110** | **257** | **687** | **965** | **1,133** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | **1,257** | |

**Graph input**

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deterministic | 1 | 6 | 14 | 103 | 110 | 257 | 687 | 965 | 1,133 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 | 1,257 |
| Stage 0 | Minimum | 1 | 5 | 12 | 21 | 28 | 128 | 296 | 496 | 681 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 |
| | 20 Perc% | 1 | 6 | 14 | 29 | 45 | 216 | 498 | 775 | 966 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 |
| | Mean | 1 | 16 | 84 | 153 | 176 | 421 | 743 | 1,016 | 1,209 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 |
| | 80 Perc% | 1 | 7 | 125 | 307 | 341 | 584 | 926 | 1,202 | 1,406 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 |
| | Maximum | 1 | 370 | 710 | 817 | 870 | 1,352 | 1,577 | 2,086 | 2,279 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 |
| Stage 1 | Minimum | 1 | 5 | 12 | 21 | 28 | 128 | 296 | 496 | 681 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 |
| | 20 Perc% | 1 | 6 | 14 | 29 | 45 | 216 | 498 | 775 | 966 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 | 1,102 |
| | Mean | 1 | 16 | 84 | 153 | 176 | 421 | 743 | 1,016 | 1,209 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 | 1,347 |
| | 80 Perc% | 1 | 7 | 125 | 307 | 341 | 584 | 926 | 1,202 | 1,406 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 | 1,560 |
| | Maximum | 1 | 370 | 710 | 817 | 870 | 1,352 | 1,577 | 2,086 | 2,279 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 |
| Stage 2a | Minimum | 1 | 5 | 12 | 21 | 28 | 128 | 296 | 496 | 681 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 |
| | 20 Perc% | 1 | 6 | 14 | 27 | 42 | 214 | 495 | 772 | 962 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 | 1,099 |
| | Mean | 1 | 6 | 75 | 143 | 166 | 411 | 733 | 1,007 | 1,199 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 | 1,338 |
| | 80 Perc% | 1 | 7 | 95 | 292 | 331 | 575 | 914 | 1,190 | 1,393 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 | 1,552 |
| | Maximum | 1 | 8 | 694 | 817 | 870 | 1,257 | 1,577 | 2,086 | 2,279 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 | 2,407 |
| Stage 2 | Minimum | 1 | 5 | 11 | 20 | 27 | 128 | 296 | 496 | 677 | 806 | 806 | 806 | 806 | 806 | 806 | 806 | 806 | 806 | 806 | 806 | 806 |
| | 20 Perc% | 1 | 6 | 13 | 24 | 32 | 189 | 455 | 726 | 913 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 | 1,045 |
| | Mean | 1 | 6 | 14 | 83 | 106 | 351 | 673 | 946 | 1,139 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 | 1,278 |
| | 80 Perc% | 1 | 7 | 15 | 97 | 147 | 517 | 836 | 1,121 | 1,319 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 | 1,468 |
| | Maximum | 1 | 8 | 18 | 817 | 825 | 1,082 | 1,500 | 1,917 | 2,141 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 | 2,260 |
| Stage 3 | Minimum | 1 | 5 | 11 | 20 | 27 | 128 | 296 | 496 | 677 | 798 | 798 | 798 | 798 | 798 | 798 | 798 | 798 | 798 | 798 | 798 | 798 |
| | 20 Perc% | 1 | 6 | 13 | 23 | 31 | 158 | 375 | 625 | 804 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 |
| | Mean | 1 | 6 | 14 | 25 | 48 | 214 | 460 | 734 | 927 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 | 1,065 |
| | 80 Perc% | 1 | 7 | 15 | 26 | 41 | 236 | 509 | 823 | 1,043 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 | 1,218 |
| | Maximum | 1 | 8 | 18 | 30 | 436 | 707 | 990 | 1,576 | 1,755 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 |
| Stage 4 | Minimum | 1 | 5 | 11 | 20 | 27 | 127 | 296 | 496 | 670 | 782 | 782 | 782 | 782 | 782 | 782 | 782 | 782 | 782 | 782 | 782 | 782 |
| | 20 Perc% | 1 | 6 | 13 | 23 | 30 | 152 | 357 | 604 | 783 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 |
| | Mean | 1 | 6 | 14 | 25 | 32 | 189 | 426 | 699 | 891 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 | 1,029 |
| | 80 Perc% | 1 | 7 | 15 | 26 | 34 | 196 | 455 | 762 | 990 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 | 1,154 |
| | Maximum | 1 | 8 | 18 | 30 | 39 | 639 | 990 | 1,576 | 1,755 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 | 1,875 |
| Stage 5 | Minimum | 1 | 5 | 11 | 20 | 27 | 126 | 290 | 491 | 649 | 774 | 774 | 774 | 774 | 774 | 774 | 774 | 774 | 774 | 774 | 774 | 774 |
| | 20 Perc% | 1 | 6 | 13 | 23 | 30 | 149 | 343 | 576 | 742 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 |
| | Mean | 1 | 6 | 14 | 25 | 32 | 163 | 371 | 618 | 786 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 | 910 |
| | 80 Perc% | 1 | 7 | 15 | 26 | 34 | 177 | 398 | 659 | 828 | 954 | 954 | 954 | 954 | 954 | 954 | 954 | 954 | 954 | 954 | 954 | 954 |
| | Maximum | 1 | 8 | 18 | 30 | 39 | 204 | 458 | 757 | 941 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 | 1,063 |

**Stage 1**
**2011**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | 0 | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**Stage 2a**
**2012**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**Stage 2**
**2013**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**Stage 3**
**2014**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**Stage 4**
**2015**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**Stage 5**

**2020**

| Risk ID | Brief title of risk | Year before risk expires | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | | 1900 | 0-1-1900 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |

**End**

**2026**

| Risk ID | Brief title of risk | 0 | Year | Date | cost added | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | b1. Emerging competitors | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | c1. Low labour productivity | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | a1. Manage diversity / cultures | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | a2. Community expectations | 2019 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5 | c2. Land availability | 2015 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | d1. Environmental accident / loss | 2019 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | e1. Required permits | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8 | d2. Standards not met | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | d3. Safety level | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | d4. Medical first aid insufficient | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | d5. Malaria | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | d6. Ship incidents | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | d7. Road and transport infrastructure | 2019 | 2016 | 31-12-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | a3. Government agreement | 2014 | 2012 | 31-12-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | a4. Corruption | 2019 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | a5. Stakeholder engagement | 2015 | 2012 | 2-7-2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | a6. Regional instability | 2019 | 2015 | 2-7-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | e2. Legal framework | 2015 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | c3. Subsoil condition | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | a7. Railway crossing borders | 2019 | 2015 | 1-1-2015 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | c4. Bathymetric survey | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | c5. Wind and wave measurements | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | c6. Coastal morphology data | 2014 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | a8. Stakeholder support | 2015 | 2013 | 2-7-2013 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25 | c7. Insufficient quarries | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | c8. Disposal dredged material | 2017 | 2017 | 2-7-2017 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | c9. New inland infrastructure | 2015 | 2016 | 1-1-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 28 | c10. Availability steel tubular piles | 2016 | 2016 | 2-7-2016 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0 | 0 | 0 | 1900 | 0 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Additional Costs from Risks** | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total capex + Total Additional Costs from Risks** | | | | | 1 | 5 | 8 | 10 | 7 | 131 | 208 | 247 | 168 | 124 | - | - | - | - | - | - | - | - | - | - | - |
| | **Total Cumulative CAPEX + Risks** | | | | | **1** | **6** | **14** | **25** | **32** | **163** | **371** | **618** | **786** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** | **910** |