“Development of Delft Central”; an underground Decision Problem

application of Decision Analysis at Ballast Nedam Engineering

Final Report
"Development of Delft Central": an underground Decision Problem

*application of Decision Analysis at Ballast Nedam Engineering*

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Amstelveen, August 2000

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Preface

This report forms the final result of the graduating project of my study at the Faculty of Civil Engineering and Geo Sciences of Delft University of Technology. In order to create a good base for my further career, I focussed on a wide range of subjects during the last years of my study. In the area of hydraulic engineering and business sciences, I decided to focus on probabilistic approaches on the design process of civil projects. It resulted in an actual subject that forms a part of large scaled investigations of contracting companies on risk management in early phases of the project process.

In order to guarantee the practical relevance of this project, Ballast Nedam Engineering supported the investigation. At Ballast Nedam Engineering ir. Armand Verweij personally advised me on how to organise the graduating project. He created a good working atmosphere at the office and gave me the opportunity to attend a workshop on the application of Decision Analysis.

Prof.drs.ir. J.K. Vrijling, ir. T.H.W. Horstmeier and dr. T. Bedford performed as my personal mentors at the Delft University of Technology. Because all three represent different professions, I have been educated on a wide range of subjects. I want to thank them for their support and education.

Furthermore I would like to thank all people, who had time to support me when I needed support.

Amstelveen, 24th August 2000

Paul John de Jong
Summary

Following from the increasing demand for “Design & Construct” projects and property development projects, Ballast Nedam is forced to perform in studies in earlier phases of the project process. In cases of infrastructure projects and large scaled building projects, Ballast Nedam also performs in connecting client, founders, contractors and users in initiative phases and feasibility phases.

In order to create a good competitive position in this new market, Ballast Nedam is forced to make strategic decisions in phases of projects where big uncertainties play a role. Decisions over a large amount of money have to be made very fast. A complex web of interests often influences the decision making process in the feasibility phase.

In order to make decisions ‘faster’ and ‘safer’ Ballast Nedam Engineering (BNE) is looking for a methodology that can support the decision making process. Decision Analysis is a methodology that helps the decision maker to decompose a complicated problem into a framework of smaller parts by using the decision tree as a representation of the decision problem.

Former tests at Ballast Nedam Engineering of Decision Analysis on a technical problem proved that Decision Analysis was found to be a faster process, with less costs and it was found to create a clearer overview on the problem. Besides that, it was evaluated as a good communication tool. The advantage of a Decision Analysis is that within the boundaries of limited information an impression of the sensitivities and optimal decision can be obtained. Ballast Nedam Engineering also wants to investigate the opportunities of application of Decision Analysis in phases where strategic decisions have to be made.

The objective of this study is to investigate the application of a Decision Analysis in early phases of project development projects of Ballast Nedam subsidiaries.

The group Plan Development of Ballast Nedam Engineering performs in studying the feasibility of building and infrastructure projects by order of Ballast Nedam subsidiaries. Decision making at higher economical levels is found to have big impact on the decision making in the feasibility study of property development projects. The outcome of political decision making is a dominant uncertainty in the feasibility study of projects.

The process that will be undertaken by project groups of the group Plan Development can be described by three phases. In the first phase the technical and market feasibility of a project are investigated. The high number of uncertainties and the possible states of uncertainties make it hard to create a quantitative representation of the decision situation. In the second phase where variants are developed and where the decision on the final variant will be made, the features on the developed variants have been quantified and the number of state of nature variables has been decreased. Quantification of the uncertainties on state of nature variables seems to be possible by expert opinion.

In the second phase the assessment of variants focus on the attributes of a variant that meet the requirements of the developers’ employer and the rate of return of a variant. Therefore a political lobby for the project and a financial analysis on the variants are performed.

In the third phase the chosen variant is optimised based on interviews with experts and involved authorities.

Decision making at projects of the group plan development is based on a qualitative approach on the interest of the client. A clear insight in the consequences of alternative actions is missing. Risk identification is only performed in a qualitative way.

Decision supporting techniques as the decision tree and the influence diagram are both tools that are able to describe the decision situation based on a single attribute. They give insight in the structure and sequential processes that influence the optimum decision for the decision problem based on the expected value of the attribute. Furthermore a tree is able to perform as a communicative tool.

When multiple interests play a role, a single attribute analysis is not sufficient for defining the optimum decision. In that case a rational decision can be derived from a Multi Attribute Utility Technique (MAUT). The MAUT combines the outcome of the single attribute decision trees in a decision table.
The MAUT seems to be a good tool for weighing multiple interests of the decision maker. The decision maker is able to express his preference on attributes into quantified values by weighing attributes. Most of the time a deterministic analysis of the decision problem does not give enough information for decision making. A probabilistic approach on the state of nature variable can give a more detailed insight in the scenario's which determines the value of the used attributes.

The sensitivity of the outcome of the variables that measure the value of the attributes can be investigated by the use of a tornado diagram. Insight in the sensitivity can form a basis for risk management activities. Based on the probabilistic outcomes the sensitivity of the optimum decision can be investigated. The decision makers' attitude towards a project is translated in the value of the discounting parameters he uses in the Net Present Value calculation in which he investigates the financial feasibility of the project. By switching a parameter as the 'Discount Rate' or the 'Time Window' between the low level and a high level, the decision maker is able to investigate the sensitivity of the outcome of the decision table of the MAUT. The switching of the variable creates a renewed decision tree, which calculate the variable with a new discounting parameter.

The study on the feasibility of the development of "Delft Central" seems to be a good case to perform a Decision Analysis and to assess the decision supporting techniques on their restrictions on use and contribution to risk management activities. The second phase of the feasibility study focus on the decision whether to propose separate - or integral development of real estate and infrastructure in the area "Delft Central". The decision will be based on an analysis of two variants; Variant I that proposes a construction in two separated construction pits and Variant II that will be constructed in one big construction pit.

The determination of the optimum decision between variants is based on the performance of a Decision Analysis that forces to create a clear structure of the scope, objectives and uncertainties influencing the decision problem. The high number of interests of the decision making "steering group", results in a high number of attributes. Based on influence diagrams of the variables that measure the attributes, an influence diagram of the complete decision model is performed. A complex web of uncertainties influences the value of financial attributes. Therefore the related object functions have been put in a numerical model. The model is able to produce quantified decision trees of the single object variables that measure the attributes. In this model the value of the state of nature variables are assumed to be independent. In order to create a decision situation in which attributes can be compared in a MAUT, the object variables as 'Public – and economical spin off' values are chosen to put also into monetary values by interviewing the decision maker.

The steering group is founded not to be able to act as a rational decision maker. Therefore in this Decision Analysis the decision tables of both the municipality of Delft and BNE and BNO are compared. For both the municipality and BNO variant II is founded to be the most attractive variant. Variant II satisfies the requirements of the state of the Netherlands. Therefore it is expected to create a higher value of subsidy than when variant I would be proposed. The attitude of BNO towards the number of uncertainties that influence the value of the NPV of the project does not change the choice for Variant II for BNO.

Evaluation of the possible outcomes of variant II shows that the 'steering group' has to focus on the political lobby that must provide the required amount of subsidy for the State of the Netherlands. Optimisation of the number of square meters real estate will have benefit for both BNO and the municipality of Delft.

The influence of the time development of the square meter price of real estate is analysed to have also big impact on the financial feasibility of the project for BNO. Further investigation on this 'state of nature' variable will be necessary. The uncertainty on the value of decision variables are also analysed to have has big impact on the financial feasibility of the project. Risk control measures that focus on the uncertainty of these variables have considerable impact on the range of possible outcomes of the Net Present Value of the project.
Because of the uniqueness of a project in the feasibility phase of the design, the few people in the decision making group also perform as an expert for the quantification of the 'state of nature' variables of the object functions. The inexperience of the experts in quantifying public and economical values forms a restriction on the quality of the model. This inexperience also affects the quality of the weighing process. Because of the fact that the decision maker also performs as an expert, the decision maker is able to control the outcome of the Multi Attribute Utility Technique by estimating the object variables and by assigning weights.

From the output of the decision model it can be stated that the MAUT is able to give an insight in the dominant attributes on which the variants will be assessed. The decision tree makes it possible to get insight in the possible scenarios' of the single attributes. In further process the decision maker is able to keep insight in the outcome of the object variables when a scenario changes. A Tornado diagram is a technique that evaluates the outcomes of the decision tree. By showing the sensitivity of the outcome of object variables, which measure the attributes, to changes in state of nature variables, this technique can contribute to risk analysis. It helps the analysis conductor of BNE to recommend the client in performing risk management activities for further development of the chosen variant.

As written above, compared to the present situation at BNE group Plan Development, Decision Analysis shows multiple additional values. In order to create support for the use of this technique it is advised to write a manual and to create an example of application for every subsidiary that acts in early phases of projects. In that case it must be noticed that the case study in this report is a special cooperation between a political stakeholder and a project developer in which both parties are not used to be open with their objectives. Therefore the steering group was not able to perform as a rational decision maker.

Expanding the expertise of performance of Decision Analysis to other subsidiaries may create more expertise on quantification of uncertainties. On long term this may contribute to the quality of the input the decision model and reduce the opportunity to manipulate the MAUT.

Now there is an example for the second phase of the feasibility study of property development projects, it would be interesting to investigate also the application of the techniques in the first phase of the feasibility study.

Furthermore creating a framework for the modelling of stochastic dependence between uncertainties can increase the quality of the decision model. Especially in more detailed or technical decision problems it could be desirable to have more detailed information on state of nature variables and their stochastic dependence. The used numerical model is able to model stochastic dependence between states of natures.
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1 Introduction

1.1 History
At the end of the eighties Ballast Nedam made great efforts to implement Risk Analysis in their project organisation structures. Risk Analysis could provide a more economic approach on the design process. By asking experts on the probability of occurrence of events that can cause a delay, Ballast Nedam was able to give a more reliable view on the planning and the costs at the start of a project. The last few years the nature of work of Contractors companies like Ballast Nedam is changing from construction projects only to ‘Design & Construct’ projects and property development projects. This change forces the contractor to make strategic decisions. This situation asks for fast and safe decision making. The present decision making is based on non-scientific discussions in which uncertainties are hard to identify and often un-quantified.

In order to make decisions ‘faster’ and ‘safer’ Ballast Nedam Engineering is looking for a methodology that can support the decision making process. Decision Analysis is a methodology that helps the decision maker to decompose a complicated problem into a framework of smaller parts by using the decision tree as a representation of the decision problem.

For this reason Ballast Nedam Engineering (BNE) is looking for applications for Decision Analysis in their scope of work. A lack of knowledge and insight in the possibilities of the described methodology at BNE formed a motive to test Decision Analysis for some design parts of the ‘Betuweroute’ part Sliedrecht Gorinchem. Compared to the standard Risk Analysis, Decision Analysis was found to be a faster process with less costs and was evaluated as producing a clearer overview. Besides that, it was found to be a good communication tool.

1.2 Objective of investigation

1.2.1 Problem description
A web of objectives and a lack of time to come to well thought decisions, characterise the decision making in the early phases of property development projects at Ballast Nedam. The uncertainties that influence the decision are bigger and not easy to quantify. The decision making in early phases has a considerable impact on future development of a project. A scientific framework could help a project team to clarify and articulate alternatives and to account for uncertainties in making strategy decisions.

1.2.2 Problem definition
In order to make strategic decisions faster, BNE wants to systemise the analysis of complex decisions by the application of Decision Analysis at Ballast Nedam subsidiaries. These decisions are influenced by uncertainties that may have considerable impact on further process of a project.

1.2.3 Objective
The objective of this thesis is to investigate the application of Decision Analysis at Ballast Nedam subsidiaries, which perform in early phases of the property development projects.
Figure 1-1 Flow Chart of report
1.3 Result

1.3.1 Structure of investigation
In order to achieve the objective of this investigation, a literature investigation and a case study are performed. Study of literature and the analysis of a simplified example of a property development project provide a general insight in the possibilities and additional value of Decision Analysis. The performance of a case study gives insight in the restrictions and quality of the performance of Decision Analysis and the use of the decision supporting tools. Furthermore it must describe opportunities for the performance of risk management at the group Plan Development of BNE\(^1\) that performs by order of Ballast Nedam Property Development (BNO).
This report describes a case at Ballast Nedam Engineering group Plan Development on which the Decision Analysis is tested.

The report consists of two parts. The first part describes the application of Decision Analysis at property development projects. Chapter 2 analyses the situation of the decision making at projects of the group Plan Development of BNE, which performs by order of BNO in the feasibility phase of property development projects. Based on this description a performance of Decision Analysis on a simplified example of a project is described in Chapter 3. Chapter 4 describes the first conclusions on the use of the decision supporting techniques on a BNO project, based on the two previous chapters. This chapter forms the base for the performance of the case study in part II.
In part II the case study, the 'Development of 'Delft Central' an "underground" decision problem', is described. Chapter 5 forms the introduction to the decision problem in the case study. In Chapter 6 a model for decision making is created. Chapter 7 describes the numerical model that is used to support decision making and to determine the quality of the performance of the Decision Analysis. This model has been structured in the same way as the simplified performance in part I. In Chapter 8 the performance and results of the Decision Analysis is described. It leads to an optimum decision for the decision problem. Based on the gained insight in the decision problem the first risk control measures can be taken in Chapter 9. Based on the experiences during the case study, the outcomes of the Decision Analysis on the variant choice for the development of 'Delft Central' and the conclusions in part I, Chapter 10 contains the conclusions and recommendations on the application of Decision Analysis at projects of BNE group Plan Development. Figure 1-1 on the left page shows a flow chart of the report.

\(^{1}\)Terms in 'italic' are defined in Chapter 12 ‘Terminology’.
PART I

Application of Decision Analysis
at
Ballast Nedam Engineering
2 Situation at BNE group Plan Development

2.1 Introduction
Decision making strongly depends on the context of the decision problem. The decision problem’s context consists of the phase of the project, the boundary conditions on working methods, the objective(s) of the decision maker and the uncertain states of nature affecting a possible action of the decision maker. Therefore this chapter describes the situation at BNE group Plan Development in feasibility studies on property development projects. Paragraph 2.2 describes features of the phase of the design process in which strategic decisions form an important part of the decision making process. Paragraph 2.3 describes the present working method of BNE Plan Development during the feasibility study. In order to get insight in the additional value of Decision Analysis in a later phase of this investigation, more detailed features of the present decision making at property development projects in a feasibility phase are described in paragraph 2.4.

2.2 Phase of project: Feasibility study

2.2.1 General
After it is decided to do a feasibility study on a project the initiative phase is finished. A feasibility study can be performed by a team of the group Plan Development of Ballast Nedam Engineering (BNE). The outcome of this study must give the initiative-taking party insight in the possibilities for further development of the project. Figure 2-1 shows the phases of a the project process and the participation of BNE group Plan Development.

![Diagram of feasibility in the project process at BNE.]

Figure 2-1 Feasibility in the project process at BNE.

2.2.2 Organisation
The organisation in the feasibility phase is described in Figure 2-2 in which the organisation chart of Ballast Nedam N.V. is connected with the organisation of a feasibility study at BNE group Plan Development.

![Organisation chart of project during feasibility phase.]

Figure 2-2 Organisation chart of project during feasibility phase

The group Plan Development of BNE performs by order of Ballast Nedam subsidiaries, which work in early phases of property development projects. BNO (Ballast Nedam Property Development) or BNI
(Ballast Nedam International) generate projects which feasibility is uncertain. These subsidiaries act as a client for a project team of the group Plan Development. In many cases BNO performs by order of a municipality. The project group performs as analyst and consultant for the client in his decision making process.

2.2.3 Decision making

The decision making at projects of BNE group Plan Development is controlled by the client of the group's project team. The project team performs as analyst and consultant in the decision making. The client's decision making consists of a three level approach, which is influenced by the economical scale on which the client acts. The level approach can be described by:

- **Level 1**: strategic decision making, which is focussed on achieving policy targets;
- **Level 2**: tactical decision making, which focuses on decisions on the design in order to achieve targets at level 1 and level 2.
- **Level 3**: operational decision making, which focuses on short-term decisions which supports the targets at the higher levels.

The economical scale on which the client acts also influences the decision making. Three economical scales can be recognised;

1. micro-economical scale;
2. mezzo-economical scale;
3. macro-economical scale.

The level approach and the economical scale determine the objective and the time perspective of the decision problem. In appendix A1 is shown that stakeholders as municipalities and the State of the Netherlands perform at the different economical scales in the context of BNO property development projects at Ballast Nedam. The objectives of the stakeholders at higher economical scales influence the judgement of alternative (intermediate) designs for the project.

**Example:**

When BNO wants to develop a building for a municipality, BNO performs as a client for the group Plan Development. The boundary conditions of the choice between variants for this building are formed by the requirements of the municipality (decision maker at macro-economical scale). Besides BNO there is an other developing company in the market for this project. The decision tree, which will be used by the municipality in order to come to a choice between two companies for the development of the building is shown in Figure A on the next page. Based on the expected values of the attributes of a proposed variant and a set of weights on these attributes, the municipality will judge the proposals made by the two development companies. In this example the municipality bases its choice on the expected value of 'spin off of a variant' and the 'profit of a variant'. In order to judge the value of both attributes in the same way, the spin off of an alternative action has been put in a monetary value. The combined expected value of the variant that will be proposed, measured by 'spin off' and 'profit' is 450 for project developer A(BNO) and 525 for project developer B. The expected outcome depends on the decision of the project developer on which variant will be proposed. This is also shown in Figure A on the next page.

---

2 BNO and BNI focus on initiating and developing of integral area development in which Ballast Nedam disciplines, like infrastructure, house-building and utility construction, can be used.

3 Spin off: The (indirect) side effects of a variant, such as the income from real estate taxes. The value of spin off depends on the uncertain value of the occupation rate of the building.
Figure A Decision Tree of the municipality

a1: Municipality chooses developer A
a2: Municipality chooses developer B

6.1.1 project developer proposes variant 1, P(θ1) = 0.5
6.1.2 project developer proposes variant 2, P(θ2) = 0.5
6.1.3 project developer proposes variant 3, P(θ3) = 0.5
6.1.4 project developer proposes variant 4, P(θ4) = 0.5

Decision tree based on MAUT (set of two weights)

Municipality

a1

[522]

variant I

[600]

variant II

[600]

variant III

[600]

variant IV

[600]

Spam-off Profit [600]

Spam-off Profit [600]

Spam-off Profit [600]

Spam-off Profit [600]

Decision tree of developing company
BNO stays uncertain towards the outcome of the choice of the municipality. Therefore the project developer bases its decision on variants on a set of attributes that are assumed to be equal to the set of attributes that the municipality\(^4\) will use. Therefore it is assumed that the decision tree that will be used by the project developer forms a 'sub-tree' of the decision tree of the municipality. Based on the set attributes and his own set of weights on attributes, the developer chooses the variant that gives him the maximum value. Variant II gives a total value of 500. This is shown in Figure 2-3.

![Decision Tree of project developer A](image)

\(\theta_{2,1}:\) occupation rate of building is 'low'; \(P(\theta_{2,1}) = 0.5\)
\(\theta_{2,2}:\) occupation rate of building is 'high'; \(P(\theta_{2,2}) = 0.5\)

Figure 2-3 Decision Tree of project developer A

2.2.4 Judgement of alternative actions

In order to assess alternative actions on his objectives, the decision maker judges the alternative actions on attributes that meet these objectives.

In the example of the decision between two variants for a building, BNO (project developer A) performs as a client of the Plan Development group of BNE. The client has a combination of multiple objectives.

Because BNO depends on decision making at municipal level it tries to get insight in the set of attributes on which variants are assessed by the municipality. The set of attributes of variants that are used by BNO, must meet the municipal objectives as ‘Environmental value’ of variant, ‘economical value’ of variant and ‘costs of a variant’. Translating these objectives to a set of attributes creates the following table:

<table>
<thead>
<tr>
<th>Objective</th>
<th>Attributes of a variant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental value</td>
<td>City view</td>
</tr>
<tr>
<td>Economical value</td>
<td>Taxes income from real estate</td>
</tr>
<tr>
<td>Costs</td>
<td>subsidy</td>
</tr>
</tbody>
</table>

Table 2-1 Objectives and attributes of municipality

Resulting from the objectives and attributes of the municipality Table 2-2 shows the objectives and attributes that are used\(^5\) by BNO in the assessment of the variants.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Attributes of a variant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Satisfy requirements of municipality</td>
<td>City view</td>
</tr>
<tr>
<td>2 Rate of return on project</td>
<td>Net Present Value (NPV) of project</td>
</tr>
</tbody>
</table>

Table 2-2 Objectives and attributes of BNO

\(^4\) By assigning the weight ‘0’ to an attribute, the decision maker is always able to manipulate the number of attributes that is equal to a decision making party on another economical scale.

\(^5\) These objectives are extracted from an interview with BNO director Sicco de Vries
In order to measure the attributes, BNO searches for variables that can be used as a representation of the attribute. Financial attributes like ‘taxes income from real estate’, ‘subsidy’ and ‘NPV of the project’ can be measured by a monetary variable that meets the objectives; the object variable. An intangible attribute as ‘city view’ can also be measured by a variable, which is subjectively chosen the proxy variable. The values of object variables and proxy variables are calculated by an object function. The values of the object variables and proxy variables are put in an ‘additive mutli attribute utility model’ in which the variants are assessed by BNO. Because of the importance of municipal objectives for BNO, it is assumed that ‘political decision making’ influences the set of attributes that is used by BNO for the judgement of variants in the feasibility study.

2.2.5 Uncertainties
In the previous paragraphs it was described that:
A. the outcome of decision making forms an uncertainty in the decision making process of BNO. The outcome of decision making can be approached as a stochastic variable (par. 2.2.3).
Furthermore it was assumed that:
B. each stakeholder is a rational decision maker. He makes decisions based on the same attributes (but not necessarily with the same weights) and an ‘additive mutli attribute utility model’ (par. 2.2.4).
Therefore it is assumed that:
C. the set of weights on attributes that is used by stakeholders at another economical scale, forms an uncertainty in the decision problems of BNO.

2.3 Working method of project teams at BNE plan development

2.3.1 Introduction
Figure 2-4 shows a flow diagram of the variant design in the feasibility study. In Figure 2-4 two important decision points are sketched. The decision which variants will be developed for further analysis and the decision which variant will be optimised and developed to a proposal. Before the decisions are made the group Plan Development performs a process as described in the figure below.

![Flow diagram variant design](image-url)
The total process during feasibility study is divided in three phases, which are described in this paragraph.

2.3.2 Phase I: Pre-investigations
The first phase investigates the technical feasibility and market behaviour of a project. Furthermore external parties perform a mass investigation. These investigations are based on qualified input statements and produce quantified information. The high number of qualitative statements on boundary conditions are hard to quantify. The information that will be provided by the process in phase I consists of quantitative statements on geographical boundaries and function descriptions that fully describe the variant.

When BNO wants to develop a building that will function as an office and housing building, the investigations from phase I must give the following information for creating variants.

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Investigation</td>
<td>Estimation of construction costs</td>
</tr>
<tr>
<td></td>
<td>Material costs</td>
</tr>
<tr>
<td>Market Investigation</td>
<td>Square meter price of real estate</td>
</tr>
<tr>
<td></td>
<td>Expected occupation of real estate</td>
</tr>
<tr>
<td>Mass Investigation</td>
<td>Distribution of functions of real estate</td>
</tr>
<tr>
<td></td>
<td>- Number of square meters housing</td>
</tr>
<tr>
<td></td>
<td>- Number of square meters offices</td>
</tr>
<tr>
<td></td>
<td>- Etc.</td>
</tr>
</tbody>
</table>

*Table 2-3 Information from investigations in phase one*

Based on this information it will be decided what variants will be developed.

2.3.3 Phase II: Variant Development
Based on PKB’s, MER’s and the geographical boundaries and function description and in accordance with a determined objective, group Plan Development of BNE develops variants for the plans of the client. The plans are adjusted to the outcomes of market investigations and focused on a relative easy political decision making. The group Plan Development discusses the created variants in a project team meeting with all involved parties. Sufficiently detailed variants are assessed on required attributes. The functional attributes of a variant will be assessed. Furthermore good expectations on market development (economy), expected political support (environment), technical feasibility (techniques) and feasible construction methods (construction) are important attributes of the discussed variant. In this phase uncertainties are only identified in qualitative way. Figure 2-5 shows the focus on the design aspects that meet the attributes during the variant development process in the feasibility phase compared to the initiative phase.

<table>
<thead>
<tr>
<th></th>
<th>Functionality</th>
<th>Economy</th>
<th>Environment</th>
<th>Techniques</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Initiative</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2. Feasibility</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

*Figure 2-5 Focus on design aspects in design phases*

In this phase of a project a formal risk analysis\(^6\) is carried out only occasionally. The quantitative outcomes from the pre-investigations in phase I stay uncertain during the development of variants. After the decision on which variants will be developed the variants will be undertaken a financial investigation combined with a study on the political feasibility on the variant.

The process in the first two phases as described above can be schemed by Figure 2-6 on the next page.

\(^6\) Formal risk analysis: A risk analysis performed by BNE group Risk Management
Figure 2-6 Decisions during first phases of feasibility study

Two different kinds of decisions can be identified in Figure 2-6 that influence the process in the second phase. (I) The decision on which variants will be developed and (II) the decision on which variants will be optimised and processed to a proposal.

Based on the text above and the information on the first phase of the feasibility study, the important features of the decision problem in both phases are described in Figure 2-4.

<table>
<thead>
<tr>
<th>Decision Problem</th>
<th>Objective</th>
<th>Decision maker</th>
<th>Boundaries</th>
<th>Features on input</th>
</tr>
</thead>
</table>
| Variant decision| Develop variants that meet technical, functional and economical requirements. | Client | • Technical investigation  
• Market investigation  
• Mass investigation | Qualified values  
- many uncertain boundary variables  
- uncertain boundary variables in many different states |
| Variant Choice | Choice for a variant that is financially feasible and gets political support. | Client | • Financial analysis  
• Political lobby | Quantified values  
- amount of boundary variables decreases |

Table 2-4 Features on decision problems in the feasibility phase

For the use of decision supporting techniques, features of alternative actions and the state of nature variables have to be quantified (Appendix M). It can be concluded that a Decision Analysis supported by techniques as the influence diagram and the decision tree can not be performed in phase I because of a lack of quantified information. The techniques can be performed in phase II in which the context of the decision problem can be quantified. The next chapter describes the performance of Decision Analysis on a variant decision at a BNO project.

2.3.4 Phase III: Variant optimisation

Based on the financial analysis and a political lobby, a variant will be chosen that will be optimized. The optimisation of the chosen variant is supported by interviews with the involved stakeholders and financial experts. A risk analysis will be performed on the final variant concept.

The last phase of the study is the production of a proposal report. The proposal report is a description of the market development (1), the definitive variant (2) and a financing plan of the project (3).

Ad.1 Indirect and direct future perspectives;
Ad.2 Total plan, construction phasing and potentials;
Ad.3 Possible structure of co-operation in design and construction phase; magnitude of investments; probability of getting subsidies; economical impulse.

2.4 Features of decision making in feasibility studies

Based on an interview with the Head Engineer of BNE group Plan Development7 in Appendix A2, this paragraph describes the features of the decision making at projects that are performed by the group Plan Development by order of BNO. The description is based on three elements:

1. The quality of the definition of the objective that will be pursued;
2. The quality of the assessment of alternative actions;
3. The insight in the effects of alternative actions.

Ad.1
The objective and boundary conditions of the problem are clear for every member of the performing project group. Because of a lack of knowledge of the objectives for other stakeholders in the developing process, in this phase starting points for the future are not always clear. The interest of the other stakeholders are approached in a qualitative way. The project team does not clearly discuss the consequences of assumptions in the problem description.

Ad.2
The project team tries to create variants that satisfy the ambition of the client within an estimated budget. This means that the team focuses the assessment of variants on the functionality, the technical feasibility and the public interest of a variant.

Ad.3
The effects of alternative actions are described in a qualitative way. The best alternative is chosen on the basis of feeling, without analysing consequences. As described under 2., the variant that meets the ambition of the client within a reasonable (and realistic price) gets the preference of the project team. Risks are identified in a relatively late phase of the variant development. The project team does not focus on scenarios of the decision taken. This causes a lack of insight in possible consequences of alternative actions for all stakeholders of the project.

---

7 Mr. Wim Snelders is Head Engineer of the group plan development at BNE.
3 Use of decision supporting techniques

3.1 Introduction
When alternative actions of a decision problem will be assessed on multiple attributes, a single attribute utility analysis is not sufficient for decision making. A Multi Attribute Utility Technique (MAUT) is necessary for decision making. The approach of attributes can be supported by the use of an influence diagram and a decision tree. The influence diagram and the decision tree give insight into which uncertainties and values influence the value of the object variables that measure the attribute. The calculation of the value of the object variable is performed by an object function, which can be derived from the influence diagram. The MAUT combines the outcome of the decision tree of each object variable in a decision table. This is shown in Figure 3-1.

![Figure 3-1 Determine the value of the attribute](image)

From each decision tree a tornado diagram can be extracted. A tornado diagram provides insight in the sensitivity of the outcome of object variables to changes in 'state of nature' variables by ordering the state of nature variables by decreasing influence.

Based on an example of an investment problem of a property developer this chapter describes the performance of a Decision Analysis and the use of decision supporting techniques. The decision is based on the outcome of a MAUT in which the alternative actions of the investment problem are assessed. In Paragraph 3.1 the example will be introduced by description of the alternative actions in more detail. In Paragraph 3.2 the influence diagrams are created for the used object functions. Because the influence diagram is a representation of the object function that calculates the outcome of the object variable, the object function can be determined.

A deterministic calculation of the object variables only determines the outcome of the base case scenario. Because insight in only one scenario does not form a good basis for decision making, it is necessary to perform a probabilistic analysis on the decision problem. The probabilistic approach of state of nature variables results in a decision tree that gives insight in multiple scenario's for the outcome of the object variable; this is described in paragraph 3.4.

A sensitivity analysis on both the object variables and the outcome of the decision table may give more information on the decision problem. A tornado diagram can perform the sensitivity analysis on the object variables. When an investment problem is approached the values of financial object variables are influenced by the time- and risk perspective of the decision maker. This perspective is represented by the use of discounting parameters as the discount rate and time window in a Net Present Value calculation. The value of the discount rate consists of two parts. A 'fixed' part that represents the value of the interest rate and an additional 'variable' part that represents the developers' attitude towards risk on the specific project. By switching these parameters between a low and a high value, the decision maker is able to investigate the sensitivity of the outcome of the decision table. This is described in paragraph 3.6.

---

8 The base case scenario calculates the value of the object variable with all state of nature variables on their mean value.
Based on the outcome of the decision table of the MAUT, the choice between the variants will be made. Insight in sensitivity of the value of the object variables and the outcome of the decision table may give the decision maker the opportunity to formulate risk management activities for the rest of the process. The decision is described in paragraph 3.7. The risk management activities are described in paragraph 3.8.

Figure 3-2 shows a flow diagram of the Decision Analysis that is performed in this Chapter.

**Figure 3-2 Flow diagram of Decision Analysis at BNE**

The example must give insight in what phase of the decision process in the feasibility study decision supporting tools can be used. Specific features of the tools will be analysed, based on the example.
3.2 Introduction to the example

A developer performs a feasibility study on a real estate project. The choice between variants is based, besides on the objectives of stakeholders at higher economical level (1), on the ‘Net Present Value (NPV) of a variant’ (2) and the ‘spin off of a variant for the own company’ (3). For the analysis of the performance of the techniques, in this example only the second and the third objective will be analysed. The NPV can be determined by calculating the Present Value of the difference between revenues and costs over a certain time window. The spin off for the company consists of the improved image for the developers’ company that can be provided by the development of a project. A better image of the company can create more turnover in future.

In order to assess the variants on these objectives, the attributes of a variant that meet the objectives are judged in a MAUT. The object variables that are used as a representation of these objectives are:
1. NPV of the project over a time window of 20 years;
2. NPV of the extra turnover in the next 10 years.

The variable ‘PV of the difference between revenues and costs’ is commonly used as a representation of the NPV.

There are many ways to model intangible values like the image of the company. For the measurement of an intangible value the decision maker could search for a subjective scale or a proxy variable. In this example the ‘extra turnover’ is not necessarily the best variable to measure the image of the company, but is a subjectively chosen proxy variable that is able to measure this value[Keeney&Raiffa].

The decision between the two variants will be based on the outcome of a MAUT. The variant with the maximum score will be chosen.

In order to get insight in the values that influence the outcome of the object variables the developer analyses the features of both variants.

- Variant I will be constructed with normal quality materials; the construction costs of this variant will be on the normal level of f 970,-/m² over a construction period of one year. The NPV depends on the occupation rate of the 2000 m² real estate. The real estate will be let for f 400,-/m² per year.
- Variant II will be constructed with high quality materials. The construction costs will be f 1400,-/m² over a construction period of one year. The area of real estate to be let is the same as Variant I. The NPV also fully depends on the occupation rate of the 2000 m² real estate. Rent level is f 400,-/m² per year.

The use of high quality materials could make the company a well-known developer of this kind of projects. It could provide an increasing turnover. The increasing volume of buildings determines the extra turnover. This volume depends on the development of the demand for BNO projects. The construction of the building starts at 1st January 2000 and has a duration of one year.

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision Variable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost price</td>
<td>(f,-/m²) / year</td>
<td>970</td>
<td>1400</td>
</tr>
<tr>
<td><strong>Fixed values</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old cost price</td>
<td>(f,-/m²) / year</td>
<td>970</td>
<td>970</td>
</tr>
<tr>
<td>Rent price</td>
<td>(f,-/m²) / year</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>m² real estate</td>
<td>m²</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td><strong>State of nature variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupation rate</td>
<td>%</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Time development of demand for projects</td>
<td>%</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 3-1 Resume of variant features

When both state of nature variables, ‘occupation rate of real estate’ and ‘development of demand for BNO projects’ can be described by one possible state, the decision problem can be described by a decision tree for both object variables.
A MAUT combines the outcome of both decision trees. Based on a set of weights for the attributes, the project developer chooses the variant that has the maximum utility score.

### 3.3 Modeling of object variables: Influence diagram

#### 3.3.1 Introduction

The use of an influence diagram supports the determination of the variables and values that influence the value of the object variable. These variables and fixed values are put in an object function, which determines the value of the object variable (see Figure 3-3). The variables can be split up in decision variables representing the decision alternatives and state of nature variables representing external uncertainties that influence the value of the object variable and fixed values.
3.3.2 Modeling financial rate of return.

![Influence diagram of NPV]

**Figure 3-4 Influence diagram of NPV**

The objective function is represented by the diagram as:

\[
NPV = PV(Revenues - Costs) = PV((\text{occupation rate } \times m^2 \text{ price } \times m^2 \text{ real estate}) - (m^2 \text{ real estate } \times \text{ cost price per } m^2))
\]

\[
NPV = \sum_{t=0}^{\infty} \left( \text{occ. rate } \times \text{rent. price } \times m^2 \text{real estate}\left(\frac{1}{(1+r)^{t-t_0}}\right) - (m^2 \text{real estate } \times \text{Cost. price} )\left(\frac{1}{(1+r)^{t-t_0}}\right) \right)
\]

**Equation 3-1 Net present Value of profit calculation**

With:
- **Fixed Values:**
  Rent price; \(m^2\) real estate; discount rate \((r)\); time window \((t_{t_1}, t_0)\).
- **Variables:**
  Decision variables: cost price (depends on decision);
  State of nature variable: Occupation rate;

- **Definition of time points:**
  - \(t_0\) = present time point = 1st January 2000
  - \(t_1\) = end of construction period (one year from now) = 1st January 2001
  - \(t_{t_1}\) = end of time window (nineteen years after the finish of the construction) = 1st January 2020

![Cash flow diagram]

**Figure 3-5 Cash flow diagram**
Deterministic calculation of PV of profit:
A first deterministic calculation of the object variable with a value for the occupation rate of 0.9 gives insight in the outcome of the PV of Profit for both variants:

**Variant I** (*cost price = f (970, -/m²)/year*)
(a) Occupation rate of real estate in the area is equal to 0.9
Rent price = f (400, -/m²)/year
m² real estate = 2000 m²
discount rate = 8%

In accordance with Equation 3-1 we have:

\[
\sum_{t=1}^{T=20} (0.9 \times 400 \times 2000) \left( \frac{1}{(1 + 0.08)^t} \right) - (2000 \times 970) \left( \frac{1}{(1 + 0.08)^t} \right)
\]

\[\omega_1 = \text{PV of profit}_{\text{variant I}} = f \ 4.606.103,-\]

**Variant II** (*cost price = f (1400, -/m²)/year*)
(b) Occupation rate of real estate in the area is equal to 0.9
Rent price = f (400, -/m²)/year
m² real estate = 2000 m²
Discount rate = 8%

\[
\sum_{t=1}^{T=20} (0.9 \times 400 \times 2000) \left( \frac{1}{(1 + 0.08)^t} \right) - (2000 \times 1400) \left( \frac{1}{(1 + 0.08)^t} \right)
\]

\[\omega_2 = \text{PV of profit}_{\text{variant II}} = f \ 3.809.807,-\]

Based on the model in Figure 3-6 it can be concluded that the value of the PV of profit of Variant I is higher than the value of the PV of profit for Variant II.

### 3.3.3 Modeling image of company

![Influence diagram on NPV of extra turn over](image)

*Figure 3-6 Influence diagram on NPV of extra turn over*
• **Object function**
  The object function\(^9\) for this object variable is derived from the diagram:

\[
\sum_{t_0}^{t_{t_2}} ((\text{time development} \times m^2\text{real estate})(\text{Cost price} - \text{old Cost price}))\frac{1}{(1 + r)^{t-t_0}}
\]

**Equation 3-2 NPV of extra turnover**

In which:

- **Fixed values:**
  Old cost price; \(m^2\) real estate; discount rate \((r)\); time window

- **Variables:**
  Decision variables: cost price (depends on decision);
  State of nature variables: time development of demand;

- **Definition of time points:**
  - \(t_0\) = present time point = 1st January 2000
  - \(t_1\) = end of construction period (one years from now) = 1st January 2001
  - \(t_{t_2}\) = end of time window for the NPV calculation (nine years after the finish of the project) = 1st January 2010

**Figure 3-7 Cash flow diagram:**

**Deterministic calculation of NPV of extra turn over:**
A first deterministic calculation of the object variable with a value for the time development of demand for BNO projects of 0.02 gives insight in the difference of both variants:

**Variant 1 (cost price = \(f \ (970,)-/m^3\)/year**

(c) Time development of demand for is equal to 0.02

- \(m^2\) Real Estate = 2000 \(m^2\)
- Old cost price = \(f \ (970,)-/m^3\)/year
- Discount rate = 8%

---

\(^9\) The extra turnover can only be used as a proxy variable for the measurement of 'image' when it is not related to other variables that measure the variant attributes. In this example the extra turnover is related to the value of the other object variable (NPV of profit) by the cost price.
In accordance with Equation 3-2:

\[
\sum_{t=1}^{10} \left(1 + 0.02\right)^t \times (2000) \times (970 - 970) \frac{1}{(1 + 0.08)^{t-1}}
\]

\[\omega_1 = \text{NPV of extra turnover}_{\text{variant I}} = f\ 0,-\]

**Variant II (cost price = f (1400,-/m²)/year**

(d) Time development of demand for is equal to 0.02

\[\text{m² Real Estate} = 2000 \text{ m²}\]

Old cost price = \(f (970,-/\text{m²})/\text{year}\)

Discount rate = 8%

In accordance with Equation 3-2 gives:

\[
\sum_{t=1}^{10} \left(1 + 0.02\right)^t \times (2000) \times (1400 - 970) \frac{1}{(1 + 0.08)^{t-1}}
\]

\[\omega_2 = \text{NPV of extra turnover}_{\text{variant II}} = f\ 5.073.860,-\]

The choice for Variant I will not affect the cost price in future. Therefore the NPV of extra turnover has a value of 0.

### 3.4 MAUT analysis

Because of the multiple attributes a MAUT analysis will be performed in order to make a decision on variants. The MAUT combines the outcome of both decision trees in a decision table.

The developer judges variants based on the importance of both attributes. The developer is able to define a measure for judgement of attributes by assigning relative weight to the attributes. The ‘swing weighing technique’ has been shown to be a good tool to create a good representation of the decision situation. The procedure of this technique is explained in Appendix M (p.34/ p.35).

Step 1: In this case the financial rate of return of the project is more important for the developer than the possible increasing image of the developing company; then

\[\lambda_{\text{NPV of Profit}} > \lambda_{\text{extra turnover}}; \lambda_1 > \lambda_2\]

Step 2: When the developer is indifferent for the NPV of Profit and the NPV of extra turnover when

\[4.606.103 \times \lambda_1 = (3.809.807 + 2.500.000) \times \lambda_2\]

Step 3: \(\lambda_{\text{NPV of Profit}} = 1.37 \lambda_{\text{extra turnover}}\)

Step 4: \(\lambda_{\text{NPV of Profit}} + \lambda_{\text{extra turnover}} = 1\)

results in:

\[\lambda_{\text{NPV of Profit}} = 0.58\]

\[\lambda_{\text{extra turnover}} = 0.42\]

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Weighting factor (\lambda_i)</th>
<th>Variant I Score</th>
<th>Variant II Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 NPV</td>
<td>0.58</td>
<td>4606103</td>
<td>3809807</td>
</tr>
<tr>
<td>2 Extra Turn over</td>
<td>0.42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2671540</td>
<td>2671540</td>
</tr>
</tbody>
</table>

*Weighted score* = 2671540

**Table 3-2 Weighted decision table; deterministic approach**
The renewed decision table shows that variant II has the highest score. The absolute difference between two deterministic outcomes does not give the decision maker much information; it is the outcome of only one scenario. A decision based on one scenario will not be made.

An analysis of multiple scenario’s can form a more reliable base for decision making. In this analysis scenario’s will be approached probabilistically. A probabilistic approach on the object functions variables could provide more insight in the decision problem.

3.5 Probabilistic approach of state of nature variables

Because only one scenario is calculated, the deterministic MAUT did not give a satisfactory result for the project development company. The decision table does not give information on the probability of outcome. Insight in the effect of the uncertainty of the outcome of the occupation rate is necessary.

A decision tree uses discrete values for the states of nature. When the project developer wants to use a decision tree as a representation of his decision problem, discretization of the continuous probability distribution of the state of nature variable is necessary. The discrete values were mentioned in paragraph 3.2. Discretization of the continuous distribution can be obtained by transforming the probability distributions of the possible states to a distribution that consists of three values. The procedure is described in Appendix M (p.22). The result of discretization is shown in Figure 3-8.

3.5.1 Occupation rate

![Discretization of triangular probability density function of occupation rate](image)

In this example the expert estimates a 10\(^{th}\) percentile value, a 50\(^{th}\) percentile value and a 90\(^{th}\) percentile value for the occupation rate of real estate.

The results of the interview are:

- 10\(^{th}\) percentile of the occupation rate = 0.80, \(\theta_{1,1} = 0.80\), \(P(\theta_{1,1}) = 0.25\)
- 50\(^{th}\) percentile of the occupation rate = 0.90, \(\theta_{1,2} = 0.90\), \(P(\theta_{1,2}) = 0.50\)
- 90\(^{th}\) percentile of the occupation rate = 0.95, \(\theta_{1,3} = 0.95\), \(P(\theta_{1,3}) = 0.25\)

The decision tree that shows the possible actions \(a_1\) (choose Variant I) and \(a_2\) (choose Variant II), the possible states of nature \(\theta_{1,1}, \theta_{1,2}, \theta_{1,3}\) and the collection of outcomes \(\Omega\), describes the decision situation.
Figure 3-9 Decision tree for the NPV

Putting the discrete values of the occupation rate in Equation 3-1 gives a collection of outcomes for the NPV for both alternative action variant I or variant II.

When Equation 3-1 is called \( f(\theta_{1,i}, \text{Cost price}_i) \), and the decision variables of variant \( j \) are determined as:

\[
\begin{align*}
\omega_{1,1} &= f(\theta_{1,i}, \text{Cost price}_i) \\
\omega_{1,2} &= f(\theta_{1,i}, \text{Cost price}_i) \\
\omega_{1,3} &= f(\theta_{1,i}, \text{Cost price}_i)
\end{align*}
\]

\[
\begin{align*}
\omega_{1,4} &= f(\theta_{1,i}, \text{Cost price}_{II}) \\
\omega_{1,5} &= f(\theta_{1,i}, \text{Cost price}_{II}) \\
\omega_{1,6} &= f(\theta_{1,i}, \text{Cost price}_{II})
\end{align*}
\]

Expected value calculation:

\[
E(\text{var}_I) = P(\theta_{1,i}) \times \omega_{1,1} + P(\theta_{2,i}) \times \omega_{1,2} + P(\theta_{3,i}) \times \omega_{1,3}
\]

\[
E(\text{var}_{II}) = P(\theta_{1,i}) \times \omega_{1,4} + P(\theta_{2,i}) \times \omega_{1,5} + P(\theta_{3,i}) \times \omega_{1,6}
\]

the collection \( \Omega \) of possible outcomes for the Net present Value is:

Figure 3-10 Decision tree of NPV; discount rate = 8%
The calculated scenarios are described below:

<table>
<thead>
<tr>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_{1,1}$</td>
<td>$p_{2,1}$</td>
</tr>
<tr>
<td>£3,894.730</td>
<td>£3,098.430</td>
</tr>
<tr>
<td>$p_{1,2}$</td>
<td>$p_{2,2}$</td>
</tr>
<tr>
<td>£4,606.100</td>
<td>£3,809.810</td>
</tr>
<tr>
<td>$p_{1,3}$</td>
<td>$p_{2,3}$</td>
</tr>
<tr>
<td>£4,961.790</td>
<td>£4,165.500</td>
</tr>
</tbody>
</table>

Range of outcomes Variant I:
4.961.790-3.894.730 = 1.067.060
Range of outcomes Variant II:
4.165.500-3.098.430 = 1.067.060

Table 3-3 Possible outcomes of the NPV

3.5.2 Time development of demand for BNO projects

Figure 3-11 Discretization of triangular probability density function of time development

In this example the expert estimates a 10th percentile value, a 50th percentile value and a 90th percentile value for the occupation rate of real estate. The results of the interview on the extra turn over are:
10th percentile = -0.02 \hspace{1cm} \theta_{2,1} = -0.02 \hspace{1cm} P(\theta_{2,1}) = 0.25
50th percentile = 0.02 \hspace{1cm} \theta_{2,2} = 0.02 \hspace{1cm} P(\theta_{2,2}) = 0.50
90th percentile = 0.04 \hspace{1cm} \theta_{2,3} = 0.04 \hspace{1cm} P(\theta_{2,3}) = 0.25

The decision tree that shows the possible actions $a_1$ (choose Variant I) and $a_2$ (choose Variant II), the possible states of nature $\theta_{1,1}$, $\theta_{1,2}$, $\theta_{1,3}$ and the collection of outcomes $\Omega$, describes the decision situation.

Figure 3-12 Decision tree of extra turnover

Putting the discrete values of the occupation rate in Equation 3-2 gives a collection of outcomes for the NPV for both alternative actions variant I or variant II.
When Equation 3-2 is called $g(\theta, \text{Cost price})$, and the decision variables of variant j are determined as:
The collection $\Omega$ of possible outcomes for the net present value of extra turnoer over is:

\[ \begin{align*}
\omega_{1,1} &= g(\theta_{1,1}, \text{Cost price}_1) \\
\omega_{1,2} &= g(\theta_{1,2}, \text{Cost price}_1) \\
\omega_{1,3} &= g(\theta_{1,3}, \text{Cost price}_1) \\
\omega_{1,4} &= g(\theta_{1,1}, \text{Cost price}_{II}) \\
\omega_{1,5} &= g(\theta_{1,2}, \text{Cost price}_{II}) \\
\omega_{1,6} &= g(\theta_{1,3}, \text{Cost price}_{II})
\end{align*} \]
\[ E(\text{var}_1) = P(\theta_{1,1}) \times \omega_{2,1} + P(\theta_{1,2}) \times \omega_{2,2} + P(\theta_{1,3}) \times \omega_{2,3} \]
\[ E(\text{var}_2) = P(\theta_{2,1}) \times \omega_{2,4} + P(\theta_{2,2}) \times \omega_{2,5} + P(\theta_{2,3}) \times \omega_{2,6} \]

\[ E(\text{var}_3) = f\ 0,- \]
\[ E(\text{var}_4) = f\ 5.048,990,- \]

**Figure 3-13 Decision tree of NPV of extra turn over; discount rate = 8%**

The calculated scenarios are described below:

<table>
<thead>
<tr>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \omega_{2,1} )</td>
<td>( \omega_{2,1} )</td>
</tr>
<tr>
<td>f 0,-</td>
<td>f 4.474,890,-</td>
</tr>
<tr>
<td>( \omega_{2,2} )</td>
<td>( \omega_{2,2} )</td>
</tr>
<tr>
<td>f 0,-</td>
<td>f 5.073,860,-</td>
</tr>
<tr>
<td>( \omega_{2,1} )</td>
<td>( \omega_{2,1} )</td>
</tr>
<tr>
<td>f 0,-</td>
<td>f 5.173,350,-</td>
</tr>
</tbody>
</table>

Range of outcomes Variant I: 0
Range of outcomes Variant II: 5.173,350 - 4.874,890 = 298,460

**Table 3-4 Possible outcomes of Extra turnover**

### 3.5.3 Summary of information from decision trees

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Value</td>
<td>Base case Value</td>
<td>Range of outcomes</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>f 4.571,180,-</td>
<td>f 4.606,100,-</td>
</tr>
<tr>
<td><strong>Extra turnover</strong></td>
<td>f 0,-</td>
<td>f 0,-</td>
</tr>
</tbody>
</table>

**Table 3-5 Information from decision tree**

### 3.5.4 MAUT analysis

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute</th>
<th>Weighting factor ( \lambda_i )</th>
<th>( E(\text{Variant I}) )</th>
<th>Score</th>
<th>( E(\text{Variant II}) )</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV</td>
<td>0.58</td>
<td>4517180</td>
<td>2619964</td>
<td>3720880</td>
<td>2158110</td>
</tr>
<tr>
<td>2</td>
<td>Extra Turnover</td>
<td>0.42</td>
<td>0</td>
<td>0</td>
<td>5048990</td>
<td>2120576</td>
</tr>
</tbody>
</table>

**Table 3-6 Decision Table; probabilistic approach**

Based on the outcome of Table 3-6 the developer decides to take variant II to the next phase of the feasibility study in which the design of the variant will be optimised. The optimisation of the variant will be based on a sensitivity analysis of the value of the object variables.
3.6 Sensitivity analysis

3.6.1 Introduction
A sensitivity analysis investigates how changes on input in the model affect the output. A model can be called 'sensitive' for two reasons:
1. Change in input has a large effect on the measure of value (value sensitivity)
2. Change in input causes the optimal decision alternative to change (decision sensitivity)
Because the information from the MAUT analysis does not give enough information on the difference between variants the decision maker can perform sensitivity analysis on the outcome of the MAUT or sensitivity analysis on the outcome of individual attributes. A tornado diagram can be used to display the results of the sensitivity analysis.
The tornado diagram shows the influence of the range and value of the state of nature variable on the value of the attribute. The bars represent the range for the object variable when the specific 'state of nature' is varied from one end of its range (10th percentile value) to the other (90th percentile value), keeping all the other variables at their base value (50th percentile value).

3.6.2 Sensitivity of the Net present Value
The tornado diagram in Figure 3-14 gives the developer insight into the dominance of input variables. This insight could be a base for risk management activities.

Figure 3-14 Tornado diagrams for both attributes
From the tornado diagram of the NPV can be concluded that the range of outcomes is fully determined by the value of the state nature variable 'occupation rate'. The range of the outcomes of the NPV of extra turnover is fully determined by the value of the 'development of demand for BNO projects'.

3.6.3 Sensitivity of the outcome of the decision table

The value of the attribute also depends on the fixed values discount rate and time window. The developer is able to analyse the sensitivity of the outcome of the decision table by changing these values. A new decision tree can be constructed.

![Decision Tree Diagram]

_Figure 3-15 New decision tree for the NPV; discount rate = 15%_

When the discount rate swings between a value of 8% and 15%, the decision tree for the PV of profit transform to a tree as shown above. Figure 3-16 shows the direct influence of the change of the discount parameter to the range and base case value of the PV of profit by a tornado diagram of the 'old' and 'new' decision tree.

![Tornado Diagram]

_Figure 3-16 Base Case tornado diagram for NPV; influence of the discount rate_

The tree and the tornado shows that the base case outcome of the NPV of profit for both variants with a discount rate of 15% decreases. A summary of the outcome of the new decision tree is given in Table 3-7 on the next page.
### 3.6.4 Summary of information provided by the decision trees.

<table>
<thead>
<tr>
<th></th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV</strong></td>
<td>Base Case Value: $f,4,606.100$,-</td>
<td>Base Case Value: $f,3,809.810$,-</td>
</tr>
<tr>
<td><strong>Discount rate = 8%</strong></td>
<td>Range of outcomes: $f,1,067.060$,-</td>
<td>Range of outcomes: $f,1,068.120$,-</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>Base Case Value: $f,2,193.700$,-</td>
<td>Base Case Value: $f,1,445.850$,-</td>
</tr>
<tr>
<td><strong>Discount rate = 15%</strong></td>
<td>Range of outcomes: $f,646.780$,-</td>
<td>Range of outcomes: $f,646.770$,-</td>
</tr>
</tbody>
</table>

*Table 3-7 Influence change discount rate on outcome of decision tree*

The influence of the increased discount rate on the outcome of the decision table is:

<table>
<thead>
<tr>
<th>$i$</th>
<th>Attribute $x$</th>
<th>Weighting factor $\lambda_i$</th>
<th>$E$(Variant I)</th>
<th>Score</th>
<th>$E$(Variant II)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV</td>
<td>0.58</td>
<td>2139780</td>
<td>1241072</td>
<td>1391950</td>
<td>807331</td>
</tr>
<tr>
<td>2</td>
<td>Extra turnover</td>
<td>0.42</td>
<td>0</td>
<td>0</td>
<td>5048990</td>
<td>2120576</td>
</tr>
</tbody>
</table>

*Table 3-8 Decision Table; probabilistic approach; discount rate = 15%*

The discount rate does not affect the NPV value of variant II values so that the weighted score of the decision table will turn to variant I.

The decision tree in Figure 3-15 shows the value of the NPV on ‘worst case’ scenario (discount rate is ‘low’ and profit has been discounted with 15% per year):

NPV$_I$: $f\,1,762.490$,-
NPV$_{II}$: $f\,1,014.670$,-

In the same way this result in the following decision table:

<table>
<thead>
<tr>
<th>$i$</th>
<th>Attribute $x$</th>
<th>Weighting factor $\lambda_i$</th>
<th>$E$(Variant I)</th>
<th>Score</th>
<th>$E$(Variant II)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV</td>
<td>0.58</td>
<td>1762490</td>
<td>1022244</td>
<td>1014670</td>
<td>588507</td>
</tr>
<tr>
<td>2</td>
<td>Extra turnover</td>
<td>0.42</td>
<td>0</td>
<td>0</td>
<td>5048990</td>
<td>2120576</td>
</tr>
</tbody>
</table>

*Table 3-9 “Worst case” scenario: the optimum decision does not change*

In the worst case the weighted score of the decision table does not switch to variant I.

### 3.7 Variant choice

#### 3.7.1 General

Because the Decision Analysis is only a model to support the decision making process, the developer only can be recommended to choose for variant II. The decision maker at the developing company is still the person that decides. Tools like the decision tree and the influence diagram did not solve the decision problem of the developer. They only created insight in possible consequences of a decision.

#### 3.7.2 Optimum decision

When the developer bases his decision on the outcome of the decision table, variant II is the optimum decision. Because the time points and income streams of both variants does not differ a lot from each other, a change in discount rate or time window did not change the optimum decision from the decision table.

The probabilistic approach of the MAUT showed that there is not a big difference between the outcome of both variants. Therefore it was tried to get more insight in the outcome when the decision tree was changed by switching the fixed value ‘discount rate’ between its low value and a higher value. The discount rate showed its influence on value of the NPV but did not change the policy for the choice between variants. Therefore variant II stays the ‘best’ variant.
3.8 Risk management

The performance of a Decision Analysis process provides an insight in the sensitivity of the outcome of the decision table. The decision maker is able to extract the range of possible consequences of an alternative action. Based on this insight the decision maker can be recommended to take risk controlling measures. The consequences of risk controlling measures can be determined.

In order to reduce the financial risk of disappointing values of the occupation rate, the developer could choose to hand over a part of the financing risk to insureing companies. When the developer wants to insure all possible states of the occupation lower than 0.9 it reduces the financial risk on the outcome of the NPV.

Example of risk reducing measure:
The consequence of this risk reducing measure can be calculated based on the decision tree of the NPV with a discount rate of 8%. The possible outcomes with a value smaller 3,809,810 x 10^6 (base case value of NPV of variant II) will be insured; this affects also the range of outcomes.

New range of outcomes:
\[ f \text{ 4,165,500,-} \rightarrow f \text{ 3,809,810,-} = f \text{ 355,690,-} \]

A renewed calculation of the expected value of the NPV:
(1) \( E(\text{NPV}_\text{old}) = f \text{ 3,720,880,-} \)

New formula:
\[ E(\text{var}_\text{II}) = (P(\theta_1) + P(\theta_2)) \times \omega_{1,5} + P(\theta_3) \times \omega_{1,6} \]

the base value of 3.8 x 10^6 has a probability of 0.75. The expected value of the NPV will increase by:
(2) \( E(\text{NPV}_\text{new}) = (0.75 \times 3.8\times10^6) + (0.25\times4.1655\times10^6) = f \text{ 3,891,375,-} \)

The expected value increases with: (2) - (1) = 3.891375x10^6 - 3.72088x10^6 = f \text{ 170,495,-} \)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Value</th>
<th>Range of outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV (no risk management)</strong></td>
<td>f 3.720.880,-</td>
<td>f 1.068.120,-</td>
</tr>
<tr>
<td><strong>NPV (risk management)</strong></td>
<td>f 3.891.375,-</td>
<td>f 355.690,-</td>
</tr>
<tr>
<td><strong>difference</strong></td>
<td>f 170.495,-</td>
<td>f 712.430,-</td>
</tr>
</tbody>
</table>

Table 3-10 Summary of risk reducing measure

The Risk Control measure will only give benefit when the costs of insurance (NPV of insurance costs for the next 20 years) does not exceed f 170.995,-. The range of outcomes has been decreased by f 712.430,-.
4 Conclusions on application of Decision Analysis

Two major decisions can be recognised in the feasibility study on projects of the group plan development;
1. Decision on variant development;
2. Choice for definitive variant.

Based on the text in Chapter 2 and Chapter 3, the following can be concluded on this these decisions.

- **Multiple objectives and interests at other economical levels influence decision making in feasibility studies.**
  BNO makes both decisions. Multiple objectives of BNO and the requirements of stakeholders at a higher economical level influence these decisions. The set of weights used by other stakeholders forms an uncertain state of nature for the decision making of BNO.

- **It is not possible to apply decision-supporting techniques in phase I of the feasibility study**
  The input of the investigations consists of a high number of uncertainties that have not been quantified. The high number of possible states of the input variables makes it hard to create discrete values for the use of decision supporting tools.

- **The use of decision supporting techniques seems to be possible in phase II of the feasibility study**
  The second phase uses information that has been provided by the investigation in the first phase. The features on the developed variants have been quantified and the number of state of nature variables has been decreased. When the decision maker is able to quantify these variables; the use of decision supporting techniques at a BNO project is possible.

- **Working methods focus on a qualitative structured risk analysis**
  The present working method at the group Plan Development is based on a qualitative approach on the interest of other actors. Project teams at Plan Development do not perform scenarios approached analysis of possible actions, therefore a clear insight in the consequences of assumptions and actions is missing. Risk identification is only performed in a qualitative way. The formal Risk Analysis and proposals on Risk Management takes place in the variant optimising process, after the choice for the definitive variant.

- **For the use of the decision supporting techniques at group Plan Development can be stated that:**

  **Influence diagram**
  - The influence diagram has its advantage in the approach of a decision problem, because of its high abstract level. The influence diagram does not necessarily need quantified input. Therefore it is a tool that gives insight in both the variant development decision and the variant choice.
  - The influence diagram can form a basis for risk management activities, because the diagram shows which values are influenced by dominant variables.

  **Decision tree**
  - The decision tree provide insight in sequential processes that influence the optimum policy on a single attribute.
  - The tornado diagram is a technique that provides a more detailed insight in the outcome of the decision tree. The diagram displays the results of a sensitivity analysis. Knowing the sensitivity of the outcome of an object variable, risk management activities can be determined.

When multiple object functions play a role single attribute utility analysis is not sufficient for defining an optimum policy. In order to come to a rational decision a Multi Attribute Utility technique can be performed.
Multi Attribute Utility Technique

- The swing weighing could be a good technique to weigh the interests of the decision maker on the decision on the definitive variant.
- Financial attributes on which variants will be tested can be quantified. Uncertainties on the financial values can be quantified based on expert opinion. Quantification of public and economical values of a variant can give problems in finding a suitable proxy variable, which is not related to other variables that measure the used attributes.
- The difference between two outcomes may be smaller than the model is capable of distinguishing. A sensitivity analysis on the outcome of the decision table could give more insight.

A study on a project case at BNE group Plan Development in which the decision for the definitive variant must be made, can give insight in the additional value of the use and the restriction on use of the decision supporting techniques for project development projects.
PART II

Case Study:

Development of Delft Central;
an "underground"
decision problem
5 Decision Problem

5.1 Introduction
The Delft municipality is looking for possibilities to remove the vision and noise hindrance of the present rail fly-over. Therefore Delft invited the Spanish architect Prof. Joan Busquets to give his view on the municipal development of Delft. In this context Busquets proposed tunneling of the city as an alternative in order to take away the hindrance. The ‘Delft Central’ area forms a part of Busquet’s tunneling plans where real estate must increase the attraction of the transport area near the station. In the second phase of the feasibility study of the development of plan area ‘Delft Central’, the group Plan Development of BNE, in co-operation with BNO and the municipality of Delft, analyses two variants for the development of the area. The history on this development of real estate and infrastructure in the area ‘Delft Central’ is described in paragraph 5.2. Paragraph 5.3 consists of a more detailed description of the variants for the project. Background information on the co-operation between Ballast Nedam and the municipality of Delft that influence the scope and objective of the decision problem is described in paragraph 5.4. The frame of the decision problem is described by the scope of the problem and the objectives of the decision maker in paragraph 5.5. In order to come to a choice between the variants a Decision Analysis will be performed. Paragraph 5.6 describes the performance of the Decision Analysis and the objective of the decision problem in this case study.

5.2 History
In order to come closer to the realisation of the tunnel Ballast Nedam Development (BNO) and the Delft municipality agreed in June 1998 to do a study on the feasibility of integral development of a ‘four track railway tunnel’ and real estate in the former ‘Politie Technische Diensten (PTD)’ area. When it is possible to do integral development the Delft municipality does not have to wait with the development of scarce territory until the finish of the tunnel.
On February 23rd 1999 the Dutch government decided that the amount of money that was to be spent on the construction of the A4 between Delft and Schiedam, will be spent on the construction of a railway tunnel in Delft. The governments contribution to this project has been set on f 360,000,000,- and can be used after 2004.
BNO and the Delft municipality aim at a phased construction of parts of the tunnel and real estate in the PTD area. This gives the advantage that it will not be necessary to construct a tunnel under real estate in later stages. An integral approach will also provide an advantage in costs.

![Figure 5-1 Overview on PTD Area](image)

In order to achieve this objective Ballast Nedam Engineering group Plan Development investigates the possibilities to develop the real estate and infrastructure in one construction pit in the area ‘Delft Centraal’, instead of separated development of real estate and infrastructure. Therefore it creates a variant for both the separate and the integral development. Integral development foresees in one construction period. The separate development consists of two phases in which first the real estate in the PTD area will be developed. Then the tunnel and the real estate in the station area will be
constructed. Besides the construction method, the two variants also differ in the amount of square meter real estate in the final design. Figure 5-2 and Figure 5-3 show the difference in construction method. The difference in result is described in the next paragraph.

**Figure 5-2 Variant I:** separated development of real estate and infrastructure

**Figure 5-3 Variant II:** integral development of real estate and infrastructure

**Figure 5-4 Section of design for ‘Politie Technische Diensten’ area**
5.3 Description of variants

The description of the variants is based on the 'design aspects'; (a) functionality, (b) economics (c) environment, (d) techniques and construction. The description is supported by the figures on the left page.

5.3.1 Variant I: separate development

Variant I focuses on separate development of real estate and infrastructure.

(a) Functionality

As shown in Figure 5-4 this variant is determined by a mix of functions; working, living and culture. Variant I does not ensure the development of the underground travelling function. The increase of the quality of living in the plan is therefore relatively low, because it is not certain that the hindrance of the rail fly-over will be taken away.

Features on the proposed functions are described below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Unit</th>
<th>Variant I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square meters housing</td>
<td>m²</td>
<td>30000</td>
</tr>
<tr>
<td>Number houses</td>
<td>#</td>
<td>1400</td>
</tr>
<tr>
<td>Value houses</td>
<td>f 1000,-</td>
<td>400</td>
</tr>
<tr>
<td>Price/m² RE</td>
<td>f 1000,-</td>
<td>3.3</td>
</tr>
<tr>
<td>Square meters offices</td>
<td>m²</td>
<td>37000</td>
</tr>
<tr>
<td>Number of parking places</td>
<td>#</td>
<td>700</td>
</tr>
<tr>
<td>Costs of construction Pit</td>
<td>f 1000,-</td>
<td>200000</td>
</tr>
<tr>
<td>Costs of Tunnel</td>
<td>f 1000,-</td>
<td>70000</td>
</tr>
<tr>
<td>Costs of Real Estate</td>
<td>f 1000,-</td>
<td>140000</td>
</tr>
</tbody>
</table>

Table 5-1 Features of variant I

(b) Economics

For the municipality of Delft this variant generates economical values. New residents will spend a part of their income in Delft. Furthermore the financial flow of the municipality is enlarged by an increased level of revenues from real estate taxes in the area.

The phased development of the project causes a phased allocation of costs for the construction pit for BNO. Revenues from real estate can be planned in an earlier phase; the project is 'paying' earlier. Because of the uncertainty on further development of the project after finishing the real estate the development of the occupation rate of the real estate can be relatively low the first years after realization. When the development of infrastructure becomes certain the occupation rate of the real estate can be expected to be higher. As separate development postpones the construction of the infrastructure, the subsidy of f 360.000.000,- in 2004 forms the big uncertainty.

The development of houses in the plan area creates revenues for the municipality of Delft. The new residents will pay real estate taxes and will also spend a part of their income in Delft. This is an advantage for the 'Delft economy'.

Because of the postponement of the construction of infrastructure, this variant does not necessarily lead to a combined development of real estate and infrastructure. Therefore it is uncertain if the project results in a Public Private Corporation for development of real estate and infrastructure. The construction of this project will not affect the image (and therefore extra turnover) of Ballast Nedam projects.

(c) Environment

This variant does not focus on the development of underground infrastructure and therefore does not ensure that the hindrance of the railway fly-over will be taken away. The quality of living will not increase when the hindrance of the rail fly-over will not be taken away.

During construction the hindrance for the environment will be relative low because of the phased construction planning. The hindrance of the construction pit is 50% of the hindrance caused by one big construction pit.
Because the municipality of Delft is the license providing actor, the necessary political lobby focus on the municipal politics. It ensures a relatively fast political decision making process. Fast decision making means an early start of the project.

(d) Construction techniques
Two small construction pits will give relatively low technical risks; consequences of technical failures are relatively low. The costs of corrective measures for one small construction pit compared to a large construction pit are relatively low.

5.3.2 Variant II: integral development
The choice for the integral construction pit implies that the process will focus on integral development of real estate and infrastructure.

(a) Functionality
Variant II also ensures the functions living, working and culture. Because this variant directly focuses on the underground travelling function it ensures a relatively high quality of living. Compared to variant I the integral development creates a larger number of square meters real estate. Features on the variants’ functions are described below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Unit</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square meters housing</td>
<td>m²</td>
<td>43000</td>
</tr>
<tr>
<td>Number houses</td>
<td>#</td>
<td>1600</td>
</tr>
<tr>
<td>Value houses</td>
<td>f 1000,-</td>
<td>550</td>
</tr>
<tr>
<td>Price/ m² RE</td>
<td>f 1000,-</td>
<td>3.8</td>
</tr>
<tr>
<td>Square meters offices</td>
<td>m²</td>
<td>37000</td>
</tr>
<tr>
<td>Number of parking places</td>
<td>#</td>
<td>1000</td>
</tr>
<tr>
<td>Costs of construction Pit</td>
<td>f 1000,-</td>
<td>160000</td>
</tr>
<tr>
<td>Costs of Tunnel</td>
<td>f 1000,-</td>
<td>70000</td>
</tr>
<tr>
<td>Costs of Real Estate</td>
<td>f 1000,-</td>
<td>188700</td>
</tr>
</tbody>
</table>

Table 5-2 Features of variant II

(b) Economics
The development of the project does not cause a phased allocation of costs for the construction pit. The capital charge at the start of construction therefore will be relative high. Because of the little uncertainty (development of infrastructure is certain) on further development of the project after finishing the real estate, the development of the occupation rate is expected to be relative high just after realization. The value of the real estate in the PTD area will be higher than when variant I will be developed. Taxes from real estate will be higher.

This variant must lead to the first Public Private Corporation contract for developing real estate and infrastructure. It can provide a good image for Ballast Nedam NV; when this project is a success it probably results in more big public private projects on long terms. The image of Ballast Nedam Development (BNO) projects is expected to increase.

(c) Environment
This variant ensures the removal of the vision and noise hindrance. The removal of the vision and noise hindrance leads to an increased urban quality in the area. The value of the houses in Delft will increase due to the higher quality of living. A big construction pit will cause a decreasing freedom of movement for traffic in the center of Delft during construction. The hindrance of the big pit is twice as high as the hindrance of the construction pit of Variant I. Public lobby is necessary to create overall acceptance of this hindrance. A large scaled political lobby on national level is necessary. The political lobby focuses on the big infrastructure value of the project after realization. This must lead to a subsidy supply of DFL 360.000.000,- in 2004. This variant tries to accelerate the decision making process for the whole tunneling project (not only PTD area) of Delft.
(d) Techniques and construction
One big integral construction pit will have more technical risks because the consequences of technical failures on the pit during construction are bigger because of the larger magnitude of the construction pit. Therefore the uncertainty on the costs of the project is bigger.

5.4 Project organisation Delft Central

Agreement
The corporation contract describes that Ballast Nedam Development (BNO) will make a proposal for the development of the area. In this proposal a mass study, construction costs and infrastructure are described. In relation to the feasibility of the project a financial paragraph of the developing plan will be produced. If the project turns out to be financial feasible and satisfies the requirements of both BNO and the municipality of Delft, the municipality Delft and Ballast Nedam will execute the development of the plans.

Organisation and procedures
The project organisation consists of a steering group “Delft Central”and a project group “Delft Central”. A project group that consists of people of BNE group Plan Development and the Municipality of Delft perform the feasibility study. The project group reports to the steering group in which two persons from BNO, one person from the group Plan Development and one person from the Municipality of Delft are represented. The steering group decides which variants will be developed and finally will be chosen to transform to a proposal. There is no decision making hierarchy in the steering group. The organisation of the project is shown in Figure 5-5.

![Figure 5-5 Organisation Chart of project during feasibility study](image_url)

Interests of Dutch railways
The objectives of the Dutch Railways focus on the removal of the bottleneck between Rijswijk and Schiedam. Both variants meet this objective. Therefore it is assumed that the NS ‘indifferent’ between both variants.

5.5 Frame of the decision problem
The decision problem can be described by essential elements: 1. Definition of the decision problem, 2. Objectives of decision maker, 3. Scope of the decision problem. These elements are described in this paragraph.

5.5.1 Definition of decision problem
The decision whether to perform integral development of infrastructure and real estate in Delft is based on the choice between the two variants. The choice between Variant I and Variant II forms the decision problem of this case study.
5.5.2 Scope of the decision problem

A ‘decision pyramid’ describes the scope of the decision problem. It helps to identify the decisions that have to be made and controlled by the steering group ‘Delft Central’ besides the decision on variants. Figure 5-6 shows the decision problem in the context of the higher levels.

1. Policy
2. Strategic decisions
3. Tactical decisions

![Decision Pyramid](image)

**Figure 5-6 Decision Pyramid for the steering group Delft Central**

5.5.3 Objectives of the steering group

The stakeholders (member of the steering group) in the decision making process are Ballast Nedam Development (BNO), the municipality of Delft and a member of Ballast Nedam Engineering (BNE) group plan development. All stakeholders have their own interest in developing “Delft Centraal”. This multiple objectivity of the decision making in this steering group can be analysed by making an “objective hierarchy chart” for the steering group “Delft Centraal”. Furthermore the requirements for getting subsidy of the State of the Netherlands are important.

![Objective chart](image)

**Figure 5-7 Objective chart of the steering group “Delft Central”**
5.6 Objective and approach of case study

The objective of this analysis can be formulated as followed:

The objective of this analysis is to get insight in the restrictions and additional value of the performance of Decision Analysis and the quality of the use of decision supporting techniques. A quantitative model has been created that can support the decision making on the definitive variant for the development of real estate and infrastructure in Delft. Furthermore it will be investigated if decision supporting techniques are able to contribute to risk managing activities in further stages of the feasibility phase.

The decision whether to develop separate or integral construction will be based on the performance of Multi Attribute Utility Technique (MAUT). The MAUT combines the outcome of the decision trees of the single attributes in a decision table. The different interests of the members of the steering group (decision maker) determines the attributes of the MAUT. The attributes are measured by object variables. The more detailed description of the variants gave insight in the uncertainties that influence the values of the object variables. The inventory of uncertainties helps to create a base for the decision model. This is supported by the use of an influence diagram.

Some attributes are not easy to put in a numerical scale. It is chosen to put spin off of a variant into monetary values. Interviewing the decision maker on his view on the value of the attributes must create a representative model for the measurement of the attributes.

The utility score of the variants is determined by weighing the attributes values. The quantification of the used weights is performed by interviewing the decision maker on his view on values of the attributes. In appendix M ‘literature study on the application of Decision Analysis’, the ‘swing weighing’ technique was shown to be a transparent technique to weigh the decision makers’ interests. The weighted scores of both variants forms a base for decision making.

Because the use of mean values does not necessarily give mean outcomes, a deterministic analysis most of the time does not give a transparent view on the outcome of the MAUT. A probabilistic approach on the state of nature variables which influence the value of the attributes can give more insight in the outcome.

The quantification of the possible states of the ‘state of nature’ variables in this decision model, is provided by expert opinion. Moment fit\textsuperscript{10} techniques creates the combined opinion. The combined opinion is used as input for the decision model that calculates the complex object functions.

The complexity of the decision problem is determined by the number of state of nature variables and decision variables that influence the value of a certain object variable. The ‘state of nature’ variables that have dominant influence on the value of the attributes are defined by a base case tornado diagram. The dominant variables are used in a simplified probabilistic model that produces the decision tree of the attributes for BNE, BNO and the municipality of Delft.

In order to get insight in the sensitivity of the outcome of the decision table, the influence of the decision maker’s attitude towards the discounting parameters on the outcome of the decision table is analysed.

Sensitivity analysis of the financial object variables must give the stakeholders of the steering group insight in the uncertainty on the values of attributes. Techniques as the tornado diagrams and the representation of the distribution of outcomes will be used.

These figures support the optimum decision that has been determined in the decision table of the MAUT by giving insight in the sensitivity of the optimum decision. Measures for risk control in the further process can be determined for both Ballast Nedam Development (BNO) and the municipality of Delft.

The decision model will be structured in Chapter 6. In Chapter 7 the design of a numerical model in a computational environment and important aspects of the model variables are described. Chapter 8 describes the Decision Analysis process that leads to the optimum decision on the choice between

\textsuperscript{10} The moment fit technique is described in appendix M, ‘literature study on application of Decision Analysis’.
variants. Based on the outcomes of the Decision Analysis process in the case, in Chapter 9 some preventive measures on risks are proposed. It shows one of the additional values of the use of decision supporting tools. Following form the experiences in the Decision Analysis and based on the outcome of the case study in Chapter 10 conclusions and recommendations on the performance of Decision Analysis and use of decision supporting techniques. The structure of the study is described below.

Figure 5-8 Flow diagram of the Decision Analysis on the decision problem "Delft Central"
6 Decision model

6.1 Introduction
The decision on the variants will be determined based on the outcome of a Multi Attribute Utility Technique (MAUT). The used attributes, their measurement by object variables and the definition of the decision table describe the MAUT; this described in paragraph 6.2. In paragraph 6.3 the object variables are modelled by an influence diagram from which object functions can be extracted. The values of the input variables and probabilities are provided by expert opinion. Therefore four experts have been interviewed on their opinion; their opinion has been combined in paragraph 6.4.

6.2 MAUT

6.2.1 Representation of Decision Problem
Based on the description of both variants, a decision tree can be constructed for the variables that measure the attributes. The MAUT combines the outcome of the single attribute decision trees in a decision table in which will be decided based on a set of weights on attributes.

When the possible states of nature variable i, which influence the value of a certain object variable, is described by $\theta_{i1}$, $\theta_{i2}$ and $\theta_{i3}$ the decision tree for the decision problem on a single attribute can be described as below.

![Decision Tree Diagram]

*Figure 6-1 Qualitative approach on decision tree of object variable*

The decision tree calculates the expected value of the NPV of the variable that measures the attribute.

The optimum decision will be determined based on the outcome of a decision table in which the decision makers’ attitude towards his objectives is expressed in a set of weights.
6.2.2 Attribute measurement

The main objectives in Figure 5-7 were divided in six sub-objectives. Two financial objectives can be recognised (in order of presentation in Figure 5-7):
1. ‘NPV of project for BNO’
5. ‘Subsidy from state’.
These objectives can be easily measured by financial variables.

The other objectives are not easy to turn into monetary values but certainly contributes to the value of the variants. The measurement of these objectives can be determined by the decision maker. The political member Mr. H. Schomaker of the steering group has been interviewed on the measurement of 'intangible' objectives for Delft. For the measurement of the values for Ballast Nedam Engineering, the Head Engineer of the group Plan Development has been interviewed. The results are shown in the table below:

<table>
<thead>
<tr>
<th>nr.</th>
<th>Objective</th>
<th>Reason</th>
<th>Model</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Maximise image of Ballast Nedam Development (BNO)</td>
<td>A good reputation on constructing infrastructure and real estate projects can provide new projects in the future</td>
<td>Planning extra turn over every year (in future).</td>
<td>DFL. per year after finish of construction</td>
</tr>
<tr>
<td>3</td>
<td>Maximise image of Ballast Nedam Engineering (BNE)</td>
<td>A good reputation on developing variants for infrastructure and real estate projects can provide new projects in the future</td>
<td>Planning extra turn over every year (in future).</td>
<td>DFL. per year after finish of construction</td>
</tr>
<tr>
<td>4</td>
<td>Minimise hindrance during construction</td>
<td>Traffic and the social activity during construction will be disturbed during the project.</td>
<td>Express the hindrance of the project in a monetary value</td>
<td>DFL. per hindrance year. during construction.¹¹</td>
</tr>
</tbody>
</table>
| 6   | Maximise spin off of project for municipality Delft | A. Public value
The Urban Quality will increase.
The hindrance of the present railway fly-over will be taken away.
B. Economical value
New residents will create economical advantages for Delft
• Taxes for Real Estate (OZB)
• The developed houses provide new inhabitants. (2,2 persons per house). | A. Estimate of the increased value of the houses in the rail area.
• OZB % per year
• Estimate the spending behaviour of a new inhabitant in Delft. | A. New average value of houses x factor in DFL. After finish of construction
B. DFL. per year after finishing the project.
• Part of income spending in Delft per year. |

Table 6-1 Modelling of intangible objectives

The spin off for the municipality can be split in a part that represents the public value of the project and a part that represents the economical value of the project. The public value will be measured by the urban quality that will be created by the variant. The economical values will be determined by the attribute 'new residents' that measures the extra income of the project for the municipality of Delft because of the increased number of residents.

Combined with the measurement of the financial objectives Table 6-2 shows the total list of attributes and their measurement that will be used to determine the utility score of both variants.

¹¹ Hindrance Costs per year: (Costs var. II – Cost var. I)/(duration var. I. - duration var. II)
Part II: Case Study: Development of Delft Central: an underground Decision Problem

<table>
<thead>
<tr>
<th>Objectives of 'Steering group'</th>
<th>Sub objectives of 'Steering group'</th>
<th>Attribute measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximise spin off for BNO</td>
<td>1. NPV of project for BNO</td>
<td>1. PV of profit</td>
</tr>
<tr>
<td></td>
<td>2. Image of BNO</td>
<td>2. Extra turn over for Ballast Nedam Development</td>
</tr>
<tr>
<td>Maximise spin off for BNE</td>
<td>3. Good image for Ballast Nedam Engineering</td>
<td>3. Extra turn over for Ballast Nedam Engineering</td>
</tr>
<tr>
<td></td>
<td>5. Subsidy</td>
<td>5. Subsidy</td>
</tr>
</tbody>
</table>

Table 6-2 Measurement of attributes

The attributes from Table 6-2 return in the decision table of the MAUT. The decision table in Table 6-3 shows that the total score of a variant will be determined by multiplying the attributes' weight and the expected value of the object variable.

<table>
<thead>
<tr>
<th>j</th>
<th>Attribute (Xj)</th>
<th>Weight (λj)</th>
<th>Variant I</th>
<th>Score</th>
<th>Variant II</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>λ1</td>
<td>E(u1)</td>
<td>λ1 x E(u1)</td>
<td>E(u1)</td>
<td>λ1 x E(u1)</td>
</tr>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>λ2</td>
<td>E(u2)</td>
<td>λ2 x E(u2)</td>
<td>E(u2)</td>
<td>λ2 x E(u2)</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>λ3</td>
<td>E(u3)</td>
<td>λ3 x E(u3)</td>
<td>E(u3)</td>
<td>λ3 x E(u3)</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>λ4</td>
<td>E(u4)</td>
<td>λ4 x E(u4)</td>
<td>E(u4)</td>
<td>λ4 x E(u4)</td>
</tr>
<tr>
<td>5</td>
<td>NPV of subsidy</td>
<td>λ5</td>
<td>E(u5)</td>
<td>λ5 x E(u5)</td>
<td>E(u5)</td>
<td>λ5 x E(u5)</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>λ6a</td>
<td>E(u6a)</td>
<td>λ6a x E(u6a)</td>
<td>E(u6a)</td>
<td>λ6a x E(u6a)</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>λ6b</td>
<td>E(u6b)</td>
<td>λ6b x E(u6b)</td>
<td>E(u6b)</td>
<td>λ6b x E(u6b)</td>
</tr>
<tr>
<td>Total score</td>
<td></td>
<td></td>
<td>E(u)</td>
<td>λE x E(u)</td>
<td>E(u)</td>
<td>λE x E(u)</td>
</tr>
</tbody>
</table>

Table 6-3 Decision table for Steering group “Delft Central”

6.3 Modelling of object variables: ‘Influence diagram’

An influence diagram of the object variables can be created, based on description of both variants and the proposed way of modelling intangibles. This paragraph describes the construction of the influence diagrams.

6.3.1 Present Value of Profit

Figure 6-2 shows the conceptual design of the area Delft Central.

Figure 6-2 Section of design for “Post Technische Dienst” area
Figure 6-2 shows that the real estate has been divided offices, parking places and houses. Combined with the description in the previous Chapter this results in the following inventory of revenues and costs.

<table>
<thead>
<tr>
<th>Costs</th>
<th>Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Construction Costs</td>
<td>• Rent income</td>
</tr>
<tr>
<td>- Real Estate</td>
<td>- Housing</td>
</tr>
<tr>
<td>- Tunnel</td>
<td>- Shops</td>
</tr>
<tr>
<td>- Construction Pit</td>
<td>- Parking places</td>
</tr>
<tr>
<td>- Obtaining Costs</td>
<td>• Subsidy</td>
</tr>
<tr>
<td>• Financing costs</td>
<td></td>
</tr>
<tr>
<td>- Interest</td>
<td></td>
</tr>
<tr>
<td>• Depreciation</td>
<td></td>
</tr>
<tr>
<td>- Discount</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6-3 Inventory of financial values**

**Phased approach**

The first step consists of creating the Net Present Value influence diagram. This Profit based approach will be adapted to the case situation by detailing the elements of the base diagram; the influence diagram for a Net Present Value Calculation.

**Figure 6-4 First step:** the case elements are connected to the base elements of a NPV influence diagram

**Figure 6-5 Second step:** Approach on revenue and costs
Decision making at a higher economical scale

As described in the description of both variants the start of the project depends on the provided building license and the amount of subsidy. Both elements are influenced by decision making processes on higher economical scale. The set of weights that will be used by politics in this decision making forms an uncertainty in this decision model (see Chapter 2). Therefore the outcome of political decision making is modelled as a state of nature variable in the influence diagram.

The outcome of political decision making determines the important time points of the project.
In this step, the uncertainty on the starting point of construction and the uncertainty on getting subsidy on the project has been inserted in the diagram.

Figure 6-6 Final step: influence of decision making at a higher economical scale

The time point of political decision making influence directly the uncertainty on time points on start of the project and getting subsidy. The influence diagram for NPV of profit is shown in Appendix B3

- Object function

\[
NPV = \sum_{t=0}^{T} \frac{(Total\_revenues - Total\_Costs)(1)}{(1+r)^{t-t_0}}
\]

Equation 6-1 Object function for NPV

Total Revenues:
Revenues offices + revenues parking places + revenues houses

\[
Total\ Rev's = \sum_{t=t_0}^{t=T} revenues\_offices + revenues\_parking\_places + revenues\_houses
\]

Equation 6-2 Time window for revenues

Rev's_houses = \sum_{t=t_0}^{t=T} (price\_per\_m^2\_house) \times (m^2\_houses) \times (occ.rate\_houses) \tag{6-2a}

Rev's_offices = \sum_{t=t_0}^{t=T} (price\_per\_m^2\_office) \times (m^2\_office) \times (occ.rate\_office) \tag{6-2b}

Rev's_parkingplaces
- \sum_{t=t_0}^{t=T} (price\_park\_place) \times (nr\_park\_places) \times (occ.rate\_park\_places) \tag{6-2c}

Total Costs
Total Costs = Costs of Tunnel + costs of real estate + obtaining costs + costs for construction pit + financing costs
In accordance with Appendix B4 the following part of the object function of the NPV can be determined:

\[ \text{Costs of Tunnel} = \sum_{t=t_{tr}}^{t_{tr}} (\text{Costs of Tunnel sec} - \text{Subsidy}) / (\text{duration constr. Tunnel}) \] (6-3a)

\[ \text{Costs of Real Estate} = \sum_{t=t_{re}}^{t_{rem}} (\text{Costs of real estate}) / (\text{duration constr. RE}) \] (6-3b)

\[ \text{Costs of Obtaining} = \sum_{t=3}^{t_t} (\text{Costs of obtaining}) / (\text{duration obtaining}) \] (6-3c)

\[ \text{Costs of Construction Pit} = \sum_{t=t_c}^{t_{c-2}} (\text{Costs of C. Pit}) / (\text{duration constr. C. Pit}) \] (6-3d)

\[ \text{Financing Costs} = \sum_{t=t_r}^{t_{t_0}} \text{Interest rate} \times \text{Costs to be financed} \] (6-3e)

**Equation 6-3a – 6-3e formulas of the object function of the NPV**

<table>
<thead>
<tr>
<th>Object variable</th>
<th>Decision variables</th>
<th>State of nature variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>Time point of getting building license from Delft</td>
</tr>
<tr>
<td></td>
<td>m² offices</td>
<td>Occupation rate</td>
</tr>
<tr>
<td></td>
<td>m² houses</td>
<td>Time development of occupation rate</td>
</tr>
<tr>
<td></td>
<td>parking places</td>
<td>Price development</td>
</tr>
<tr>
<td></td>
<td>Costs of Construction Pit</td>
<td>Interest rate</td>
</tr>
<tr>
<td></td>
<td>Costs of Real Estate sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Costs of Tunnel sec m² price houses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>m² price offices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>price parking place</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Duration construction RE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Duration construction Tunnel</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6-7 Model variables for the NPV of project**

**Time points**

**Figure 6-8 Cash flow diagram for BNO**

With:

\[ t_s = \text{time point of start of construction} \]

\[ t_s = \min (t_{IT}, t_{RE}) \]

\[ t_{IT} = \text{start point of construction Tunnel} \]

\[ t_{RE} = \text{start point of construction Real Estate} \]
### 6.3.2 Extra turnover for Ballast Nedam Property Development (BNO)

- **Influence diagram**

![Influence diagram of extra turnover for BNO](image)

- **Object function**

The object function that can be derived from the cash flow diagram and the influence diagram:

\[
NPV(\text{extra\_turnover}) = \sum_{t=t_i}^{t_f} ((\text{extra\_turnover\_BNO})) \left( \frac{1}{(1 + r)^{t-t_i}} \right)
\]

**Equation 6-4 Object function extra turnover BNO**

**Variables:**

- **Decision variables:** Extra turnover of BNO
- **State of nature variables:**

**Fixed Values**

- Discount rate \( r \); time window

- **Definition of time points:**

![Cash flow diagram for BNO](image)

**Figure 6-10 Cash flow diagram for BNO**

With:

- \( t_s \) = time point of start of construction
- \( t_{w2} \) = end point of time window for business economical spin off
6.3.3 Extra Engineering's turnover for Ballast Nedam Engineering (BNE)

- **Influence diagram**

![Influence diagram of extra engineering's turnover for BNE](image)

**Equation 6-5 Object function for extra turn over BNE**

Variables:
- Decision variables: extra engineering's turnover for BNE
- State of nature variables:
  - Discount rate (r); time window

**Definition of time points:**

![Cash flow diagram extra turnover for BNE](image)

With:
- $t_0$ = time point of start of construction
- $t_{n2}$ = end point of time window for business economical spin off

6.3.4 Subsidy

- **Object function**

  \[
  \text{Subsidy} = \sum_{t=2004}^{t=2004} \text{Subsidy \_by\_State\_of\_Netherlands}
  \]

**Equation 6-6 Object function for Subsidy**

With:
- **Variables:**
  - State of nature variable: Subsidy by State of the Netherlands
6.3.5 Modelling of values for the municipality of Delft

The values of the development of real estate and underground infrastructure for the municipality of Delft were determined:

- Hindrance during construction
- Urban quality
- New residents

The resulting influence diagram is shown in the figure below.

Figure 6-14 Influence diagram of values for municipality of Delft

- Object functions

The object function that can be derived from the influence diagram and the cash flow diagram is:

\[
NPV\text{(hindrance)} = \sum_{t=0}^{T} (\text{Hindrance}\_\text{Costs}) \left(\frac{1}{(1+r)^t}\right)
\]

Equation 6-7 Object function of hindrance during construction

The object function that can be derived from the influence diagram and cash flow diagram is:

\[
NPV\text{(urban\_quality)} = \sum_{t=0}^{T} \left(\text{number\_of\_houses} \times \text{new\_average\_value}\right) \left(\frac{1}{(1+r)^t}\right)
\]

Equation 6-8 Object function of urban quality
new aver. value = \frac{(nr.\ houses \times value\_houses) \times (nr.\ houses\_in\_Delft \times old\_aver.\_value)}{(nr.\ houses + nr.\of\_houses\_in\_Delft)}

Equation 6-9 Calculation of new average value

- **Object functions 'new residents'**
Transforming the influence diagram and the cash flow diagrams of these object variables into object functions gives the following result:

\[ NPV(\text{taxes from real estate}) + NPV(\text{spending}) = NPV(\text{New Residents}) \]

\[ NPV(\text{taxes\_real\_estate}) = \sum_{i=1}^{n} (OZB \times number\_of\_houses \times value\_houses) \left(\frac{1}{(1 + r)^{t_i}}\right) \quad (6-8a) \]

\[ NPV(\text{spendings}) = \sum_{i=1}^{n} (spending\_behaviour \times Income\_per\_resident \times number\_of\_residents) \left(\frac{1}{(1 + r)^{t_i}}\right) \quad (6-8b) \]

**Equation 6-10a and 6-8b Object functions for New residents**

With:

- **Fixed Value:**
  - Income new residents; nr. houses in Delft; old average value of houses;

- **Variables:**
  - Decision variables (variant I or variant II): value of houses; number of houses; number of residents;

- **Definition of time points for hindrance during construction**
  - \( t_s \) = start of construction
  - \( t_e \) = end of construction

*Figure 6-15 Cash flow diagram of hindrance during construction*

With:

- \( t_s \) = start of construction
- \( t_e \) = end of construction
• Definition of time points of urban quality

\[ f \]
\[
\begin{align*}
t_c & = \text{time point of end of construction} \\
\end{align*}
\]

**Figure 6-16 Cash flow diagram of urban quality**

• Definition of time points new residents:

\[ f \]
\[
\begin{align*}
t_c & = \text{time point of end of construction} \\
t_w & = \text{end point of time window} \\
\end{align*}
\]

**Figure 6-17 Cash flow diagram new residents**

6.4 Expert opinion on model variables

Experts quantify the uncertainties, which were identified during the modelling of the object variables. For price- and time uncertainties 4 experts were interviewed. The experts were asked to give, for every uncertain variable, a 10% value\(^{12}\) and a 90% value\(^{13}\). The third scattering is the value of which the expert is indifferent whether the value will be lower or higher than this value. The results per uncertainty are put in a table. In this way every expert fixes a triangular density function with a modulus that is equal to the 50% value.

**Figure 6-18 Expert opinion represented by triangular distributions**

*Input of KlaverCom*

The input worksheet for KlaverCom is shown in Appendix F. The required variables are noted in the cells under the headers ‘q’ (10%-value), ‘Mode’ and ‘1-q’ (90%-value).

Now we have a triangular distribution for every variable we are able to create a combined distribution by using the ‘moment fit’ method.

\(^{12}\) the expert expects that the realisation will be higher than this value with a chance of 95%  
\(^{13}\) the expert expects that the realisation will be lower than this value with a chance of 95%
Features on experts
Because of a lack of experience in collecting expert opinion in these phases of the project process it is
decided to choose a group of experts that contain individuals who supplement each other in their fields
of knowledge. The experts are interviewed individually. Further in this report this working method is
evaluated. The following experts are interviewed:
• Expert 1: dhr. Diederik van Hoogstraten; Financial analyst Ballast Nedam International (BNI)
• Expert 2: dhr. Wim Snelders; Head Engineer of the group Plan Development at Ballast Nedam
Engineering (BNE). Also a member of the steering group “Delft Centraal”.
• Expert 3: dhr. Henk Schomaker; co-operator of the service city development in Delft. Also a
member of the steering group “Delft Centraal”.
• Expert 4: dhr. S. de Vries; Director of Ballast Nedam Plan Developing (BNO). Also a member of
the steering group “Delft Centraal”.

Combining opinion
Besides the 10% value and the 90% value the first and second moment are important features of a
distribution. This feature can be used in fitting on the combination of the triangular distribution
provided by expert opinion. The process of combining distributions and fitting on the combination can
be performed by the software package KlaverCom. KlaverCom uses the moment fit for creating a
combine distribution. KlaverCom is an excel add-in and already used at BNE. The input for
KlaverCom are the results of the interview on experts. The results from the interviews are shown in
appendices C1- C4. The combined opinion is shown in appendix C5.

Paragraph 2.4 already described that the values of the decision variables are uncertain. This is shown in
Appendix C5. The values of the decision variables are influenced by ‘states of nature’ which are not a
result from decision making at other economical scales.
In this phase of investigation there is a lack of insight in the combination of state of nature variables
that influence the value (the scattering of the expert) of the decision variable. Therefore the
combination of state of nature variables that influence the scattering of the expert is assumed to be
‘black-box’. The decision variable itself can be modelled by a ‘change node’ in the influence diagram
in Appendix B5.
7 Numerical model

7.1 Introduction

The calculation of the object variables is based on the object functions that were defined in the previous chapter. Because of the complexity of the calculations these functions are put in a numerical model. In paragraph 7.2 the spreadsheet that calculates the deterministic values of the object variables is described. In accordance with the modelling of the variables in chapter 6, the modelling of the input data of the spreadsheet is described in paragraph 7.3.

When the state of nature variables that influence the value of the object variable are approached probabilistically, the spreadsheet can be linked to the software package DPL4.0. the performance of this link and the features of this package are described in paragraph 7.4.

7.2 Deterministic model

The model is based on the phased approach of the decision problem. The object functions have been put in a spreadsheet that is able to calculate the value of the object variable when the calculation becomes too complex. A first deterministic run of the spreadsheet gives a first identification of the value of the object variables.

When the value of the object variable is influenced by a large number of ‘state of nature’ variables the model is able to identify dominant variables on the value of the object variable. Therefore a macro is connected to the spreadsheet model that produces tornado diagrams on the ‘base case’ value of the object variables.

The numerical model is constructed in a Microsoft Excel environment and is able to take correlation between ‘state of nature’ variables into account.

7.2.1 Excel97 spreadsheet

In order to keep a clear overview on the calculation the spreadsheet is divided in three sections; an input section, a calculation section and an output section. This is shown in appendix D1.

1. Input section

The first column of the input section contains all state of nature variables, decision variables and fixed values of the influence diagram. The second column is used for checking the variables units in order to keep overview in detailed parts of the calculation. Column ‘name’ is used as reference for the cells in column ‘active’ that will be used in the calculation. This is shown in Figure 7-1 where the active cell is named ‘discount’. The columns ‘low’, ‘base’ and ‘high’ are used to fill in the combined distributions (triangular) provided by experts in the previous chapter.

<table>
<thead>
<tr>
<th>POA Macros</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
</tr>
<tr>
<td>8 Input section</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Input Variable</td>
<td>Dimension</td>
<td>Name</td>
<td>Low</td>
<td>Base</td>
<td>High</td>
<td>Active</td>
<td>Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Discount rate</td>
<td>(%)</td>
<td>Discount</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>15%</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 m2 offices</td>
<td>m2</td>
<td>m2offices</td>
<td>25000</td>
<td>37019</td>
<td>40000</td>
<td>37019</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 m2 houses</td>
<td>m2</td>
<td>m2houses</td>
<td>40000</td>
<td>43004</td>
<td>45000</td>
<td>43004</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 parking places</td>
<td>m2</td>
<td>parking</td>
<td>950</td>
<td>700</td>
<td>770</td>
<td>700</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 time development sqm price</td>
<td>m2</td>
<td>sqmdev</td>
<td>-0.019</td>
<td>0.015</td>
<td>0.020</td>
<td>1.50%</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7-1 The input section of spreadsheet. Example on how to fill in the low, base and high values in the input section

Figure 7-1 shows that all decision variables have the same ‘low’, ‘base’ and ‘high’ value. In a further stadium it is possible to change these values in order to investigate the sensitivity of the optimum policy for changes in decision variables.
In the ‘index column’ the state of the variable can be determined. Putting all variables on ‘2’ creates a base case analysis. The decision maker is able to put the index on ‘1’ for the lower value or ‘3’ for the higher value. In this way correlation between two variables can be modelled by putting correlated variables on the same index.

The input section is separated in a revenue section, a cost section and a section in which the time variables can be noted.

2. Calculation section

Time windows section

In a spreadsheet model the NPV of the value nodes of the influence diagram are calculated. For a NPV calculation it is important to assign the model variables to the right time point. Therefore the spreadsheet uses ‘Time windows’. A time window assigns a ‘1’ to the calculating formula in order to create a value in the output section. When no output is required, the time window multiplies the formula with a ‘zero’ in order to create a 0-value in the output.

![Time window Construction project](image)

Figure 7-2 representation of time series. The expected value for the construction period is 8 years. The window creates a ‘1’ or a ‘0’.

Object functions

In the calculation section the time influence on the NPV of a variant attribute is connected to the input variables. The used formulas are in accordance with the object functions in paragraph 6.2 and are presented in Appendix D2.

3. Output section

In the output section the NPV of the object variable is calculated based on the values of the subjects of the influence diagram. The active cell shows how the ‘discount rate’ has been taken into account.

<table>
<thead>
<tr>
<th>C153</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>=NPV(Discount;RSREVminCosts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>144</td>
<td></td>
<td>total/revenues</td>
<td>FI/year</td>
<td>2832760</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>147</td>
<td></td>
<td>Revenues - Costs</td>
<td>FI/year</td>
<td>2290410</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>148</td>
<td></td>
<td>difference discounted</td>
<td>FI/year</td>
<td>2213477</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>151</td>
<td></td>
<td>current difference</td>
<td>2290410</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td></td>
<td>NPV of difference</td>
<td>2213477</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7-3 The calculation of the NPV: discounting D148.

Macro

In order to identify deterministic dominance of input variables, a ‘macro’ has been developed that is able to produce base case tornado diagrams. The tornado shows the impact of a change in input on the outcome of the ‘Base Case analysis’.

The spreadsheet will be run with all input variables on their base value.
7.3 Features on data

Modelling time influence on uncertainties
The decision variables are ‘only’ influenced by internal factors during design and construction. In the report “literature study on application of Decision Analysis” the uncertainties on these variables were mentioned as uncertainties that are connected to the quality of the performance of the parties that contribute (internal) to the final result of the project. The project management is able to control these uncertainties in time. Therefore these uncertainties will be represented as a triangular distribution that will not change in time. See Figure 7-4.

![Figure 7-4 No time influence on variable X](image)

The following uncertainties in the influence diagram are modelled as a triangular distribution:
- Square meters real estate
- Duration of construction of tunnel and real estate
- Construction and obtaining costs of project
- Time points on starting project and construction real estate and tunnel
- OZB-value
- Spending behaviour

The state of nature variables are influenced by external factors that are not easy to control by the management. Because of the uncertainty in time, ‘decision making’ by other parties (political) and the ‘market development’ are variables, which are hard to be scattered. Therefore a scattering on the development in time has to be modelled as in Figure 7-5.

![Figure 7-5 Variable X is uncertain in time](image)

\( \alpha \) describes the development of variable X in percentage of base value per year

The following variables is modelled as described:
- Price uncertainties

These features affect the formulas and relations that will be used in the spreadsheet that calculate the Net Present Value (NPV). When necessary the input variable “time development of variable X” will be added in the input section of the spreadsheet.
In some cases it is not possible to get expert opinion on the modelled state of nature variable. When this is the case the connected object variable is modelled as a fixed item. The spreadsheet treats this item as a triangular function with the same 5%, 50% and 95% value. This is shown in Figure 7-6.

![Figure 7-6 Variable X is considered as a fixed item](image)

The variables that are expressed as fixed item are the quantified spin off values.
- Extra turnover for BNE and BNO
- Hindrance during construction
- Urban quality

*Modelling probabilistic independence*

The spreadsheet is able to make an inventory of the influence of modelling probabilistic dependence of state of nature variables. In this case the state of nature variables that influence the value of the object variables are assumed to be independent.

### 7.4 Probabilistic model

When the deterministic calculation does not give satisfying results for decision making, a probabilistic model on the object variables can give more information. Therefore modelling of the possible states of nature \( \theta_1, \theta_2, \theta_3 \) is necessary. In this phase of the project it is hard to quantify the probability on the state of nature. The results of the expert opinion will be transformed by discretization in accordance with the example in Chapter 3. A low value with \( P(\theta) \) equal to 0.25, a mode value with \( P(\theta) \) is equal to 0.50 and a high value with \( P(\theta) \) is equal to 0.25, will proceed in the spreadsheet in Appendix D1 that determines the Net Present Value of the object variables for both variants.

The influence diagrams that were created in the software package DPL 4.0, can be connected to the spreadsheet cells that contains the input variables. In this way the software is able to produce and calculate decision trees. A more detailed description of the performance of this package can be found in subparagraph 7.4.1.

#### 7.4.1 Link with spreadsheet

The probabilistic model in DPL 4.0 is based on an influence diagram that only shows the dominant 'state of nature' variables. In order to get a well performing model, the nodes in the influence diagram will be connected to the spreadsheet in Excel97. This is shown in appendix D3 and DPL 4.0 is able to export its own input to the spreadsheet. The spreadsheet calculates the outcome of the model (NPV on difference between revenues and costs). DPL imports the outcomes from the spreadsheets and assigns probability values to these outcomes. In this way DPL 4.0 is able to calculate the expected value of the outcome. Appendix D4 shows the dialogue windows that help the user in creating the connection between Excel7.0 and DPL 4.0.

*Objective function*

The value of the object variable of the model gets calculated at every end point of the decision tree by the objective function. As described the object function forms a part from the spreadsheet. In this case the objective function is 'maximize' ‘NPV of profit’. Appendix D4 shows how to create the objective function 'maximise NPV of profit'.
8 Optimum decision

8.1 Introduction

The determination of the optimum decision for the decision problem is based on the outcome of a MAUT in which the outcome of multiple decision trees are combined and weighted. The weights of attributes are determined by interviewing the decision maker on his attitude towards the attributes in the context of the decision problem. A first deterministic run of model variables gives a first insight in the 'base case scenario'\(^{15}\) on both variants in paragraph 8.2. Because a web of uncertainties influences the outcome of the MAUT and the mean value approach of attributes does not necessarily gives mean outcomes, this approach does not give insight in the possible scenario’s. Therefore the state of nature variables are approach probabilistically.

In order to come to a transparent probabilistic analysis, in paragraph 8.3 the dominant uncertainties will be determined. The probabilistic analysis in paragraph 8.4 only focuses on the dominant state of nature variables. Based on the information that is provided by the decision table of the MAUT and the decision tree and techniques that evaluates the outcome of the tree, it is possible to define a decision in paragraph 8.8. In paragraph 8.9 the use of the decision supporting techniques will be evaluated shortly based on the experiences during this case.

8.2 MAUT analysis of deterministic approach

8.2.1 Values of attributes

Financial values

Based on the combined opinion in appendix C5, a first deterministic (base case) calculation of the Net Present Value of the project and the amount of subsidy can be performed. With a time window of 25 years \((t=0\) in 2000) for the financial values this result in the following:

<table>
<thead>
<tr>
<th>No.</th>
<th>Attribute</th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>-13500</td>
<td>-19330</td>
</tr>
<tr>
<td>5</td>
<td>NPV of Subsidy</td>
<td>134238</td>
<td>201356</td>
</tr>
</tbody>
</table>

\[\text{Table 8-1 Financial Values; } x \times 1000,\text{-}\]

The calculation of the NPV of the project has been performed by the spreadsheet and is shown in Appendix E1 and E2. The NPV of Subsidy is calculated in Appendix E3.

Spin off values

In accordance with the object functions in Chapter 6, the outcomes of the spin off values can be determined.

The spin off for BNO and BNE is discounted over a time window that begins at the start of the construction of the project and stops 10 years later. Because the municipality of Delft wants to return their investments in the project in a time period of 15 years\(^{16}\) after the finish of the project, this time window stops at 2032 in case of variant I and in 2025 in case of variant II. The discounted values of the spin off values are calculated in appendix E3 and are presented in the following table.

<table>
<thead>
<tr>
<th>Attr. no</th>
<th>Attribute(Xo)</th>
<th>Var. I(^*)</th>
<th>NPV</th>
<th>Var. II(^*)</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>0 per year</td>
<td>0</td>
<td>25000 per year</td>
<td>54244</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>0 per year</td>
<td>0</td>
<td>500 per year</td>
<td>1084</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>6000 per year</td>
<td>16170</td>
<td>120000 per year</td>
<td>39600</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>271.600 after realisation</td>
<td>50449</td>
<td>344.000 after realisation</td>
<td>85031</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>39455 per year</td>
<td>47789</td>
<td>55455 per year</td>
<td>69698</td>
</tr>
</tbody>
</table>

\[\text{Table 8-2 Expected values of attributes; } x \times 1000,\text{-}\]

\(^{15}\) Base case scenario: All variables are put on their base level

\(^{16}\) This was appointed by Mr. Schomaker from the municipality of Delft
8.2.2 Values of weight

In Appendix E4 the weights of attributes are determined in accordance with the values from Table 8-1 and Table 8-2. From this performance can be concluded that:

- Swing weighting can not be applied for determination of all weights, because the decision maker is not always able to give a ‘value of indifference’ by swinging the value of spin off values between its’ low and high value.
- Because swing weighting was not always applicable in the right way for determination of weights it created a situation in which the municipality of Delft and BNE use the same set of weights.
- The Steering group can not be modelled as a rational decision maker.

The results of the calculation of weights are shown in the tables below:

<table>
<thead>
<tr>
<th>i</th>
<th>_attribute</th>
<th>$\lambda_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>0.09</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>0.12</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>0.12</td>
</tr>
<tr>
<td>5</td>
<td>NPV of subsidy</td>
<td>0.21</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.17</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**Table 8-3 weights on attributes of BNE/Delft**

<table>
<thead>
<tr>
<th>i</th>
<th>_attribute</th>
<th>$\lambda_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>0.11</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>0.09</td>
</tr>
<tr>
<td>5</td>
<td>NPV of subsidy</td>
<td>0.20</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.14</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.17</td>
</tr>
</tbody>
</table>

**Table 8-4 weights on attributes of BNO**

*Quality of quantification of weights*

Putting spin off in monetary values indirectly influences the value of the weighing factor ($\lambda_i$) because the steering group member were not able to define monetary values between the high and low value of the intangible attributes. In order to create ‘optimal’ weights, the members the steering group are able to manipulate the monetary value of the spin off.

*Modelling the steering group as a rational decision maker*

The difference in weighing of the attributes by the steering group members of BNO on one hand and BNE and the municipality on the other hand were shown. The interests of the members of the steering group are expressed in the difference in ordering of the attributes in appendix E4. Because of the difference in weights, the steering group does not act as a rational decision maker. Therefore this model is not able to create the optimal decision for the steering group. The decision model will be used for the municipality of Delft and BNE and for BNO.

8.2.3 Result for BNE and the municipality of Delft

**Weighted analysis**

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute (X_i)</th>
<th>Weight ($\lambda_i$)</th>
<th>NPV</th>
<th>Score</th>
<th>NPV</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>0.14</td>
<td>-13500</td>
<td>-1890</td>
<td>-19330</td>
<td>-2706</td>
</tr>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>0.09</td>
<td>0</td>
<td>0</td>
<td>54244</td>
<td>4882</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
<td>1084</td>
<td>131</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>0.12</td>
<td>-16170</td>
<td>-1940</td>
<td>-39600</td>
<td>-4752</td>
</tr>
<tr>
<td>5</td>
<td>NPV of subsidy</td>
<td>0.21</td>
<td>134238</td>
<td>28190</td>
<td>201356</td>
<td>42285</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.17</td>
<td>50449</td>
<td>8576</td>
<td>85031</td>
<td>14455</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.15</td>
<td>47789</td>
<td>7169</td>
<td>69698</td>
<td>10455</td>
</tr>
<tr>
<td>Total score</td>
<td>1.00</td>
<td>40105</td>
<td>64750</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 8-5 Weighted decision table: all values x f 1000,-**

The decision tables show the influence of weights on the outcome of the decision table. The relative low weigh factor of ‘NPV of project’ does not affect the difference between the scores of both variants. The table also shows the influence of the score of the attribute ‘NPV of subsidy’. It can be concluded that variant II (integral development) is only desirable for BNE and the municipality of Delft when the uncertainty on getting subsidy will decrease. The value of the attributes ‘Urban quality’ and ‘New residents’ for Delft also has big influence on the outcome of the table.
The dominant attributes for the municipality of Delft and BNE are:
1. NPV of subsidy;
2. Urban quality;
3. New residents.

### 8.2.4 Result for BNO

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute (Xi)</th>
<th>Weight (λi)</th>
<th>NPV</th>
<th>Score</th>
<th>NPV</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPV of project</td>
<td>0.19</td>
<td>-13500</td>
<td>-2565</td>
<td>-19330</td>
<td>-3673</td>
</tr>
<tr>
<td>2</td>
<td>Extra turn over for BNO</td>
<td>0.11</td>
<td>0</td>
<td>0</td>
<td>54244</td>
<td>5967</td>
</tr>
<tr>
<td>3</td>
<td>Extra turn over for BNE</td>
<td>0.10</td>
<td>0</td>
<td>0</td>
<td>1084</td>
<td>108</td>
</tr>
<tr>
<td>4</td>
<td>Hindrance during construction</td>
<td>0.09</td>
<td>-16170</td>
<td>-1455</td>
<td>-39600</td>
<td>-3564</td>
</tr>
<tr>
<td>5</td>
<td>NPV of subsidy</td>
<td>0.20</td>
<td>134238</td>
<td>26848</td>
<td>201356</td>
<td>40271</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.14</td>
<td>50449</td>
<td>7063</td>
<td>85031</td>
<td>11904</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.17</td>
<td>47789</td>
<td>8124</td>
<td>69698</td>
<td>11849</td>
</tr>
<tr>
<td></td>
<td>Total score</td>
<td>1.00</td>
<td>38015</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 8-6 Weighted decision table: all values \( \times f 1000 \)**

The relative high weigh factor of ‘NPV of project’ decreases the difference between the scores of both variants.

It can be concluded that variant II (integral development) is only desirable for BNO when the uncertainty on getting subsidy will decrease. As described above the value of the attribute NPV of project has big influence on the outcome of the table.

The dominant attributes for BNO are:
1. NPV of project
2. NPV of subsidy
3. Urban quality
4. New residents

### 8.3 Dominant variables

In order to make the decision problem less complex, an analysis of dominant model variables of the dominant attributes will be performed. The spreadsheet is able to produce a tornado diagram of the ‘base case’ outcome of the object variables. Keeping the variable on its base value, the macro switches every state of nature variable from its low value to its high value and visualises the outcome in a diagram. In this way the steering group is able to identify the variables that have big impact on the outcome of the object variables.

#### 8.3.1 Model variables

By using combined expert opinion (appendix E5) as input for the model, the outcome of the object variables ‘NPV of project’ for BNO and the spin off attributes for Delft can be analysed. The influence of the following model variables are analysed:

1. **Decision variables**:
   - The values for the decision variables were given in appendix E5. The features of the variants determine these values. Because in this phase the design for both variants is not fixed, the experts provide three possible values for the decision variables.
2. **State of nature variables**:
   - The input values of the state of nature variables for the spreadsheet can be extracted from the combined expert opinion. Appendix C5 shows the list of input for the calculation of the NPV of both variants.
8.3.2 Analysis of values for the municipality of Delft

*Quality of quantification of spin off values (Table 8-2)*

<table>
<thead>
<tr>
<th>Variant</th>
<th>Spin off value for Delft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate development</td>
<td>98,240</td>
</tr>
<tr>
<td>Integral development</td>
<td>154,730</td>
</tr>
</tbody>
</table>

*Base Case values in f 1000,-*

![Spin off for Delft of both variants](image)

**Figure 8-1 Behaviour of spin off for both variants.**

Figure 8-1 shows the additional value of variant II compared to variant I. Variant II ensures by an integral development a higher level of 'urban quality' than variant I in which the development of infrastructure is not certain. Although the municipality of Delft and BNE can easily manipulate the monetary value of spin off from new residents and the spin off for the urban quality, this method of quantifying spin off forms a good representation of the value of both variants.

**Dominant variables - (tornado diagram)**

Following from the decision tables in paragraph 8.2 the spin off attributes have big influence of the outcome of the MAUT. In order to get insight in the uncertainties that influence the values of the attributes that determine the value of the spin off, in this sub-paragraph the values the dominance of the variables are analysed.

1. **Urban quality**
   - The value of the urban quality is a value that is estimated by the decision maker. It was analysed not to be influenced by any (state of nature) variable.
2. **Spin off from new residents**
   - From the object functions in Chapter 6 can be extracted that the value of the spin off from new residents is influenced by state of nature variables; OZB(1) and spending behaviour(2) of new residents and the decision variable number of houses(3).

8.3.3 Analysis of values for BNO

The table below shows the NPV of the project for BNO incl. subsidy. The first column shows the NPV of the financial analysis minus the discounted subsidy, which is expected in 2004. The second column shows the value of the NPV included the subsidy. The total amount of subsidy will be put in the development of “Delft Central” in order to force the development of tunneling for the rest of Delft.

<table>
<thead>
<tr>
<th>Variant</th>
<th>NPV excl. subsidy</th>
<th>NPV incl. subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate development</td>
<td>-13500</td>
<td>106466</td>
</tr>
<tr>
<td>Integral development</td>
<td>-19330</td>
<td>117746</td>
</tr>
</tbody>
</table>

*Base Case Values x f 1000,-*

![Financial analysis](image)

**Figure 8-2 Behaviour of the NPV for both variants**

Figure 8-2 visualises the difference on outcome between the two variants. The following can be concluded:

- Both variants need extra money to create positive NPV;
- When the subsidy will be provided both variants will get profitable project;
Dominant variables - (tornado diagram)
The variables are set out vertically and the length of the horizontal bar sets out the behaviour of the NPV caused by a change in value of a variable. A large bar describes great sensitivity of the ‘NPV of project’ for changes in input. The input values are derived from Appendix C5.

Figure 8-3 Tornado diagram for BNO of scenario I choice for separate development in area “Delft Central”

Figure 8-4 Tornado diagram for BNO of scenario II choice for integral development in area “Delft Central”

Figure 8-3 Figure 8-4 gives information about dominant variables on the NPV of variant II. Variables have their own nature of dominance on the NPV value. 1. Because of its ‘indirect influence’ on
important values in the used formula's. 2. Because of the direct influence on the value of the NPV of project by a large spreading of possible values.

<table>
<thead>
<tr>
<th>Decision Variable</th>
<th>Nature of dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Duration of construction RE</td>
<td>indirect influence</td>
</tr>
<tr>
<td>5. Costs of Real Estate</td>
<td>direct influence</td>
</tr>
<tr>
<td><strong>State of Nature variables</strong></td>
<td><strong>Nature of dominance</strong></td>
</tr>
<tr>
<td>6. Subsidy</td>
<td>direct influence</td>
</tr>
<tr>
<td>7. Price development</td>
<td>indirect influence</td>
</tr>
</tbody>
</table>

Figure 8-4 showed that the consequences for the 'NPV from project' of a little change in 'duration of construction' and 'price development' are big. The influence diagram of the value of the NPV shows that the big influence is caused by the big interest of the variable in the revenue calculation. 'Subsidy' and 'Costs of real estate' has direct influence and are dominant because of their high value.

8.4 Probabilistic approach of state of nature variables

8.4.1 Introduction

Before running the probabilistic model, the dominant model variables are assessed by gaining background information on the expert opinion in the first subparagraph. The municipality and BNE focus on the spin off that will be provided by the urban quality and new residents. The complexity and the number of uncertainties that influence these values is low. Therefore the influence diagram of the object variable that was created in Chapter 6 will not change.

Based on the tornado diagrams of the value of the NPV for BNO in Figure 8-3 and Figure 8-4, a simplified influence diagram can be constructed for probabilistic analysis. The two 'new' influence diagrams are modelled in DPL4.0. These diagrams are connected to the spreadsheet in Excel97.

8.4.2 Quality of expert opinion

The background of the provided information on the variables will be investigated more detailed. Second interviews with the experts take place give insight in the meaning of the new input. Because the members of the steering group are also asked to give weights on attributes, this interview is the second time that their opinion on the decision problem influences the outcome of the MAUT. Remarkable outcomes on the interviews with experts are shown in the table below.

<table>
<thead>
<tr>
<th>Expert</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td>All experts have their own profession and interests. Therefore they do not give a independent opinion on a part of the input. The experts supplement each other.</td>
</tr>
<tr>
<td><strong>H. Schomaker</strong> (municipality of Delft)</td>
<td>This expert has big interests in reaching the municipality targets. Because of his experience in developing public projects his opinion on time points seems to be realistic. Mr. Schomaker is also a member of the steering group.</td>
</tr>
<tr>
<td><strong>S. de Vries</strong> (chairman of BNO)</td>
<td>This expert wants to start the project as soon as possible. He focuses on the requirements of the municipality of Delft. He wants to achieve these requirements as soon as possible. For financial values he refers to mr. Hoogstraten. Mr. De Vries is a member of the steering group.</td>
</tr>
<tr>
<td><strong>D. van Hoogstraten</strong> (financial engineer BNI)</td>
<td>This expert is financial engineer and has experience in creating financial structure of real estate projects. His estimations on real estate subject seem s to be reliable because all other experts refer to the opinion of this expert. Estimates on time development of stochastic variables were hard to quantify. Mr. Van Hoogstraten is not a member of the steering group.</td>
</tr>
<tr>
<td><strong>W. Snelders</strong> (Head Engineer of division plan development BNE)</td>
<td>This expert seems to go hand in hand with the representative of the municipality. Therefore he also seems to be conservative in estimation time points. Mr. Snelders is a member of the steering group.</td>
</tr>
</tbody>
</table>

*Table 8-7 Remarks on expert opinion*
Three of the four of the experts are member of the steering group. The experts focus on the lobby that is needed for this project. For financial, political and process information they are used to go to specialists within their own company. For the financial analysis they refer to the expert mr. Hoogstraten. All experts supplement each other in the knowledge of different professions.

Analysing the outcome of the deterministic analysis and the remarks in Table 8-7, it can be concluded that the 'state of nature' variables and values estimated by the representative of Delft and the financial engineer have the biggest impact in the assessment of the variants in this phase.

8.4.3 Results for the municipality of Delft

In paragraph 8.3 was analysed that the state of nature variables ‘OZB’ and ‘spending behaviour’ and the ‘number of houses’ influences the value of the spin off from new residents. The values of the state of nature variables and the uncertain decision variables are derived from expert opinion in Appendix C5:

- **Representation of decision problem**

<table>
<thead>
<tr>
<th>( \theta_1 ) = OZB</th>
<th>( \theta_2 ) = Spending behaviour</th>
<th>( \theta_3 ) = Number of houses</th>
<th>P(( \theta_3 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_{1,1} ) = 0.04</td>
<td>( \theta_{2,1} ) = 0.48</td>
<td>( \theta_{3,1} = 1200 )</td>
<td>( \theta_{2,1} = 1400 )</td>
</tr>
<tr>
<td>( \theta_{1,2} ) = 0.05</td>
<td>( \theta_{2,2} ) = 0.50</td>
<td>( \theta_{3,2} = 1400 )</td>
<td>( \theta_{2,2} = 1600 )</td>
</tr>
<tr>
<td>( \theta_{1,3} ) = 0.07</td>
<td>( \theta_{2,3} ) = 0.54</td>
<td>( \theta_{3,3} = 1600 )</td>
<td>( \theta_{2,3} = 175 )</td>
</tr>
</tbody>
</table>

Variables for municipality of Delft and BNE

The collection of possible outcomes of the spin off from residents is described in the decision tree in Appendix G1.

**Variant I:**
- Lowest value of \( \omega \): NPV of economical spin off = \( f \) 34.497.200,-
- Highest value of \( \omega \): NPV of economical spin off = \( f \) 63.811.500,-
- Range = 29234300

**Variant II:**
- Lowest value of \( \omega \): NPV of economical spin off = \( f \) 50.804.300,-
- Highest value of \( \omega \): NPV of economical spin off = \( f \) 85.749.800,-
- Range = 34945500

<table>
<thead>
<tr>
<th>Attribute</th>
<th><strong>Variant I</strong></th>
<th><strong>Variant II</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Value</td>
<td>Base case Value</td>
<td>Range of outcomes</td>
</tr>
<tr>
<td><strong>NPV of spin off for Delft</strong></td>
<td>( f ) 47.914.000,-</td>
<td>( f ) 47.789.000,-</td>
</tr>
<tr>
<td></td>
<td>( f ) 69.789.000,-</td>
<td>( f ) 79.234.300,-</td>
</tr>
<tr>
<td></td>
<td>( f ) 68.478.000,-</td>
<td>( f ) 69.698.200,-</td>
</tr>
<tr>
<td></td>
<td>( f ) 34.945.500,-</td>
<td>( f ) 34.945.500,-</td>
</tr>
</tbody>
</table>

**Table 8-8 Summary of information from decision tree; all values x \( f \) 1,000,-

8.4.4 Results for BNO

**NPV of project**

The dominant decision variables and ‘state of nature’ variables will be modelled probabilistically in further analysis:

<table>
<thead>
<tr>
<th>( \theta_4 ) = Duration of construction RE</th>
<th>( \theta_5 ) = Costs of Real Estate</th>
<th>( \theta_6 ) = Price development</th>
<th>( \theta_7 ) = Subsidy by state of Netherlands</th>
<th>P(( \theta_7 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_{4,1} ) = 5.3 year</td>
<td>( \theta_{5,1} ) = 90000</td>
<td>( \theta_{6,1} = -0.02 )</td>
<td>( \theta_{7,1} = 0 )</td>
<td>0.25</td>
</tr>
<tr>
<td>( \theta_{4,2} ) = 6.0 year</td>
<td>( \theta_{5,2} ) = 140000</td>
<td>( \theta_{6,2} = 0.015 )</td>
<td>( \theta_{7,2} = 360000 )</td>
<td>0.50</td>
</tr>
<tr>
<td>( \theta_{4,3} ) = 11.8 year</td>
<td>( \theta_{5,3} ) = 173000</td>
<td>( \theta_{6,3} = 0.02 )</td>
<td>( \theta_{7,3} = 360000 )</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Table 8-9 Value of state of nature variables Variant I**
8.5.2 Analysis for BNO

The subsidy has been integrated in the ‘NPV of project’ calculation. Therefore the weight of the subsidy will be added to the weight of the ‘NPV of project’.

\[
\lambda \lambda_{1+5} = 0.39 \Rightarrow 0.39(0.39+0.14+0.17) = 0.56 \\
\lambda_{64} = 0.14 \Rightarrow 0.14(0.39+0.14+0.17) = 0.20 \\
\lambda_{6B} = 0.17 \Rightarrow 0.17(0.39+0.14+0.17) = 0.24
\]

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute (X_i)</th>
<th>Weight (\lambda_i)</th>
<th>E(NPV)</th>
<th>Score</th>
<th>E(NPV)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+5</td>
<td>NPV of project for BNO incl. subsidies</td>
<td>0.56</td>
<td>106466</td>
<td>59621</td>
<td>117127</td>
<td>65591</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.20</td>
<td>50449</td>
<td>10090</td>
<td>85031</td>
<td>17006</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.24</td>
<td>47914</td>
<td>11499</td>
<td>68845</td>
<td>16523</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1.00</strong></td>
<td><strong>81210</strong></td>
<td><strong>99120</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8-13 Decision table of BNO: based on expected values

From the decision table can be derived that the decision maker is recommended to choose for variant II.

The renewed decision table shows that a probabilistic approach on the object variables also makes clear that variant II is desirable. Both the municipality and BNO want to create variants that provide in a high spin off values.

The tornado diagrams showed that the objectives as ‘economical spin off’ for Delft and ‘rate of return for BNO’ can be optimised in the further process of the feasibility study by maximising the number of houses.

In spite of a difference in set of weights both members come to the same rational decision.

8.6 Sensitivity Analysis on object variables

8.6.1 Result for Municipality of Delft

A tornado diagram gives the municipality of Delft insight in the dominance of input variables on the output of the economical spin off from new residents. In paragraph 8.3.2 was analysed that the ‘OZB-value’, the spending behaviour of the new residents and the number of houses are dominant for the value of the spin off from new residents.

![Tornado diagram](image)

Figure 8-5 Base Case Tornado diagram of ‘New residents’
Table 8-10 Value of state of nature variables Variant II

The Decision Analysis in DPL 4.0 provides a decision tree with the collection of possible outcomes $\Omega$. Based on the possible outcomes of the 'NPV from project' the tree shows the expected values for both variants that lead to the best choice for this object variable. It is shown in appendix F. Every combination of state of nature that influences the outcome of the value of profit is shown. By showing the expected value of the 'NPV from project' at every 'change node' the decision tree ensures to control the possible scenario on the outcome.

**Variant I:**
- Lowest value of $w$: NPV of economical spin off = $-f\ 85.978,000,-$
- Highest value of $w$: NPV of economical spin off = $f\ 161,464,000,-$

**Variant II:**
- Lowest value of $w$: NPV of economical spin off = $-f\ 13,142,000,-$
- Highest value of $w$: NPV of economical spin off = $f\ 205,977,000,-$

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Value</th>
<th>Variant I</th>
<th>Range of outcomes</th>
<th>Expected Value</th>
<th>Variant II</th>
<th>Range of outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV of project</td>
<td>$f\ 64,657,100,-$</td>
<td>$f\ 106,466,-$</td>
<td>$f\ 247,442,000,-$</td>
<td>$f\ 98,846,500,-$</td>
<td>$f\ 117,127,000,-$</td>
<td>$f\ 219,119,000,-$</td>
</tr>
</tbody>
</table>

Table 8-11 Summary of information from decision tree;

8.5 MAUT analysis of probabilistic approach

The new information on the values of the attributes affects the outcome of the decision tree. Only the dominant attributes will be measured in the decision table of both stakeholders municipality of Delft and BNO. This affects the value of weights. The relation between the weights does not change.

8.5.1 Analysis for the municipality of Delft

The new information results in the following table. Because four attributes were found to have no dominant influence on the outcome of the decision table, the table reduces to three attribute scores. The value of weights increases proportional.

\[
\lambda_4 = 0.21 \Rightarrow 0.21/(0.21+0.17+0.15) = 0.40 \\
\lambda_{4A} = 0.17 \Rightarrow 0.17/(0.21+0.17+0.15) = 0.32 \\
\lambda_{4B} = 0.15 \Rightarrow 0.15/(0.21+0.17+0.15) = 0.28
\]

<table>
<thead>
<tr>
<th>$i$</th>
<th>Attribute ($X_i$)</th>
<th>Weight ($\lambda_j$)</th>
<th>$E(\text{NPV})$</th>
<th>Score</th>
<th>$E(\text{NPV})$</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Subsidy</td>
<td>0.40</td>
<td>134238</td>
<td>53695</td>
<td>201356</td>
<td>80542</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.32</td>
<td>50449</td>
<td>16144</td>
<td>85031</td>
<td>27210</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.28</td>
<td>47914</td>
<td>13416</td>
<td>68845</td>
<td>19277</td>
</tr>
</tbody>
</table>

Table 8-12 Decision table of the municipality of Delft: based on expected values $\times f\ 1000,-$.

The optimum policy that can be derived from the decision table is to choose for variant II.

\[17\] In order to make the decision tree transparent, the outcomes of both variants have been split up; two A3-flaps, with each one branch of the tree, is the result in the appendix F.
Reading the tornado diagram and the object function for the spin off (Chapter 6), it can be concluded that the difference in outcome lies in the number and value of houses that will be developed. Optimising the number of m² real estate is a measure for optimising the income from taxes by OZB.

8.6.2 Result for BNO

**Base Case Tornado diagram**
The tree result in the following ‘mixed’ tornado diagram for both variants:

![Tornado Diagram](image)

*Figure 8-6 Tornado diagram of NPV of profit for both variants; values x f 1000,-*

Figure 8-6 gives insight in the sensitivity of the NPV value for changes in input. From the tornado can be concluded that the range of the outcome of the NPV of profit mainly is determined by the uncertainty on the ‘value of subsidy’, ‘duration of construction’ and ‘the price development of real estate’. Insight in the set of state of nature variables, which influence the value of ‘duration of construction’ could be useful.

8.7 Sensitivity of outcome decision table

*Changing discounting parameters?*
The value of every single attribute depends on the attitude of the decision maker. The discount rate is feature of the decision makers’ attitude towards the project. Because of the high number of uncertainties on the financial feasibility all values of attributes had been discounted by a value of 15% per year.

When the decision maker is able to control the uncertainties he is able to lower the value of the discount rate to a value that is equal to the interest rate; 8% per year. The renewed tree can be used to determine the expected NPV value when the discount rate = 0.08.

The decision tree is shown in appendix G.

<table>
<thead>
<tr>
<th></th>
<th>Variant I</th>
<th></th>
<th>Variant II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV</strong>&lt;br&gt;<strong>Discount rate = 15%</strong></td>
<td>Expected value</td>
<td>Base Case Value</td>
<td>Range of outcomes</td>
<td>Expected value</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>64657</td>
<td>106466</td>
<td>247442</td>
<td>98846</td>
</tr>
<tr>
<td><strong>NPV</strong>&lt;br&gt;<strong>Discount rate = 8%</strong></td>
<td>213895</td>
<td>306938</td>
<td>537831</td>
<td>265527</td>
</tr>
</tbody>
</table>

*Table 8-14 Influence change discount rate on outcome of decision tree; values x f 1000,-*
This results in a renewed decision table:

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute (Xj)</th>
<th>Weight (λj)</th>
<th>E(NPV)</th>
<th>Score</th>
<th>E(NPV)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+5</td>
<td>NPV of project for BNO incl. subsidy</td>
<td>0.56</td>
<td>306938</td>
<td>171885</td>
<td>310779</td>
<td>174036</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.20</td>
<td>50449</td>
<td>10090</td>
<td>85031</td>
<td>17006</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.24</td>
<td>47914</td>
<td>11499</td>
<td>68845</td>
<td>16523</td>
</tr>
<tr>
<td></td>
<td>Score</td>
<td>1.00</td>
<td>193474</td>
<td></td>
<td>207565</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8-15 Influence of change in discount rate on decision making of BNO; discount rate = 8%**

The discount rate does not affect the value of the NPV of Variant II so that the weighted score of the decision table will turn to variant I. The difference between the score of the variants has been decreased compared to the calculation by a discount rate of 15%.

**Changing Time Window**

When the decision maker wants to lower the value of the time window a new decision tree occurs; it is shown in Appendix H. From the tree can be derived that:

<table>
<thead>
<tr>
<th></th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV</strong></td>
<td>Expected value</td>
<td>Base Case Value</td>
</tr>
<tr>
<td>Time Window = 25 years</td>
<td>64657</td>
<td>106466</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>Expected value</td>
<td>Base Case Value</td>
</tr>
<tr>
<td>Time window = 20 years</td>
<td>50376</td>
<td>89005</td>
</tr>
</tbody>
</table>

**Table 8-16 Influence of change in time window; values x 1,000,-**

It results the following decision table:

<table>
<thead>
<tr>
<th>i</th>
<th>Attribute (Xj)</th>
<th>Weight (λj)</th>
<th>E(NPV)</th>
<th>Score</th>
<th>E(NPV)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+5</td>
<td>NPV of project for BNO incl. subsidies</td>
<td>0.56</td>
<td>50376</td>
<td>28211</td>
<td>85289</td>
<td>47762</td>
</tr>
<tr>
<td>6A</td>
<td>Urban quality</td>
<td>0.20</td>
<td>50449</td>
<td>10090</td>
<td>85031</td>
<td>17006</td>
</tr>
<tr>
<td>6B</td>
<td>New residents</td>
<td>0.24</td>
<td>47914</td>
<td>11499</td>
<td>68845</td>
<td>16523</td>
</tr>
<tr>
<td></td>
<td>Score</td>
<td>1.00</td>
<td>49800</td>
<td></td>
<td>81291</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8-17 Decision table for BNO; time window = 20 years; discount rate = 15%**

Because the expected time point of finishing variant I is later than the finishing of variant II, a switch of the time window to 20 years will not affect the outcome of the decision table.

**8.8 Variant choice**

The choice which variant will be optimised is based on the outcome of the decision table. The use of evaluation techniques provides insight in the sensitivity of the values of attributes on uncertain state of nature and changes in decision variables. Therefore this single attribute approached evaluation techniques will be used as supporting information for the development of the variant to a proposal in the third phase of the feasibility study.

**8.8.1 Reading the decision tables of Delft and BNO**

The choice is based on the outcome of the decision tables for the municipality of Delft and BNO. When Delft bases its decision on the outcome of the decision table, variant II is the ‘rational’ decision. The choice decision for BNO can be extracted from the decision table. Variant II is the best choice for BNO.
Both Delft and BNO will have profit from Variant II. Therefore it is recommended to the steering group to work out the plan of variant II in the last phase of the feasibility study. It will result in a proposal for the integral development of Real Estate and infrastructure in the area “Delft Central”.

8.8.2 Reading the decision trees
The decision trees show that Variant II and Variant I create a high spin off value for both BNO and the municipality of Delft. Because variant II seems to satisfy the requirements of the state of the Netherlands it is expected to have a higher value of subsidy and therefore the tree shows scenario’s for variant II that have a higher expected value than for variant I.

8.8.3 Reading the tornado diagrams
The tornado diagrams on financial values for both BNO and the municipality of Delft were shown. The impact of the subsidy on the financial feasibility is of that magnitude that the expected value of variant II is much higher than that of variant I.

The tornado also shows that BNO has to focus on optimising the duration of construction of real estate. The influence of the uncertainty on price development of m² real estate is big. An important internal variable for further design could be the number of m² office. Maximising the number of houses and the total m² real estate will create maximum profit for BNO. The number of m² office was also analysed to be a dominant variable for the municipality. Therefore it can be concluded that optimising the number of square meters in the third phase of the feasibility study will increase the benefits from the variant for both the municipality and BNO.

8.9 Evaluation of techniques
The use of the techniques offered the following insight in the performance of each tool.

Multi Attribute Utility Technique
- The number of experts influences the quality of the outcome of the score in the decision table. Because of the uniqueness of a project in the feasibility phase there are too few experts on one project.
- In this case the decision maker is practically the only expert, he is able to manipulate the MAUT twice.
  1. In order to create his ‘favourite’ outcome, the decision maker is able to manipulate the monetary values of public spin off. Because spin off values of a variant form a big part of the judgement the influence of manipulating behaviour could grow.
  2. Swing weighting was found not be applied properly for all attributes. Because of the ‘2-staged’ approach of the weights heavily depend on the discounting values

Single attribute’ Decision Tree
- The tree makes it possible to keep insight in the possible scenario’s of a single attribute during the rest of the process of the project.

Tornado diagram
- The tornado shows, which input variable, influences the outcome of the model. It gives a clear overview on which uncertainties has to be focussed in optimising the design (decision variables) and further risk management.

18 2-staged process:
1. Discount money streams
2. Swing weighting
9 Risk management for “Delft Central”

9.1 Introduction
The performance of Decision Analysis provides insight in the sensitivity of the outcome of the object variables. It is possible to extract the range of outcomes of an alternative action from the decision tree. Based on this insight the decision maker can be recommended to take risk management activities in order to increase the expected value and to decrease the range of possible outcomes of the object variables. Measures, which decrease the probability of occurrence or the consequences of an event, are defined in paragraph 9.2. The consequences of risk controlling measures are determined in paragraph 9.3 by manipulating the decision tree of the object variable.

9.2 Measures

9.2.1 Influencing probability
1. Political lobby for the subsidy (reducing probability)

Ad.1 Figure 8-3, in the previous chapter, showed the importance of getting subsidy for the financial feasibility of this project. Therefore it is necessary to perform an active political lobby in order to convince political structures of the need of underground infrastructure.

9.2.2 Influencing consequences
Following from the Decision Analysis, measures can be taken in order to control future phases of the design and construction of the project.
2. Optimising square meters real estate (reducing consequence)
3. Insurance of price development of Real Estate (reducing consequence)

Ad.2 In order to decrease the influence of the uncertainty on square meter price development, it is necessary to optimise the distribution of square meters real estate. Furthermore it was noticed that the amount of square meters is the only decision variable that has influence on the outcome of the object variables for both stakeholders; BNO and the municipality of Delft.
Ad.3 The consequences of time development of the square meter price for the NPV of the project were shown in the previous chapter. Because the square meter price development is a consequence of decision making at other economical levels the client it is hard to influence this item directly. Cover a part of the decreasing development of the square meter price by insurance;

9.3 Consequences of measures
When possible, this chapter describes the consequences from measures in a quantitative way. This is performed by a renewed Decision tree. Changing input variables in the input section results in the following financial consequences of risk controlling measures.

Ad.1 Influence of political lobby
A well performed political lobby must lead to $360.000.000,- in 2004. No subsidy of $360.000.000,- means no integral development of infrastructure and real estate. When this first big amount of subsidy is supplied, it is expected that the subsidy can grow up to $450.000.000,-. When we assume that the lobby leads to this value of subsidy, the NPV of the project by a renewed decision tree can be performed:

\[ P(\Theta_2 = 360.000.000) = 0.75 \quad \quad P(\Theta_2 = 450.000.000) = 0.25 \]

The result of this change for the decision tree is shown in Appendix II. The consequences of this change for the possible outcomes of the scenarios in the tree are shown in the table on the next page.
### Part II: Case Study: Development of Delft Central; an underground Decision Problem

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E(NPV)</td>
</tr>
<tr>
<td><strong>NPV (no risk management)</strong></td>
<td>$\mathcal{N}(98.846.000,-, 219.119.000,-)</td>
</tr>
<tr>
<td><strong>NPV (risk management)</strong></td>
<td>$\mathcal{N}(108.301.000,-, 182.501.000,-)</td>
</tr>
<tr>
<td><strong>difference</strong></td>
<td>$\mathcal{N}(9.155.000,-, 36.618.000,-)</td>
</tr>
</tbody>
</table>

**Consequences of political lobby for the NPV**

The range of outcomes of the NPV of profit will decrease by $36.618.000,-. The Costs (NPV of political lobby in the next 25 years) of the political lobby may not exceed the $9.155.000,-. It results in a decreased range of outcomes.

**Ad.2 Influence the consequences of insurance disappointing square meter prices**

In case of variant II, BNO is able to insure the consequences of a decreasing square meter price. Insurance of the possible outcomes lower than 2% per year affects the value of the NPV of the project. Performing a new probabilistic analysis on variant II gives a new expected value. A renewed decision tree can be performed.

\[ P(\theta_4 = 0.015) = 0.75 \quad P(\theta_4 = 0.02) = 0.25 \]

The result of this change is shown in Appendix I2.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E(NPV)</td>
</tr>
<tr>
<td><strong>NPV (no risk management)</strong></td>
<td>$\mathcal{N}(98.846.000,-, 219.119.000,-)</td>
</tr>
<tr>
<td><strong>NPV (risk management)</strong></td>
<td>$\mathcal{N}(111.858.000,-, 188.476.000,-)</td>
</tr>
<tr>
<td><strong>difference</strong></td>
<td>$\mathcal{N}(13.012.000,-, 30.643.000,-)</td>
</tr>
</tbody>
</table>

**Consequences of insurance for the NPV**

The consequence of insuring the square meter prices is a smaller range of outcomes of the NPV of the project. The Costs of insurance (NPV of insurance costs for the next 20 years) may not exceed $13.012.000,-. It results in a decreased range of outcomes.

**Ad.3 Maximise the square meters housing**

Optimising the amount of square meters housing creates financial advantages for both BNO and the municipality of Delft. Here the new economical spin off for Delft and the NPV of the project are calculated by an optimum of square meters:

- 40.000 m² offices
- 45000m² houses > 1675 houses
- 1100 parking places

<table>
<thead>
<tr>
<th>Municipality of Delft</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV (1600 houses)</strong></td>
<td>$\mathcal{N}(69.845.100,-)</td>
</tr>
<tr>
<td><strong>NPV (1675 houses)</strong></td>
<td>$\mathcal{N}(73.116.100,-)</td>
</tr>
<tr>
<td><strong>difference</strong></td>
<td>$\mathcal{N}(3.271.000,-)</td>
</tr>
</tbody>
</table>

**Ballast Nedam Development (BNO)**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NPV (1600 houses)</strong></td>
<td>$\mathcal{N}(98.846.000,-)</td>
</tr>
<tr>
<td><strong>NPV (1675 houses)</strong></td>
<td>$\mathcal{N}(102.795.000,-)</td>
</tr>
<tr>
<td><strong>difference</strong></td>
<td>$\mathcal{N}(3.949.000,-)</td>
</tr>
</tbody>
</table>

**Consequences measure for Delft**

In spite of the separate modelling of the decision situation for BNO and BNE/municipality of Delft, both parties can perform risk management activities in the same field. Optimising the number houses creates an increasing Cash flow for both the Municipality of Delft and BNO.
10 Conclusions and Recommendations

10.1 Introduction
Starting point on the description of conclusions and recommendations is the problem definition of this investigation.

"BNE wants to systemise the decision making of complex decisions by the application of Decision Analysis at Ballast Nedam subsidiaries."

Based on the conclusions in Chapter 4 and the intermediate evaluations in the case study chapters, this Chapter describes the conclusions and recommendations on the performance of a Decision Analysis and the use of decision supporting techniques at BNE group Plan Development. Several interviews with people with experience in this field and by studying of the theory on DA and case studies supported these conclusions. These first conclusions form the basis of this chapter. Furthermore it must provide an example of application of Decision Analysis at BNE by order of a BNO. Conclusions on the performance of the developed model focus on its additional value and the restrictions on use of the quantitative model. The recommendations are related to the performed case study and further use of Decision Analysis in the feasibility studies within Ballast Nedam subsidiaries.

10.2 Conclusions
Decision Analysis can support the variant choice in feasibility studies of BNE group Plan Development by order of BNO. Decision analysis does not solve decision problems at Ballast Nedam subsidiaries. It creates insight in the decision situation and possible consequences of the choice for a variant.

The additional value of the use of Decision Analysis at group Plan Development focuses on three aspects, which will be described more detailed in the following sub paragraphs:
1. The additional value of the performance of Decision Analysis compared to the present situation at BNE group plan development.
2. Additional value of the decision supporting techniques.
3. The restrictions on use of a quantitative model for decision making.

10.2.1 Additional value of Decision Analysis
- Decision Analysis forces the analyst and the client to structure their thoughts.
A good frame of the elements of the decision problem forms a good basis for communication about the problem.

- Performing an analysis of the alternative actions forces the project group to create a clear overview on the 'states of nature' and decision variables that influence the value of the object variables. The influence diagram can be used as a communicative tool.

- The decision tree is a good tool to structure external decision making processes that influence the decision situation at Ballast Nedam subsidiaries.
The decision tree of Ballast Nedam subsidiaries forms a part of the decision tree of stakeholders at higher economical levels.

- The Multi Attribute Utility Technique creates a rational basis for the choice between variants.
The MAUT forces the decision maker to be clear on his judgements of variants by assigning utility and weights on attributes.

- Risk Managing activities can be performed in an earlier phase of the process.
Based on the information of the consequences of possible actions, BNE and its client have the possibility to perform risk-managing activities earlier and in a more efficient way.
10.2.2 Additional value of the decision supporting techniques

- Evaluation techniques on attributes form a basis for Risk Management in further phases of the design process.
  - Decision Tree
    The tree makes it possible to keep insight in the possible scenario's of a single attribute during the further process of the project.
  - The tornado shows which input variable influences the outcome of the model
    It gives a clear overview on which uncertainties has to be focussed for optimising the design (decision variables) and for risk control measures.

10.2.3 The restrictions on use of a quantitative model for decision making

The performance of Decision Analysis based on a quantitative model, provided insight in the restrictions on application at BNE group Plan Development.

- In case of decision problem for multiple stakeholders, the model can not perform as a basis for decision making.
  The different interest of the stakeholders of the steering group did not create a uniform set of weights for decision making. The decision problem was split in a decision problem for the municipality of Delft and BNE and an decision problem for BNO.

- Swing weighting can not be applied in the right way for the calculation of weights.
  The members of the steering group are not able to define values of indifference between the 'low-' and 'high-values' of the 'spin off attributes'.

- Because the decision maker is also the only expert, he is able to manipulate the MAUT twice.
  The decision maker was asked to provide input for both the model and the weighing process. Because of the relative easy manipulating of the spin off values, the decision maker is able to manipulate the weight factor of an attribute.

- In this phase of the design process besides the influence of decision making at other economical levels, the uncertainties on the value of decision variables are also dominant for the value of the financial feasibility of the project.
  The uncertainty on the value of costs for the development of real estate and the uncertainty on the value of the duration of construction were analysed to have big impact on the value of the NPV of the project.

- The number of experts influences the quality of the outcome of the decision table.
  There is a lack of experts in the fields that are important in the feasibility phase. Expertise in quantifying uncertainties in the field of politics can not be found because of the uniqueness of the project.

- It is hard to get expert opinion on time development of uncertain input variables.
  Experts noticed that modelling and estimating of the time development of a 'state of nature variable' in this phase does not have any value. Their estimate on the m² price includes the development of the m² price in time.

- It is not easy to model a decision making hierarchy.
  The decision hierarchy in the steering group can only be modelled when all four members give the same view on the hierarchy in the decision making process. This case showed a special situation in which the stakeholders show their objectives. In reality it could be possible that members of the decision making group do not show all their negotiating tactics and objectives.
10.3 Recommendations

- Add the expertise of performance of Decision Analysis to the group Risk Management at Ballast Nedam Engineering.
  A member of the group Risk Management can perform as the analyst of the Decision Analysis.

- Create a basis for the use of decision supporting techniques at the group Plan Development of Ballast Nedam Engineering.
  A member of the group Risk Management can perform as consultant for use of decision supporting techniques by members of BNE group Plan Development.

10.3.1 Recommendations on application of Decision Analysis

- Create a manual for the performance of Decision Analysis.

- Investigate the application in the first phase of the feasibility study.
  This case study was an example of a suitable decision situation for the use of decision analysis techniques. In order to expand the application forward it would be interesting to investigate the application in the first phase of the feasibility study. In that phase a short analysis on the desirability of a variant must be performed. When one is able to create a standard frame of attributes and a standard for output of the pre-investigation, evaluating techniques as a tornado diagram and risk profile could support this analysis.

10.3.2 Recommendation on the use of decision supporting techniques

- Write a manual for the use of decision supporting techniques

- Create a basis for the use of decision supporting techniques on projects of other subsidiaries.
  In order to promote the additional values of decision analysis it is advised to create an example of application for every subsidiary that acts in early phases of projects.

10.3.3 Recommendations on use of quantitative model for decision making

- Reduce the risk of manipulation of the MAUT.
  Experts were interviewed individually. 'Groupthinking' interview processes could increase the quality of the expert opinion that is used as model input.

- Investigate the need for getting insight in the state of nature variables that influence the uncertainty on outcome of the decision variables.

- Investigate the need for modelling probabilistic dependence of variables per case.
  In more detailed phases of the design process it could be desirable to model correlation between 'state of nature' variables. The spreadsheet always gives the opportunity to get a first insight in the consequences of correlation.
11 References

11.1 Interviews

Interviews focussed on application of Decision Analysis
- Ir. H.Wels. (NRG, Risk Analyst)
  Workshop: “Decision Analysis; strategy selection and portfolio management”

- Ir. B.Polle (NRG, Risk Analyst)
  Workshop: “Application of DPL 4.0 at strategy decision problems”

Interviews that focus on Risk Analysis and Management
- Ir. D. Roeleven (Ballast Nedam International, group Financial Engineering)
  Decision Analysis as a part from risk management

- Ir. A.J.P.Verweij (Ballast Nedam Engineering, group Risk Management)
  Working method of group risk management

- Ir. A.Repko (Ballast Nedam Engineering, group Risk Management)
  Risk Analysis at infrastructure projects

- Ir. J.W. Rösing (Ballast Nedam Engineering, group Plan Development)
  Risk Analysis for Public Private Corporation projects

Interviews focus on plan development at Ballast Nedam
- Ir. W. Snelders (Ballast Nedam Engineering, group Plan Development)
  Working method of group plan development in feasibility studies

- Ir. S. de Vries (Ballast Nedam Development, director)
  The requirements of a client; and the role of the developing company.

- Drs. D. van Hoogstraten (Ballast Nedam International, financial engineer)
  Cost estimates in feasibility studies

Interviews focus on development of plan area “DelftCentraal”
- Ir. H.J. Schomaker (Municipality of Delft, plan development services)
  Quantification of public values of a project

- Ir. M. Spoelstra (Ballast Nedam Engineering, group Plan Development)
  Organisation of project “Delft Centraal”

11.2 Literature

Literature on risk management


Part II: Case Study: Development of Delft Central; an underground Decision Problem


Literature on decision analysis


Literature on decision theory


[Vrijling] “Kansen in de Civiele Techniek, CUR rapport”, Prof.drs.ir. J.K. Vrijling e.a.,


12 Terminology

1. Decision Analysis
   A methodology that helps the decision maker to decompose a complicated problem into a framework of smaller parts that can be easily analysed and understood [Clemen]

2. Decision analysis supporting techniques
   Techniques as the decision tree and influence diagram that create a transparent representation of the decision problem;

3. Risk Analysis
   Identification of events and quantification of risks of a project;

4. Risk Management
   The control of deviation of time, costs and technique of a project;

5. Objective
   Goal that has to be achieved by the decision maker;

6. Objective variable
   Variable with which the objective can be measured;

7. Proxy variable
   Variable with which intangible objectives can be measured;

8. Decision
   Choice for an action;

9. Decision variable
   Variable that represent a feature of an action;

10. State of Nature
    The circumstances of nature that influence the consequences of the decision makers alternative actions;

11. State of nature variable
    Variable that expresses the state of nature that influences the value of the object variable;

12. Objective function
    Function description for the object variable or proxy variable in terms of decision variables, state of nature variables and fixed values;

13. Attribute
    Feature of an alternative action on which the value of the alternative can be measured;

14. MAUT analysis
    Multi Attribute Utility Technique analysis. Combines the values of multi attributes to a total utility score of an alternative action;

15. Utility score
    Outcome of the expected value of the utility for a particular decision alternative;

16. Utility function
    A function that represents the decision makers preferences between alternatives with uncertain outcomes;

17. Influence diagram
    An diagram that describes the dependence or relations between decisions and uncertainties within a decision problem;
<table>
<thead>
<tr>
<th></th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Base Case Tornado diagram</td>
<td>A diagram that represents the outcomes of a decision tree by measuring the effect of a change in the value of a parameter on the value of an object variable;</td>
</tr>
<tr>
<td>19</td>
<td>Deterministic calculation</td>
<td>Calculation of the outcome of a value by putting all input variables on their mean value;</td>
</tr>
<tr>
<td>20</td>
<td>Probabilistic calculation</td>
<td>Calculation of the expected value by assigning probability to the possible outcomes of the input variable;</td>
</tr>
<tr>
<td>21</td>
<td>Decision Tree</td>
<td>A technique that represents the possible utilities on different actions of the decision maker;</td>
</tr>
<tr>
<td>22</td>
<td>Discount rate</td>
<td>A rate that discounts case flows in future time points. In this report the discount rate consist of two parts. A fixed part, that represents the expectations on the interest rate and an additional variable part that represents the decision makers’ attitude towards uncertainties that influence the cash flows of the project;</td>
</tr>
<tr>
<td>23</td>
<td>Time window</td>
<td>Time period on which the project cash flows are calculated;</td>
</tr>
<tr>
<td>24</td>
<td>Net Present Value</td>
<td>Difference between revenues and costs discounted to a value date over a certain time period.</td>
</tr>
</tbody>
</table>
"Development of Delft Central"; an underground Decision Problem

application of Decision Analysis at Ballast Nedam Engineering

Appendices
“Development of Delft Central”; an underground Decision Problem

application of Decision Analysis at Ballast Nedam Engineering

Appendices

P.J. de Jong

Amstelveen, August 2000

Section Hydraulic Engineering/Section Business Sciences
Faculty of Civil Engineering and Geo Sciences
Delft University of Technology

Ballast Nedam Engineering
Amstelveen
Summary

As a result of the final report of "Development of Delft Central; an underground Decision Problem", this report bundles the appendices. This Report contains eight appendices that support the outcomes of the investigation of application of Decision Analysis techniques at Ballast Nedam Engineering.

Appendix A and B correspond with the text in part I of the report. The other appendices show the results of the performance of the case study on the development of infrastructure and real estate in area "Delft Central".

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Appendix A

Situation at BNE Plan Development

A1: Objectives at economical levels
A2: Interview on working method at plan development
Appendix A1    Objectives at economical scales

Macro: State of the Netherlands
- Image country

Mezzo: Municipality
- Minimise hindrance during construction
- Image municipality
- Employment
- Max. inhabitants
- Urban quality
- Employment

Micro: Ballast Nedam NV
- Max. Profit
- Max. Turnover
- Image of company
- Urban quality

Macro economical
Mezzo economical
Micro economical
Appendix A2

Interview on working method at plan development

Interview in Dutch
Doel; besluitvorming binnen plan ontwikkeling in beeld brengen.

1. Behandeling varianten/alternatieven
Worden alle alternatieven geïdentificeerd en in voldoende mate meegenomen?

Komen jullie wel eens op alternatieven die strikt genomen buiten de randvoorwaarden zouden liggen?

2. Helderheid vraagstuk
Is iedereen op de hoogte wat de randvoorwaarden van het probleem zijn?

Is het altijd duidelijk wat er precies besloten moet worden?

Zijn alle betrokken partijen geïdentificeerd?

3. Belangen
Hoe wordt met belangen binnen de groep omgegaan?

Worden belangen in kaart gebracht? En op welke wijze?

Hoe worden de belangen tegen elkaar afgewogen?

3. De beslissing
Kan je aangegeven op grond waarvan jullie een beslissing nemen(techniek/tijd/geld/organisatie/informatie/kwaliteit)? Welk onderdeel krijgt het meeste aandacht?

4. Evaluatie en documentatie
Worden beslissingen geëvalueerd? Zo ja, hoe?

Hoe worden beslissingen gedocumenteerd?

Zijn de gronden voor de genomen beslissingen traceerbaar en inzichtelijk?

5. Risico Management
Wordt er een risico analyse toegepast op tussentijdse vraagstukken? Zo ja; hoe en wanneer(achteraf/vooraan)?

Wordt er een risico analyse toegepast op het hele project? Zo ja; hoe en wanneer (achteraf/vooraan)?

Als de discussie zich richt op risico's, worden de risico's dan het liefst vermeden(kans op ongewenste gebeurtenis verkleinen) of worden de gevolgen geprobeerd te beïnvloeden (consequentials beïnvloeden)?
Vragenlijst voor Wim Snelders met betrekking tot stuurgroep “Delft Centraal"

Doel: besluitvorming van plan ontwikkeling in beeld brengen.

1. Behandeling varianten/alternatieven

Worden alle alternatieven geïdentificeerd en in voldoende mate meegenomen?

Er zijn een aantal alternatieven onderzocht en uitgezet.

Komen jullie wel eens op alternatieven die strikt genomen buiten de randvoorwaarden zouden liggen?

Zouden kunnen bijge? ja het kan om ook de treknotjes te gebruiken.

2. Helderheid vraagstuk

Is iedereen op de hoogte wat de randvoorwaarden van het probleem zijn?

Is het altijd duidelijk wat er precies besloten moet worden?

Zijn alle betrokken partijen geïdentificeerd?

3. Belangen

Hoe wordt met belangen binnen de groep omgegaan?

Worden belangen in kaart gebracht? En op welke wijze?

Hoe worden de belangen tegen elkaar afgewogen?
3. De beslissing
Kan je aangegeven op grond waarvan jullie een beslissing nemen (techniek/tijd/geld/organisatie/informatie/kwaliteit)? Welk onderdeel krijgt het meeste aandacht?

Bijna reeds aangegeven werd in de bijlage, dat de interne groep een onderscheid moet maken. In dit onderwerp is de reden laten we het gehele project vooruit denken, dus ook techniek, omdat er bij techniek dus wel verschillende fasen zijn.

4. Evaluatie en documentatie
Worden beslissingen geëvalueerd? Zo ja, hoe?

Er wordt altijd een stelsteek bij standpunten van eigen en externe partijen (interne Units, wetenschap, GMS, EO etc.)

Hoe worden beslissingen gedocumenteerd?

via reeds aangegeven bijlage
ja aanwezig documentatie

Zijn de gronden voor de genomen beslissingen traceerbaar en inzichtelijk?

Niet altijd

5. Risico Management
Wordt er een risico analyse toegepast op tussentijdse vraagstukken? Zo ja; hoe en wanneer (achteraf/vooraan)?

Gelet op de stelsteek zijn er enkele cases waar de inkoop een rol heeft

Wordt er een risico analyse toegepast op het hele project? Zo ja; hoe en wanneer (achteraf/vooraan)?

Ja, - zie bijlage

Als de discussie zich richt op risico’s, worden de risico’s dan het liefst vermeden (kans op ongewenste gebeurtenissen verkleinen) of worden de gevolgen geprobeerd te beïnvloeden (consequenties beïnvloeden)?

Er worden wel elke gebeurtenis met behulp van reisverslagen en andere inkooppunten met bewijs vermeden. In 2 of 3 gevallen is dat er nog niet aan.

Omdat de interne partijen nog niet genoeg op van volledige en rechtvleugelige beslissingen leven.

Appendix A2
Appendix B

Modelling of object variables

Influence diagram
B1: Objectives of steering group
B2: Spin off elements
B3: Financial elements
B4: Final influence diagram I
  Decision variables are modelled by value nodes

B5: Final Influence diagram II
  Decision variables are modelled by change nodes
Appendix B2: Spin off elements
Appendix B1: Object variables

Multi Objectives:
Maximize NPV of Profit for BNO
Maximize NPV of Spin off for Delft
Maximize NPV of Spin off for Ballast Nedam Engineering
Maximize NPV of Spin off for Ballast Nedam Development
Appendix B3: Financial elements
Appendix B4: Final Influence diagram I:
Decision variables are modelled by value nodes
Appendix B5: Final Influence diagram II:

Decision variables are modelled by change nodes
Appendix C

Expert opinion
Results of interviews with experts

C1: Expert Diederik van Hoogstraten
C2: Expert Henk Schomaker
C3: Expert Wim Snelders
C4: Expert Sicco de Vries

C5: Combined opinion
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#### Variant nr.1

**All costs in €1000,-**

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### Name Expert: Wim Snelders

#### Variant nr.2

**All costs in €1000,-**

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Appendix C5  Combined opinion

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Financial values x f 1000,-

Decision variables:

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State of Nature Variables

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Time Series

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*Calculation of hindrance costs in accordance with formula on page 44 of report:
(Cost Var.II)-(Costs Var.I)/(duration Var.I-durataion Var.II) =

Variant II = (454,700,000-446,000,000)/(2016-2009) = f 1,200,000,- per year
Variant I = 50% of Hindrance Costs Var.II. = f 600,000,- per year
Appendix D

Numerical model

D1: Spreadsheet
   • Input section
   • Time window section
   • Calculation section

D2: Formulas spreadsheet
D3: Simplified probabilistic model
D4: Link between DPL4.0 and Excel7.0
### Results

- **NPV of cost difference**: 117127 NLG.
- **Current cost difference**: 1022570 NLG.

### Input Section

####Alle kosten in f1000,-

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Appendix D1
## Appendix D1 Spreadsheet
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<td>26558</td>
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<td>32374</td>
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<td>Revenue parking places Fi/year</td>
<td>140655</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>5152</td>
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<td>Revenue houses Fi/year</td>
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<td>Rev's real estate</td>
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<td>72460</td>
<td>75271</td>
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<td>81232</td>
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<td>total revenues Fi/year</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>5928</td>
<td>62244</td>
<td>64651</td>
<td>67154</td>
<td>69755</td>
<td>72460</td>
<td>75271</td>
<td>78194</td>
<td>81232</td>
</tr>
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<td>Revenues - Costs Fi/year</td>
<td>1022570</td>
<td>0</td>
<td>0</td>
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<td>92214</td>
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<td>78194</td>
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</tbody>
</table>

**Appendix D1**
Appendix D2    Formulas Spreadsheet

Object Variable: Net Present Value (NPV)

A. Input Section
1. Decision variables
2. State of Nature variables
3. Discounting parameters: Time Window; Discount rate

For the NPV of profit calculation, the input section of the spreadsheet contains the following variables. When possible the symbols from the object functions in Chapter 6 are given. The third column shows the name of the cell that will be used in the calculation section.

<table>
<thead>
<tr>
<th>Input Variable</th>
<th>Symbol</th>
<th>Name</th>
</tr>
</thead>
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<tr>
<td>Discount rate</td>
<td>r</td>
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</tr>
<tr>
<td>m2 offices</td>
<td>m2offices</td>
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<td>m2houses</td>
<td>m2houses</td>
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<tr>
<td>parking places</td>
<td>parking</td>
<td>parking</td>
</tr>
<tr>
<td>time development sqm price</td>
<td>sqmdev</td>
<td>sqmdev</td>
</tr>
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<td>Price m2 office</td>
<td>pricesqnm</td>
<td>pricesqnm</td>
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<tr>
<td>Price m2 house</td>
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<td>pricesqnm1</td>
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<tr>
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<td>development occupation rate</td>
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<td>OrcateDev</td>
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<td>Duration Construction RE</td>
<td>tWR-tRE</td>
<td>Duco2</td>
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</tbody>
</table>

B. Calculation Section:

Object function: \( NPV = \sum_{i}^{n} \left( \frac{\text{Total_revenues} - \text{Total_Costs}}{(1+r)^{t_i}} \right) \)

Time Windows:
- TimeWRREWindow = time window revenues real estate = \( t_W - t_e \)
- TimeWRelyear = time window = \( t_W \)
- TimeWFInRelWindow = time window financing = \( t_F - t_F \)
- Time Windowobt = time window obtaining = \( t_o - t_o \)
- TimeWindowConsTun = time window construction tunnel = \( t_T - t_T \)
- TimeWindowConsRE = time window construction real estate = \( t_{RE} - t_{RE} \)
- TimeWindowConsCP = time window construction pit = \( t_p - t_p \)

Time Window Construction Real Estate

Cell name time point of construction Real Estate

<table>
<thead>
<tr>
<th>F80</th>
<th>=IF(delayest-F79&lt;=0;E80+1,0)</th>
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<tr>
<td>77</td>
<td>78</td>
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<tr>
<td>79</td>
<td>80</td>
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<tr>
<td>81</td>
<td>82</td>
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25
Appendix D2    Formulas Spreadsheet

Object Variable: Net Present Value

Costs section

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<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
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Other formulas in cost section:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Formula in Cell (costs per year)</th>
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</thead>
<tbody>
<tr>
<td>Costs of Tunnel</td>
<td>((tunsec-Subs*(1+Subsdev)/Year)/Ducol)*Time Window Construct. tunnel</td>
</tr>
<tr>
<td>Costs of Real estate</td>
<td>((estatesec/Ducol)*TimeWindow Constr. RE</td>
</tr>
<tr>
<td>Costs of construction Pit</td>
<td>(((Cocol+Cocol)/(MAX(Duco1;Ducol)))*TimeWindow Const. CP</td>
</tr>
<tr>
<td>Obtaining Costs</td>
<td>(obtcost/(MAX(Duco1;Ducol)))*Time Window obt.</td>
</tr>
<tr>
<td>Financing Costs</td>
<td>IF(TimeWFinRelWindow=1;interest*(CS2Fin);0)</td>
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</table>

Revenues section

<table>
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<tr>
<th>J136</th>
<th>J137</th>
<th>J138</th>
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</table>

Other formulas in revenue section:

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<th>Formula in Cell (Revenues per year)</th>
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<tbody>
<tr>
<td>Revenues offices</td>
<td>(((m2offices<em>pricesqm</em>Ocrate2)/Ducol)<em>TimeWRREWindow</em>((1+sqmdev)<em>TimeWRelyear)</em>((1+ocratedev)*TimeWRelyear)</td>
</tr>
<tr>
<td>Revenues Parking places</td>
<td>(((parking<em>pricesqm2</em>Ocrate2)/Ducol)<em>TimeWRREWindow</em>((1+ocratedev)*TimeWRelyear)</td>
</tr>
<tr>
<td>Revenues houses</td>
<td>((m2houses<em>pricesqm1</em>Ocrate2)/Ducol)<em>TimeWRREWindow</em>((1+sqmdev)<em>TimeWRelyear)</em>((1+ocratedev)*TimeWRelyear)</td>
</tr>
</tbody>
</table>
Appendix D2  Formulas Spreadsheet

Object Variable: Net Present Value

C. Output section
Object variable: Net Present Value

In this section the difference per year between revenues and costs are discounted. The Cells E148 until AD148 represents this difference over the time window of 25 years.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<th>M</th>
<th>N</th>
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<tbody>
<tr>
<td>157</td>
<td></td>
<td>=NPV(Discount;RSREVminCosts)</td>
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<td></td>
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<tr>
<td>148</td>
<td>Revenues - Costs</td>
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<td>FL/yr</td>
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<td>151</td>
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</tbody>
</table>

Formula in cell C153 = NPV(Discount;RSREVminCosts) = NPV(0.15;E148:AD148)

1 The same spreadsheet model calculates the object variables ‘Urban Quality’ and ‘New residents’. Only difference:
- Decision variables
- State of nature variables
- Object functions
- Time Windows

For a more detailed insight in the performance of the spreadsheet it is advised to look at the BNE network: The spreadsheet has been saved: “C:\afstudierwerk\V de Jong\Final Report\appendices\spreadsheets\NPV”
Appendix D3  Simplified probabilistic model
Linked with Excel 7.0 spreadsheet

This node export the values of state of nature to the spreadsheet

Price development

revenues real estate

m2 offices

Cost real est

Duration construction RE

duration construction tunnel

Costs

Tunnel

Costs Rf

Subsidy

Spin off for Ballast Nedam

Spin off for Delft

Time window

discount rate

profit

This node import calculated NPV value from the spreadsheet

Variant I of Variant II

Ballast Nedam Engineering

TUDelft
Appendix D4  Link between DPL4.0 and Excel 7.0

Step 1: Connection between influence diagram node and excel spreadsheet

Double click on node!!

Step 1: create link to Excel

Linked Excel7.0 spreadsheet

Linked cell in spreadsheet

Spreadsheet:
c:\my documents\vapportage\case study\var2.xls

Cell/Variable name (blank means same as node name):
PDAmodule\zgodov

Link type:
- Import (get data from sheet/program)
- Export (send data to sheet/program)
- Drawup
- Cancel

Step 2: Determine object function of influence diagram

Action: Choose the menu ‘model’ from the menu bar. The choose ‘objective…’

Variant Attribute on which the decision will be made

Choose value from influence diagram that has to be optimised
Appendix D4  Link between DPL4.0 and Excel 7.0

Step 3: Choose a Get/Pay expression. The Get/Pay expression determines which attribute will be calculated at the end of the policy tree.

Step 1: Select chance node that is the endpoint of the decision tree.
Step 2: Hit right mouse button
Step 3: Choose 'Get/Pay'
Appendix E

Values for Multi Attribute Utility Analysis

*Results from spreadsheet*
E1: Calculation section of variant I
E2: Calculation section of variant II
E3: Deterministic values of object variables
E4: Weighing factors
### Financial Analysis

#### Costs Section

<table>
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<tr>
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#### Revenue Section

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*Appendix E1 Spreadsheet Variant I*
### Costs section

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### Revenue section

| Revenue offices               | FL/year  | 723716| 0    | 0    | 0    | 22309 | 23087 | 23912 | 24756 | 28630 | 28635 | 27471 | 28441 | 29445 | 30484 |
| Revenue parking places        | FL/year  | 140665| 0    | 0    | 0    | 6154  | 5287  | 5362  | 6469  | 5579  | 5890  | 5804  | 5920  | 6039  | 6159  |
| Revenue houses                | FL/year  | 752225| 0    | 0    | 0    | 23188 | 24008 | 24884 | 26731 | 26840 | 27580 | 28553 | 29561 | 30565 | 31685 |
| Rev's real estate             | FL/year  | 161036| 0    | 0    | 0    | 50651 | 52360 | 54128 | 55657 | 57848 | 50805 | 61829 | 63923 | 66089 | 68329 |
| Residents                     | FL/year  | 0      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Sustainability                | FL/year  | 0      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Spin off for Defit            | FL/year  | 0      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Spin off new project          | FL       | 0      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Spin off of hindrance         | FL/year  | 0      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| **total revenues**            | FL/year  | 1514555| 0    | 0    | 0    | 50651 | 52360 | 54128 | 55657 | 57848 | 50805 | 61829 | 63923 | 66089 | 68329 |
| Revenues - Costs              | FL/year  | 364410| 0    | 0    | 20739 | 76815 | 24493 | 22784 | 21016 | 19178 | 17296 | 18853 | 61829 | 63923 | 66089 |
| **difference discounted**     | FL/year  | -19335| 0    | 0    | -13636 | -43910 | -12177 | -3850 | -7901 | -8272 | -4916 | 4600  | 13290 | 11948 | 10741 |

**current difference**         | 364410   | -19335| 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

**NPV of difference**          | -19330   | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

Appendix E2
Appendix E3  Deterministic values of object variables

2. Economical spin off for BNO

\[ NPV(\text{extra\_turn\_BNO}) = \sum_{t=2004}^{2015} \frac{(\text{Extra\_turnover\_BNO})(1)}{(1 + r)^{t-2004}} \]

There is no detailed information available. The extra turnover is estimated on \$25,000.000,- in accordance with the steering groups opinion. The extra turnover of \$25,000.000,- per year is estimated over a time period of 10 years after the start of the Delft project.

Variant I:
No extra turn over

Variant II:
\[ NPV(\text{extra\_turn\_BNO}) = \sum_{t=2004}^{2015} (25,000,000) \frac{1}{(1 + 0.15)^{t-2004}} = 54,243,804 \]

3. Economical spin off for BNE

\[ NPV(\text{extra\_turn\_over\_BNE}) = \sum_{t=2004}^{2015} \frac{((\text{Extra\_engineerings\_turnover\_BNE}))(1)}{(1 + r)^{t-2004}} T \]

Here is no detailed information available on the time development of extra turnover. The extra engineering turnover is estimated on \$500,000,- in accordance with the steering groups opinion. The extra turnover of \$500,000,- per year is estimated over a time period of 10 years after the start of the Delft project.

Variant I:
No extra turn over

Variant II:
\[ NPV(\text{extra\_turn\_BNE}) = \sum_{t=2004}^{2015} (500,000) \frac{1}{(1 + 0.15)^{t-2004}} = 1,084,876 \]

4. Hindrance during Construction:

\[ NPV(\text{hindrance}) = \sum_{t=2006}^{2017} \frac{(\text{hindrance\_Costs\_per\_year})(1)}{(1 + r)^{t-2006}} \]

Variant I:
\[ NPV(\text{hindrance}) = \sum_{t=2006}^{2017} (6000) \frac{1}{(1 + 0.15)^{t-2006}} = 16,170.034 \]

Variant II
\[ NPV(\text{hindrance}) = \sum_{t=2003}^{2012} (12000) \frac{1}{(1 + 0.15)^{t-2003}} = 39,599.062 \]
Appendix E3  Deterministic values of object variables

5. Subsidy

Subsidy is expected in 2004; four years from the value date.

\[ NPV(\text{Subsidy}) = \text{Subsidy by State of the Netherlands} \left( \frac{1}{(1 + r)^4} \right) \]

Variant I:

\[ NPV(\text{Subsidy}) = 270.00.000 \left( \frac{1}{(1 + 0.15)^4} \right) = f \ 134.238.000,- \]

Variant II:

\[ NPV(\text{Subsidy}) = 360.000.000 \left( \frac{1}{(1 + 0.15)^4} \right) = f \ 201.356.000,- \]

6. Spin off of project for municipality of Delft

a. Urban quality – value factor for houses

\[ NPV(\text{urban quality}) = \text{number of houses} \times \text{new average house value} \left( \frac{1}{(1 + r)^4} \right) \]

nr. of houses in Delft: 32000 houses
average value of houses in Delft: f 185.000,-/house

Variant I:

\[ \text{New average house value} = \frac{(1400 \times 400000) + (32000 \times 185000)}{(32000 + 1400)} = f \ 194.000,- \]

\[ NPV(\text{urban quality}) = (1400 \times 194000)(\frac{1}{(1 + 0.15)^4}) = 50.448.700 \]

Variant II:

\[ \text{New average house value} = \frac{(1600 \times 750000) + (32000 \times 185000)}{(32000 + 1600)} = f \ 215.000,- \]

\[ NPV(\text{urban quality}) = (1600 \times 215000)(\frac{1}{(1 + 0.15)^4}) = 85.031.500 \]
Appendix E3 Deterministic values of object variables

b. New residents:

\[
NPV(taxes\_real\_estate) = \sum_{t=2013}^{t=2025} (0.05 \times 1600 \times 550000) \left(\frac{1}{(1 + 0.15)^{t-2013}}\right)
\]

\[
NPV(spendings) = \sum_{t=2013}^{t=2025} (0.5 \times 63000 / 2 \times 1600 / 2.2) \left(\frac{1}{(1 + 0.15)^{t-2013}}\right)
\]

Variant I:
1. \(NPV(taxes\_real\_estate) = \sum_{t=2013}^{t=2025} (0.05 \times 1400 \times 400000) \left(\frac{1}{(1 + 0.15)^{t-2017}}\right)\)
2. \(NPV(spendings) = \sum_{t=2017}^{t=2025} (0.5 \times 63000 / 2 \times 1400 / 2.2) \left(\frac{1}{(1 + 0.15)^{t-2017}}\right)\)
3. + 2. = 47,789,000

Variant II:
3. \(NPV(taxes\_real\_estate) = \sum_{t=2013}^{t=2025} (0.05 \times 1600 \times 550000) \left(\frac{1}{(1 + 0.15)^{t-2013}}\right)\)
4. \(NPV(spendings) = \sum_{t=2013}^{t=2025} (0.5 \times 63000 / 2 \times 1600 / 2.2) \left(\frac{1}{(1 + 0.15)^{t-2013}}\right)\)
3. + 4. = 69,698,000
Appendix E4 Weighing factors

I. Ordering weighing factors

F. Interview in Dutch

Doel: Dit stuk heeft als doel uw mening over de eigenschappen van varianten, die ontwikkeld worden in een haalbaarheidsstudie, in kaart te brengen en een wegingsfactor toe te kennen.

Korte situatieschets: De stuurgroep "Delft Centraal" houdt zich bezig met een onderzoek naar mogelijkheden om infrastructuur en vastgoed naast elkaar te ontwikkelen. Hierin worden er twee varianten onderzocht en uitgewerkt als een scenario. De ene variant behelst het gescheiden en na elkaar ontwikkelen van vastgoed en infrastructuur. Hiervoor zullen twee 'kleine' bouwkuipen na elkaar geconstrueerd worden om de ontwikkeling te laten plaatsvinden. De andere variant richt zich op een integrale ontwikkeling van vastgoed en infrastructuur. Hierin wordt gekozen voor een grote bouwkuip die gedurende de hele bouw aanwezig is. Om tot een goede keuze te komen tussen deze twee varianten zijn twee gedetailleerde beschrijvingen toegevoegd om de situatie helderder in kaart te brengen.

Beslissing: Keuze tussen Variant I (twee gescheiden bouwkuipen na elkaar en beperkte hoeveelheid vastgoed) en Variant II (één grote integrale permanente bouwkuip en hoge graad van vastgoedontwikkeling).

Bij het goed in kaart brengen van de beslissingssituatie is het van belang de eigenschappen van varianten te wegen. Om dit te bewerkstelligen vraag ik u het volgende uitgaande van de lijst van eigenschappen hieronder:

Eigenschappen van een variant (Alle waarden x f 1000,-)

<table>
<thead>
<tr>
<th>Eigenschap</th>
<th>Laagste waarde</th>
<th>Hoogste waarde</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Netto Contante Waarde voor het project</td>
<td>-19.330 over 25 jaar</td>
<td>- 13.500 over 25 jaar</td>
</tr>
<tr>
<td>2  Imago verbetering voor BNO door het ontwikkelen van een Publiek Privaat Project</td>
<td>Geen imago verbetering</td>
<td>Extra omzet van 52.244 over eerste 10 jaar na start bouw Delft Centraal</td>
</tr>
<tr>
<td>3  Imago verbetering voor BNE door de opgedane ervaring in het ontwikkelen van haalbaarheidsudies voor Publiek Private projecten.</td>
<td>Geen imago verbetering</td>
<td>Extra omzet van 1.084 over eerste 10 jaar na start bouw Delft Centraal door bezit expertise</td>
</tr>
<tr>
<td>4  Hinder tijdens de bouw - hinder voor verkeer en omwonenden tijdens de bouw</td>
<td>6000 per jaar gedurende de bouw periode van 12 jaar</td>
<td>12000 gedurende de bouw periode van 6 jaar</td>
</tr>
<tr>
<td>5  Verwachte Subsidies(indirecte inkomsten)</td>
<td>270.000 per 1 jan. 2004</td>
<td>405.000 per 1 jan. 2004</td>
</tr>
<tr>
<td>6  Maatschappelijke neveneffecten van een variant - waarde stijging van de grond in het centrum gebied</td>
<td>50.449 na oplevering project</td>
<td>85.031 na oplevering project</td>
</tr>
<tr>
<td>7  Economische neveneffecten van een variant - Extra inkomsten voor de gemeente via de Onroerend Zaal Relasting (OZB) - Extra uitgave van nieuwe bewoners in Delft</td>
<td>47.789 jaar na afloop van project</td>
<td>69.698 per jaar na afloop van het project</td>
</tr>
</tbody>
</table>

Stap 1: Zet in gedachte alle criteria op hun laagste score
Stap 2: Schrijf het criterium op dat u zou kiezen als u de mogelijkheid had om voor een enkel criterium de score te maximaliseren. En schrijf deze op....
Stap 3: Verwijder het gekozen criterium uit de lijst
Stap 4: Herhaal stap 2 voor de nieuwe lijst
Stap 5: Ga op deze manier door tot u alle criteria op bovenstaande wijze uit de lijst hebt verwijderd.
Appendix E4  Weighing factors

Objective: Determine the $\lambda_j$'s of the total value function

$$u(x_5, x_{6A}, x_{6B}, x_1, x_2, x_3) = \sum_{j=1}^{7} \lambda_j u_j(x_j)$$

The order of $\lambda$'s for the members of the steering group can be described by:

<table>
<thead>
<tr>
<th>Member of Steering group</th>
<th>Order of $\lambda$'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delft (Henk Schomaker)</td>
<td>$\lambda_1 &gt; \lambda_{6A} &gt; \lambda_{6B} &gt; \lambda_2 &gt; \lambda_3 &gt; \lambda_4 &gt; \lambda_5$</td>
</tr>
<tr>
<td>BNE (Wim Snelders)</td>
<td>$\lambda_2 &gt; \lambda_{6A} &gt; \lambda_{6B} &gt; \lambda_1 &gt; \lambda_3 &gt; \lambda_4 &gt; \lambda_5$</td>
</tr>
<tr>
<td>BNO (Sicco de Vries)</td>
<td>$\lambda_3 &gt; \lambda_1 &gt; \lambda_{6B} &gt; \lambda_{6A} &gt; \lambda_2 &gt; \lambda_4 &gt; \lambda_5$</td>
</tr>
</tbody>
</table>

Remarks on interview:

- Generally the municipality of Delft focus on the urban quality that will be provided by the project. In this phase of the process getting subsidy for the project has the absolute priority for municipality.
- Generally BNE focus on the requirements of the municipality of Delft. Therefore BNE and Delft has the same opinion on the order of attributes. Getting subsidy for BNE has the absolute priority.
- Generally the project developer (BNO) focus on its own short-term objective (NPV of profit) and the requirements of the municipality of Delft. Getting subsidy has absolute priority.
- 'New residents' has a higher priority than the 'urban quality' for BNO. In this phase BNO wants to convince the municipality of Delft of its' secondary incomes so that Delft will participate in the financing of the project during construction.
Appendix E4  Weighing factors

II. Determine the values of indifference.
Assumption: Both BNE and BNO focus on the requirements of the municipality of Delft. Therefore the opinion on the value of indifference between the objectives of the municipality of Delft ($\lambda_{6A}$ and $\lambda_{6B}$, $\lambda_{8A}$ and $\lambda_4$, $\lambda_1$ and $\lambda_4$, and $\lambda_3$ and $\lambda_4$) will be copied by BNE and BNO. The values of indifference are determined based on Table 8-2; discounted values of the attributes.

Swing weighing

Put the attribute with the highest ‘ranking’ on its’ lowest value and the rest of the attributes on their lowest value. In accordance with Appendix M (p.36) this is the profile $x^{[3]}$. This profile will be compared with the profile $x^{[1,2,3,4,6,6B]}$. ‘Swing’ the value of the attribute with the second ranking between it’s lowest and highest value the decision maker is indifferent between the value of the profile $x^{[3]}$ and $x^{[1,2,3,4,6,6B]}$.

A. Municipality of Delft:
1. $\lambda_{3B} > \lambda_{6A}$
Besides the development of “Delft Central”, the amount of subsidy is also necessary for the development of the rest of the tunneling project of Delft. Therefore subsidy has the absolute priority compared the value of urban quality. The high value of urban quality must lead to the subsidy of at least $\text{f} 270.000.000$.- in 2004. Because the decision maker assumes that the highest value of urban quality of a variant will result in the needed subsidy, swing weighting is possible. The decision maker is indifferent between the highest value of urban quality and the lowest value of the subsidy

![Urban Quality vs Subsidy Diagram]

Figure A-1 Indifference curve of NPV of Subsidy and the urban quality

2. $\lambda_{6A} > \lambda_{6B}$
One of the municipality targets is to win back their costs of investments in the project in a period of 15 years after the finish of the project. In this phase of the design process it is not clear what the investment costs are for the municipality of Delft. Therefore in this phase the municipality of Delft is not able to determine the value of the spin off from new residents compared to the value of urban quality. A value of indifference between urban quality and new residents can only be determined when is stated that creating urban quality is always more important than getting spin off from new residents. Swing weighting is not possible. This results in:
Appendix E4  Weighing factors

Figure A-2 Indifference curve of urban quality and new residents

3. \( \lambda_{eb} > \lambda_{i} \)
   The spin off from the project for Delft is not always more important than the NPV of profit. Delft is not able to give a value of indifference between its own target and the target of BNO because it is not used to compare the financial feasibility of a project and spin off values (secondary incomes for other stakeholders). Therefore again it is chosen to model safe by assuming that:

   When the NPV is equal or higher than 0 the attribute ‘new residents’ would be less important for the municipality. Therefore the municipality of Delft is indifferent between the lowest value of spin off from the project and the highest value of the NPV. This value of the NPV would give a NPV of 0.

Figure A-3 Indifference curve of new residents and the NPV
Appendix E4  Weighing factors

4. $\lambda_1 > \lambda_4$.
The municipality is not able to create a value of indifference between the hindrance and the financial value of the NPV for BNO. In order to create a weighing factor for 'hindrance during construction' the lowest value of NPV will be compared with the highest value of 'hindrance'. Application of swing weighting is not possible.

![Graph showing indifference curve of PV of Profit and hindrance during construction](image)

Figure A-4 Indifference curve of PV of Profit and the hindrance during construction

5. $\lambda_2 > \lambda_3$
The extra turnover for BNE is only more important than the hindrance for the municipality when there is no hindrance. Swing weighting is not possible. This result is in the following Figure A-5:

![Graph showing indifference curve between hindrance during construction and image of BNE](image)

Figure A-5 Indifference Curve between hindrance during construction and image of BNE
Appendix E4 Weighing factors

6. $\lambda_2 > \lambda_3$
   The municipality appraise to award the image of BNO in the same proportion to the hindrance during construction as he appraise the image of BNE. *Swing weighting is not possible*; the highest value of ‘Image BNO’ is compared to the highest value of the ‘image of BNE’.

![Figure A-6 Indifference Curve between image BNE and image of BNO](image)

B. Ballast Nedam Engineering:

1. $\lambda_2 > \lambda_3$
   Subsidy has the absolute priority compared the value of urban quality.

![Figure B-1 Indifference Curve between urban quality and NPV of subsidy](image)

- According to the remarks on the interview, BNE uses the same ratio’s between the attribute weights of the spin off (see Figure A2 – Figure A5).
- BNE is also not able to compare the value of its’ own image with the value of hindrance. Therefore it is assumed that the image of BNE only exceed the hindrance value when there is no hindrance.
- BNE stay only indifferent towards its’ own image and the image of BNO when both ‘extra turnover values’ are appraised the same. This is the same approach as the approach of the municipality of Delft.
Appendix E4  Weighing factors

![Figure B-2 Indifference Curve between image BNE and image BNO](image)

C. Ballast Nedam Development:
1. $\lambda_3 > \lambda_1$
   Subsidy has the absolute priority compared to the value of the NPV. Too much subsidy is always welcome for the development of the tunneling of Delft outside the plan area. Therefore NPV has been put on its highest value compared to the Subsidy.

![Figure C-1 Indifference Curve between NPV of subsidy of PV of Profit](image)

2. $\lambda_2 > \lambda_{6a}$
   The project developer stays indifferent between the NPV and the urban quality of a variant when the NPV has a value higher than $f \, 0,-$. In this case the NPV of profit is lower than $f \, 0,-$ and therefore the NPV is always more important to BNO than the urban quality of the project. The NPV must be $f \, 19.330.000,-$ higher for creating a situation in which the urban quality will be more important for BNO.
In accordance with the assumption the ration between the weights of the spin off values is equal to the ratio values that were determined by the municipality of Delft.

- According to the remarks on the interview, BNO uses the same ratio's between the attribute weights of the spin off (see Figure A1 – Figure A2 and Figure A-4).

**General conclusion on interviews on the values of indifference:**
Because Delft is not used to put its targets in monetary values this steering group member is not always able to determine a 'value of indifference' by swinging the value of spin off values between its' low and high value. In this cases the lowest value has been compared with the highest value of the next attribute in ranking.
The swing weighing can not always be applied for the calculation of weights of spin off values like urban quality, spin off from new residents, image for the company and hindrance during construction.
Appendix E4 Weighing factors

III. Calculation of weights
This results in the following calculation of weights:

\[ x^{(5)} > x^{(6,4)} > x^{(6B)} > x^{(1)} > x^{(4)} > x^{(3)} > x^{(2)} \]

\[ x^{(5)} \text{ versus } x^{(1,2,3,4,5,6,6B)} ; \]
\[ \lambda_{5A} \times 6,6 (\lambda_{5} = 85031) = \lambda_{5} \]
\[ \text{(SUM}(19330;0;0;39600;134238;50499;47789) \times \lambda_{5} \]
\[ = \text{(SUM}(19330;0;0;39600;134238;85031;47789) \times \lambda_{6A} \]
\[ \lambda_{5} = 1.20 \times \lambda_{6A} \]

\[ x^{(6,4)} \text{ versus } x^{(1,2,3,4,5,6B)} ; \]
\[ \text{(SUM}(19330;0;0;39600;134238;50499;47789) \times \lambda_{6A} \]
\[ = \text{(SUM}(1933000;39600;134238;50499;69698) \times \lambda_{6B} \]
\[ \lambda_{6A} = 1.13 \times \lambda_{6B} \]

\[ x^{(6B)} \text{ versus } x^{(1,2,3,4,5,6,4)} ; \]
\[ \text{(SUM}(19330;0;0;39600;134238;50499;47789) \times \lambda_{6B} \]
\[ = \text{(SUM}(13500;0;39600;134238;50449;47789) \times \lambda_{4} \]
\[ \lambda_{6B} = 1.04 \times \lambda_{4} \]

\[ x^{(1)} \text{ versus } x^{(2,3,4,5,6,4,6B)} ; \]
\[ \text{(SUM}(19330;0;0;39600;134238;50499;47789) \times \lambda_{41} \]
\[ = \text{(SUM}(19330;0;16170;134238;50449;47789) \times \lambda_{4} \]
\[ \lambda_{4} = 1.14 \times \lambda_{4} \]
\[ X^{(4)} \text{ versus } X^{(1,2,3,5,6,6B)}; \]
\[
\begin{align*}
\text{(SUM}(19330;0;0;39600;-134238;-50449;-47789) \times \lambda_4 &= \text{(SUM}(19330;0;-1084;39600;-134238;-50449;-47789) \times \lambda_3 \\
\lambda_4 &= 1.01 \times \lambda_3
\end{align*}
\]

\[ X^{(3)} \text{ versus } X^{(1,2,4,5,6,6B)}; \]
\[
\begin{align*}
\text{(SUM}(19330;0;0;39600;-134238;-50449;-47789) \times \lambda_4 &= \text{(SUM}(19330;-54244;0;39600;-134238;-50449;-47789) \times \lambda_3 \\
\lambda_3 &= 1.31 \times \lambda_2
\end{align*}
\]

result in:
\[
\begin{align*}
\lambda_3 &= 1.20 \times \lambda_{6B} \\
\lambda_{6A} &= 1.13 \times \lambda_{4B} \\
\lambda_7 &= 1.04 \times \lambda_1 \\
\lambda_1 &= 1.14 \times \lambda_4 \\
\lambda_4 &= 1.01 \times \lambda_3 \\
\lambda_3 &= 1.31 \times \lambda_2
\end{align*}
\]

Same procedure for weight calculation for BNE and BNO:

<table>
<thead>
<tr>
<th>Results:</th>
<th>BNE</th>
<th>BNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\lambda_3)</td>
<td>=1.20 \times \lambda_{6A}</td>
<td>(\lambda_5)</td>
</tr>
<tr>
<td>(\lambda_{6A})</td>
<td>=1.13 \times \lambda_{4B}</td>
<td>(\lambda_1)</td>
</tr>
<tr>
<td>(\lambda_{4B})</td>
<td>=1.04 \times \lambda_3</td>
<td>(\lambda_{6B})</td>
</tr>
<tr>
<td>(\lambda_7)</td>
<td>=1.14 \times \lambda_4</td>
<td>(\lambda_{6A})</td>
</tr>
<tr>
<td>(\lambda_4)</td>
<td>=1.01 \times \lambda_3</td>
<td>(\lambda_2)</td>
</tr>
<tr>
<td>(\lambda_3)</td>
<td>=1.31 \times \lambda_2</td>
<td>(\lambda_3)</td>
</tr>
</tbody>
</table>

Results of for all stakeholders (to MAUT):

<table>
<thead>
<tr>
<th>Delft</th>
<th>0,14</th>
<th>0,09</th>
<th>0,12</th>
<th>0,12</th>
<th>0,21</th>
<th>0,17</th>
<th>0,15</th>
<th>1,00</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNE</td>
<td>0,14</td>
<td>0,09</td>
<td>0,12</td>
<td>0,12</td>
<td>0,21</td>
<td>0,17</td>
<td>0,15</td>
<td>1,00</td>
</tr>
<tr>
<td>BNO</td>
<td>0,19</td>
<td>0,11</td>
<td>0,10</td>
<td>0,09</td>
<td>0,20</td>
<td>0,14</td>
<td>0,17</td>
<td>1,00</td>
</tr>
</tbody>
</table>

Conclusion:
The lack of experience in putting spin off values in monetary values made it hard to create values of indifference for the spin off attributes. In this case it resulted in the same set of weights for the municipality of Delft and BNE.
Appendix F

Results of probabilistic modelling

F1: Decision tree of the NPV of 'New residents' for Delft
   Flap a: Variant I
   Flap b: Variant II

F1: Decision tree of the NPV for BNO
   Flap a: Variant I
   Flap b: Variant II
Appendix F1a: Decision tree of the NPV of 'New Residents'

Variant 1
Appendix F1a: Decision tree of the NPV of ‘New Residents’

Variant II
Appendix F1b: Decision tree of the NPV of Profit for BNO

Variant 1
Appendix G

Decision tree for NPV for BNO

Changing Risk level
Discount rate = 8%

Renewed decision tree of NPV
Flap I: Variant I
Flap II: Variant II
Appendix G: Decision tree of the NPV of Profit for BNO;

Variant I, Discount rate = 8%
Appendix G: Decision tree of the NPV of Profit for BNO;
Variant II; Discount rate = 8%
Appendix H

Decision tree for NPV for BNO

Changing Time Window
*Time Window = 20 years*

Renewed decision tree of NPV
*Flap I: Variant I*
*Flap II: Variant II*
Appendix H: Decision tree of the NPV of Profit for BNO;

Variant II; Time Window = 20 years
Appendix I

Decision tree for NPV for BNO

Risk Control Measures

Renewed decision tree of NPV

II: Result of political lobby

Flap 12: Result of insurance time development m² price
Appendix II: Decision tree of the NPV of Profit for BNO;

Result of political lobby
Appendix 12: Decision tree of the NPV of Profit for BNO; 
Result of insurance time development m² price
Appendix M

Application of Decision Analysis at Ballast Nedam

Literature study
Appendix M

Application of Decision Analysis at Ballast Nedam

Literature study

P.J. de Jong

Amstelveen, August 2000

Section Hydraulic Engineering/Section Business Sciences
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Summary

Following from the increasing demand on "Design & Construct" projects Ballast Nedam is forced to perform in earlier phases of the project process. In cases of infrastructure projects Ballast Nedam also perform in initiative phases and pre-feasibility phases connecting client, founders, contractors and users.

In order to create a good competitive position in this new market, Ballast Nedam is forced to make decisions in stage of projects where big uncertainties on the project process play a role. Decisions over a large amount of money has to be made very fast in order to keep the competitive position. In decision making the large number of involved parties create a complex web of stage, multi objectives and multi criteria. In these processes a clear overview on the problem is often missing.

Decision Analysis seems to be a appropriate tool in supporting decision problems. This report describes the aspects influencing the use of Decision analysis at Ballast Nedam based on literature investigation. Aspects like the theory on Risk Management, the theory on Decision Analysis, mathematical and theoretical approaches on decision problems, and the uncertainties at Ballast Nedam are analysed to have influence on the applicability of Decision Analysis.

The Bayesian approach on Risk management focuses on the interpretation of Risk Management. Insight in information based on experience from experts form the base of risk qualification as apart of the Risk management process at the contractors offices.

Important features on risks are their source (internal sources or external sources) and their effect (time and money). These two features have influence on the Risk quantification and allocation. Therefore it have direct influence on the applicability of a tool like Decision Analysis.

A phased approach on handling problems and using different kinds of supporting tools form the base of Decision Analysis. Decision Analysis' framing and modeling of the decision problem is based on the mathematical approach on decision making. This tool uses influence diagrams and decision trees in order to represent the decision situation and to help in communication about the problem.

By first modeling in deterministic values of variable, the decision maker is able to analyse which aspects of his problem influences the outcome most. The probabilistic model calculates the influence of uncertainties on the value of these aspects. By using tools as Risk Profiles, Expected values or sensitivity analysis the decision maker is able to compare the expected return of alternatives or to examine the risk of decision alternatives or to determine what it is worth to reduce uncertainty or control events.

This Risk management supporting tool can be performed by using software that is able to produce decision trees, influence diagrams and tornado diagrams. DPL (Decision Programming Language) seems to be a good software package. Its management supporting qualities are a big advantage of this tool. Its calculating speed is sufficient. When higher calculating speeds are necessary software packages like Microsoft Excel can be very useful.

Structuring decision situations and modeling the problem is based on the recognition of the sources of risks. Knowing the sources makes it easier to describe the values and objectives and to define the decision to make.

The decision maker can take several actions in order to achieve the objectives. A mathematical model is used that determines on every action a (uncertain) state of nature and an outcome. In order to qualify the outcome it is possible to award every outcome in accordance with the decision maker's objective. Therefore it is expressed as the utility of the outcome. A often used tool to represent the value or utility of outcome of different successive actions is a decision tree.

Problems occur when different objectives and criteria are expressed in different scales or when it is hard to quantify the state of nature. Techniques as Cost Benefit Analysis (CBA) and Multi Criterior Analysis (MCA) are able to support the decision maker in expressing his situation into a mathematical model. Techniques like Multi Attribute Utility Technique (MAUT) seem to be appropriate to support a MCA as a good representative for the decision situation.
Besides features on Decision Theory and Decision Analysis the applicability depends on the features of Ballast Nedam subsidiaries. A division in groups, based on the appearance of the Ballast Nedam subsidiaries in the different phases of the project, seems to be appropriate for analysing the possibilities of application of Decision Analysis.

In early phases uncertainties involving special events and plan uncertainties play a role. These uncertainties are identified by analysing the Plan development of ‘Maasvlakte 2’ performed by Ballast Nedam Development and by analysing working methods and organisation of Ballast Nedam International. There is little experience in quantifying these uncertainties. The influence of this lack of experience on application of Decision Analysis, will be part of further investigation.
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1 Introduction

1.1 History
At the end of the eighties Ballast Nedam made great efforts to implement Risk Analysis in their project organisation structures. Risk Analysis could provide a more economic approach on the design process. By asking experts on the probability of occurrence of events that can cause a delay, Ballast Nedam was able to give a more reliable view on the planning and the costs at the start of a project.
The last few years the nature of work of Contractors companies like Ballast Nedam is changing from construction projects only to ‘Design & Construct’ projects and project development. This change forces the contractor to make strategy decisions. This situation asks for fast and safe decision making. The present decision making is based on non-scientific discussions in which uncertainties are hard to identify and often un-quantified.
In order to make decisions ‘faster’ and ‘safer’ Ballast Nedam is looking for a methodology that can support the decision making process. Decision Analysis is a methodology that helps the decision maker to decompose a complicated problem into a framework of smaller parts by using the decision tree as a representation of the decision problem.
Ballast Nedam Engineering (BNE) is looking for applications for Decision Analysis in their scope of work. A lack of knowledge and insight in the possibilities of the described analysis at BNE formed a motive to test Decision Analysis for some design parts of the ‘Betuweroute’ part Sliedrecht Gorinchem. Compared to the standard Risk Analysis, Decision Analysis was found to be faster process with less costs and was evaluated as producing a clearer overview. Besides that, it was evaluated as a well performing communication tool.

1.2 Objective of investigation

1.2.1 Problem description
A web of objectives and a lack of time to come to well thought decisions, characterise the decision making in the early phases of project development projects at Ballast Nedam. The uncertainties that influence the decision are bigger and not easy to quantify. The decision making in early phases has considerable impact on future development of a project. A scientific framework could help a project team to clarify and articulate alternatives and to account for uncertainties in making strategy decisions.

1.2.2 Problem definition
In order to make decisions faster, BNE wants to systemise the analysis of complex decisions by the application of Decision Analysis at Ballast Nedam subsidiaries. These decisions are influenced by uncertainties that may have considerable impact on further process of a project.

1.2.3 Objective
The objective of this thesis is to investigate the application of Decision Analysis at Ballast Nedam subsidiaries, which perform in early phases of the project.

1.3 Result

1.3.1 Structure of investigation
In order to achieve the objective of this investigation, a literature investigation and a casestudy will be performed. Interviews with involved parties will support both studies. This report describes the literature investigation that is focused on four area’s influencing the applicability of Decision Analysis; Risk Management, Decision theories, Theory on Decision Analysis and the identification of the ‘decision profile’ at Ballast Nedam subsidiaries.

Chapter 2 describes the Risk Management theories. In this chapter it is described what sorts of risks exist and how to deal with different sorts of risk in different situations. Based on these theories Chapter
3 describes Decision Analysis as a tool supporting decision problems in Risk management processes. The concept and techniques used in a decision analysis are based on theoretical approaches that are described in Chapter 4. In order to be able to judge the applicability of Decision Analysis at Ballast Nedam it is necessary to identify uncertainties and other aspects influencing the decision making process at Ballast Nedam subsidiaries. The background of these uncertainties and the decision environment are described in Chapter 5 supported by two cases.
2 Theory on Risk Management

The nature of work at Contractor's companies is changing from construction work only to 'Design & Construct' and Project Development studies. This change forces the contractor to make important strategically decisions in an earlier stage of the project. These decisions have a great influence on the further process of the project. Therefore the analysis and management of Risks has become more important to contractors.

This chapter describes the theory on Risk Management. Literature and interviewing provides a clear insight in definitions in Risk Management and making decisions under uncertainties. Sources of Risks and important effects of Risks are described. The second paragraph describes the process of risk analysis and risk management. Paragraph 2.3 describes an hot item in corporate Risk Management. Public Private Corporation co-ordinates risks in such way that the involved parties take the risks together.

2.1 Risk and Uncertainty

2.1.1 Definitions in Risk Management

Before describing the analysis and management of risk it is necessary to focus on the definitions of risks and uncertainties. There are no clear definitions of these two subjects available. But there is one similarity in some descriptions. All of the descriptions analyses the difference between risk and uncertainty.

The difference between risk and uncertainty is based on a specific difference in information the risk manager or decision maker owns at the moment of making a decision. The following two examples gives an insight:

Risk: A Decision has been made under risk when the decision maker was able to predict the event in a rational way. There are data based on former events available. The decision maker is able to quantify the probability of occurrence[Plamagan]. Therefore the following definition is used:

\[ Risk = \text{probability} \times \text{consequence} \]

Definition 2-1

This definition quantifies the expectation of the consequence of a process (see[Vrijling]). In chapter 4 it is pointed out how to measure these consequences.

2.1.2 Approaches on risk

In theory two different approaches in qualifying uncertainty(see[RWS]):

- The classical(statistic) approach[RWS]:
  This approach is based on the determination of probabilities of similar events that had occurred in the past. By collecting data from these events one is able to produce probability distributions. This type of uncertainty is objective an measurable, therefore it is called inherent uncertainty. One is able to make decisions based on the data. A lack of information means that no information is available and therefore it is not possible to make a decision.

- Bayesian approach[RWS]:
  The Bayesian approach focuses on the interpretation of information. Insight in the available information is provided by experts based on their experience. It is possible to make decisions based on this experience and the scarce information. This approach is often used in the Risk Management of contractors.
Figure 2—1 shows the differences between the Bayesian and statistical approach compared to definitions that can be read in project management literature.

<table>
<thead>
<tr>
<th>Bayes</th>
<th>Inherent uncertainties</th>
<th>Lack of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayes</td>
<td>Inherent uncertainties</td>
<td>Statistical uncertainties</td>
</tr>
<tr>
<td>Statistics</td>
<td>Inherent uncertainties</td>
<td>Unable to quantify</td>
</tr>
<tr>
<td>Project Management Literature</td>
<td>Risk</td>
<td>Uncertainty</td>
</tr>
</tbody>
</table>

**Figure 2—1 Classification of uncertainties**

**Uncertainty:** When a decision maker makes a decision under uncertainty he is not able to predict the event. The data to predict the occurrence may be subjective determined by expert opinions [Raftery].

For building projects difference between risk and uncertainty is superfluous. This chapter about Risk Management will not make a difference between the two definitions.

**We talk about risk or uncertainty when there is a probability that the state of an event differs from the expected state at the decision moment.**

The following subparagraph describes the general classification of uncertainties.

**2.1.3 General classification of uncertainties**

Uncertainties can be classified in three ways:
1. uncertainties involving normal events
2. uncertainties involving special events
3. plan uncertainties

ad.1.) Uncertainties involving normal events

Examples of normal uncertainties are uncertainties on costs or time-planning. During the project a more detailed view can be provided so the uncertainties will decrease. These uncertainties can be divided in two kinds of uncertainties.

a) fixed items; These are costs items or activities of which the value is known. These kind of uncertainties are presented by the following probability density function.

![Probability density function](image)

**Figure 2—2 Fixed item**

b) Very often the costs or time planning depend on external influences (for example: negotiation period). The decision maker does not exactly know what the costs of project items will be. But he is able to judge within what properties the value will be. The probability density function of such an item can be like Figure 2—3.
ad.2) Uncertainties involving special events
Especially during construction of a project unforeseen events occur. Very often this involves accidents. Also in this case this kind of uncertainties can be divided in two different kinds.

a) Special events with probability $p$ of which the consequence are known. Attention: It is not desirable that the event occurs.

b) On the other hand special events often do not have a predictable consequence.

ad.3) In plan developing phases more variants are studied. The choice between a bridge or a tunnel is not certain during this phase. The phase often results in a choice for one of the variants. During the developing phase the uncertainty about the choice out of variants is covered by parallel working on different variants. Sometimes it is hard to predict which variant will be chosen. One is used to draw the two probability density functions of the variants just like Figure 2—6.
Figure 2—6 Two variants are separately considered

It becomes more difficult when the total costs or the expected time planning is asked. One has to determine one time period and one total cost result. The most rational approach would be weighing every variant by the probability of its election. Figure 2—7 presents the result when two variants are considered.

Figure 2—7 Weighing variants

In Chapter 5 it is described how these uncertainties are identified at BNO projects and at BNE (plan developing) projects. This will be done based on two cases.

2.1.4 Risk sources

Uncertain events in future have a cause. These causes are the risk sources (see Flanagan). The most important sources occur in the starting phase of the project. In that phase the potential risks are high because there is relative few information available. Decisions in this phase have a great influence on the further process of the project. This subparagraph will describe the difference between two sources and the accompanying sorts of risk (Edwards).

Internal risk sources:

These are the activities and events that influences the project from inside and are also the sources for risks with consequences for circumstances apart of the project. (Example: A design fault that causes damage to the construction and the environment.).

The risks caused by internal sources must be managed by the project management and therefore called the influenced risks. Influenced risks are divided in two groups (de Ridder), the management risks(1) and the operational risks(2).

1. The risks connected to the five management aspects money, organisation, time, information and quality.

2. The risks connected to the quality of performance of the parties that contribute (internal) to the final result of the project. These are the project partners and parties which are contracted to do parts of the project. For example: parties that were contracted to do consulting-, designing or constructing activities.
External sources:
External sources influence the project from the outside. Project managers do not have the capability to control them. The following external risk factors lead to risks that are difficult to manage:

- **Market factors**: market developing caused by change in supply and demand.
- **Financing factors**: risk factors related to finance and funding aspects of a project.
- **Location factors**: risk factors specific related to the site location. For example risk on soil investigation.
- **Political/Juridical factors**: These risk factors are caused by government policy, juridical regulations. For example the risk of no acceptance of permission to build.
- **'Force majeure' factors**: Big accidents, natural disasters, earthquakes, fluid streams.

The longer the developing time of the project, the bigger the chance those external circumstances will influence the state of the project. Therefore it is necessary that decision makers at this kind of projects accept these factors and are able to handle them.

2.1.5 Risk effects
The consequences of risks are called risk effects. The effects can be split up in short- and long term effects. During developing/planning phase the short term effects are the effects that occur during this phase. Long term effects are consequence of risk during the planning phase but occur in design, constructing or exploitation phase.

The most important risk effects are related to:
- money: more spending or less income than was planned
- time: long preparation- and construction phase and therefore a shorter exploitation time than estimated.
- quality: exploitation or realisation not in accordance with the quality demands.

2.2 Risk Management Process

2.2.1 General
The Risk Management Process has to serve as a tool to make decision in a more rational way. Another objective is to handle the identified risks as efficient as possible. The Risk Management Process can be divided in a Risk Analysis and the Risk Control.

Following form the ‘RISMAN-method’ this process can be divided in the five steps[RISMAN]:

1. Strategy definition
2. Identify risks
3. Quantify risks
4. Definition of risk control
5. Control risks

Time has a great influence on the process. In starting phases of a project one is able to identify only few risks. Further on some risks has become clear and therefore are easier to determine. Optimal risk management asks for a cyclic process in which these five steps are a continuing issue. The following figure gives an overview on the RISMAN-method.
Figure 2—8 Overview on RISMAN-method

The RISMAN-method distinguishes itself from other project management theories, like the ISO\(^1\) and PMI\(^2\) theories, by identifying the first step of strategy definition.

The following sub paragraphs describe these five steps.

2.2.2 Strategy definition

To be sure of an effective and efficient risk management it is important to determine strategy in the begin of every phase of the project. This is like determining boundaries of the system in which will be worked. Also the responsibilities of the different parties in the project are determined. Furthermore it is important to adjust the risk management activities on the other activities in every phase in order to control risk synchronically on the design process.

This process can be described by the following steps[RISMAN]:

1. Define objective
2. Determine starting point
3. Determine the involved parties and their responsibilities and authorities.
4. Time planning

ad.1) The objective describes the demands of the risk management system and the risks.
ad.2) By Determining a staring point one is able to analyze the influence of changes or events occurring during the process.
ad.3) A clear view on the organisation is necessary. One is possible to see where the needed information can be collected.
ad.4) The time planning of the project forms the base of the planning of Risk Management. Deadlines and task descriptions of different specialist can be adjusted on the project planning.

2.2.3 Risk Analysis

Objective of the Risk Analysis is to analyze the risks on a project in order to manage the risks during the project. A Risk Analysis is divided in a qualitative analysis and a quantitative analysis[Vrijling].

Qualitative Analysis:
This analysis describes the project, produces a list of possible risk sources and determines the risks and their effects.

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\(^1\) Project Management Institute
\(^2\) International Standardisation Organisation
Qualitative Analysis are performed on two levels. The analysis is used at a global level on the whole project. At that level it is important to produce a list with important risks and their sources in order to make a first estimation of the possible effects. A detailed qualitative analysis is also often used in project phases. This analysis is performed in order to detect possible problems at the execution of activities during that phase. The risk analysis produces a detailed overview of the activities, the needed experts and the measures that has to be taken in the following project phases.

Four identifying methods techniques are presented[Thompson]:

- Hazard providing techniques:
  1. checklists of risks produced from former experiences and investigation
  2. interviews with important project parties or external experts
  3. brainstorm of the project team
- Structuring techniques:
  4. Fault trees
  5. Influence diagram

Appendix B 'Features on Risk Identification Methods' describes the objective, procedure, advantages and disadvantages of each of these methods.

Quantitative risk analysis
The quantitative risk analysis is performed after finishing the qualitative part[Thompson]. It produces the calculation of the probability of occurrence, the quantification of the consequences and the calculation of the risks. Specific experience is asked because of analytical techniques and models. Estimations of uncertainties and prediction of costs and time of activities and a probabilistic combination of separate uncertainties are necessary. Two different approaches on quantifying risks can be mentioned.

The statistical approach
This approach is based on determining chances on similar events. By collecting these data one is able to produce statistical data. One is able to produce distributions. Data acquisition can be performed in the own business(internal) or one can choose to consult a data bank(external). Problems occur when data sets are not large enough to represent the variable that has to be quantified.

The Bayesian approach
Bayesian analysis is based on quantifying of the stochastic information of the variables on insight based on expert opinions. Several techniques in collecting probability judgement. Some of these methods will be discussed and evaluated.

1. Own insight
   This technique requires expertise of the problem owner. He has the capacities to judge probabilities of (for example) tri-angle distribution parameters.

2. Interviewing
   Interviewing is necessary when the own judgement capacities are insufficient. Interviewing can take place via individual talks or via a 'group thinking' process. Groupthink only works when the expert's professions differ from each other.

3. Delphi method & Cooke method
   These methods are used to formulate clear answers based on different expert opinions.
   The Delphi method gives the experts the opportunity to review their opinion after seeing the opinions of the other experts[Vrouwenvelder]. In case of extreme values the argumentation is asked. When the expert is not able to give an argumentation his opinion will not influence the results.
   The Cooke method determines a weight on every expert opinion. This weight can be determined by calibrate the expert opinion based on a question list of relevant questions connected to the subject. The interviewer knows the answers on these questions. Based on the answers, the problem owner is able to give a weight on a expert opinions.
2.2.4 Risk Control

Risk Control consists of all the actions or measures that has to be executed in order to control the project after producing the Risk Analysis. In this part of the Risk Management Process the following steps has to be taken:

- developing an risk control strategy in order to handle and anticipate on the identified risks;
- the factual performance of the measures in order to control the risks in accordance with the developed strategy.

Risk Control is valuable when 'the tool' is used in an early stadium of the project. At that time there is enough space to think how to handle with the risks and how to avoid risks. Not all risks can be avoid; therefore the controlling process goes on during the project.

The process focus on the following possibilities [De Ridder]
- Taking Risks and therefore reducing consequences by
  - Preventive measures
  - Corrective measures
- Allocation of the risk and therefore insure the chance by
  - Risk Contracting

![Figure 2—9 Risk level [de Ridder]](image)

**Preventive measures (avoiding, reducing)**

Preventive measures are always taken before the undesired event. The measure's objective is to avoid the risk (decreasing the chance) or to reduce its effect. Not all risks can be prevented. External risks like terrorist actions can not be predicted. Some risks can not be predicted but also can not be prevented. For example the risk on inflation. This risks ask for corrective measures after the undesirable event happened. It is also possible to hand over some risks to other parties (insurance companies).

**Hand over of risks or buying risks in contract**

Risk contracting does not reduce the risk. It only replaces the consequences of a risk to other parties. The other party takes responsibility for the risks and the risk management. The most common way to take over the risks is by insuring. This means that the exposure to the risk is replaced by certain amount of costs.

**Corrective measures (reducing)**

This kind of measures are focused on decreasing effect after the risk occurred. Generally more measures are necessary to decrease these kind of risks. Therefore the term corrective plans is introduced. The client often chooses to make corrective plans when there are no possibilities to prevent or efficiency consideration. Some risks are cheaper to take and when it occurs to reduce the effect than decreasing the change of occurrence.

**Residual risks (taking)**

These risks are all the risks where no preventive or corrective actions are possible. A consortium will not always be able to avoid risks by allocating them to other parties. Therefore it is necessary to identify risks in an early stage and to reserve an amount of money in budget and time planning.
Risk allocation
At present projects most of risks are tried to avoid or are insured. In spite of the efficient effect of risk allocation, too few project organisations show a clever way of risk allocation. The risk has to be settled at the parties that are able to manage the risk.
Main objective of risk allocation is to avoid the fact that risks are not being taken or that to avoid that risks are taken by different parties.

The following principals are recommended for allocation of risks in a project organisation. (Thompson & Perry, 1995):
- What party is able to control the events that lead to a risks the best (identification of the different parties is important)?
- What party is able to manage the risk the best?
- What party has to take the risk when it is not possible to control the risk?

Prof.dr.ir. H.A.J. de Ridder defines two kinds of risk in the context of Design and Construct:
- Product risks: these are the risks involving the system in his environment. This is the risk that the product does not meet the requirements. The will be allocated at the developer-owner. It is responsibility to control these risks with the founder and the environment.
- The process risks: all risks that meets the developing, realisation and exploitation of the system. The risks will be allocated at the owner and contractors.

![Diagram of Product risks and process risks](image)

**Figure 2—10 Product risks and process risks [de Ridder]**

During the contracting process one has to pay attention on risks allocation. A well performed risk allocation is only possible when every party gets the risks which they are able to control and sees that their interests are managed. This is only possible in a contract that is not too specified. Only the main lines are important. The involved parties has to control the detailed risks on their own and define their risk management. Depending on the influence of different risks on the project a compensation system, dealing with the allocation of risks, will be chosen. Features on compensation systems are described in the next subparagraph

### 2.3 Public Private Corporation
Another consequence of risk allocation is Public Private Corporation (PPC). In order to create a bigger social and financial acceptance, a project is considered in its own environment. Parties will be involved which have interest in the projects and will participate in the development of the project. For the development of big infrastructure projects the following points are of importance for risk management (see [de Ridder]).
- Values are expressed as monetary. In this way variants can be compared. One gets insight and have influence on the way the values are being managed. This is essential for create general acceptance.
- Variants are being evaluated on 'public utility'. Public utility is defined as the difference between value and costs. The order of variants influencing public utility gives insight in the desirability and general acceptance of variants.
- Variants with an high public utility will be assessed on financing feasibility. This is essential because financing is the main condition on feasibility of a variant.
2.4 Starting points on investigation

To create an insight on the influence of Risk Management on the application of Decision Analysis an analysis of boundary conditions that influences the application of Decision Analysis is pointed out below.

- Sort of project. The sort of project defines the source of the problem. That forms that base and objective of the decision making process.
- Project phase; decisions on activities in a project phase and events lead to risks and their effects. In early stages of a project the uncertainties are bigger. Actions under bigger uncertainties will have bigger effects.
- Different parties influencing Decision making. Allocation of risks influences the objective of a decision maker.
- Kind of risk. Whether a decision maker has to deal with product risks or process risks has influence on the decision maker's attitude. Product risks are difficult to quantify.

2.5 Summary

Risk and uncertainties are connected to building projects. The changing roles of parties, the increasing influence of rules and the requirement of new production techniques are aspects that contributed to the importance of a good Risk Management for every party in the building process.

We talk about risk or uncertainty when there is a probability that the state of an event differs from the expected state at the decision moment.

Two different approaches on risk can be recognised:
- The classical approach;
- The Bayesian approach.

Future events or activities are called risk sources.

- Internal risk sources: These are the activities and events that influences the project from inside and are also the sources for risks with consequences for circumstances apart of the project. They can be divided in:
  - management risks;
  - construction risks.
- External risk sources: External sources influence the project from the outside. Project managers do not have the capability to control them. They can be divided in:
  - Market factors;
  - Financing factors;
  - Location factors;
  - Political/Juridical factors;
  - 'Force majeure' factors.

The consequences of risks are called risk effects and are related to:
- money: more spending or less income than was planned;
- time: long preparation- and construction phase and therefore a shorter exploitation time than estimated;
- quality: exploitation or realisation not in accordance with the quality demands.

In order to control the risks in the RISMAN-method is often used. Main parts of this process are:
- Risk analysis, which contains of
  - a qualitative risk analysis, where an inventory of risk sources is made;
  - a quantitative analysis, where the risks are defined by values for the probability of occurrence and values for the possible consequence.
• Risk Control, which contains of
  • developing an risk control strategy in order to handle and anticipate on the identified risks;
  • the factual performance of the measures in order to control the risks in accordance with the developed strategy.

The qualitative risk analysis uses the following methods:
  • checklists of risks produced from former experiences and investigation;
  • interviews with important project parties or external experts;
  • brainstorm of the project team;
  • Fault trees.

The quantitative risk analysis recognizes the following approaches:
  • Statistical approach;
  • Bayesian approach.

Risk Control focuses on the following possibilities:
  • avoiding/reducing (preventive measures);
  • reducing(corrective measures);
  • taking(residual measures);
  • handing over(assurance);
  • dividing(allocation).

Risk Allocation is considered as a eminent stage of the Risk Management process. Based on the following questions the allocation has to be performed:
  • What party is able to control the events that lead to a risks the best (identification of the different parties is important);
  • What party is able to manage the risk the best;
  • What party has to take the risk when it is not possible to control the risk?

The definition of the difference between process risks and product risks is of great importance for risk allocation.

Another consequence of risk allocation is Public Private Corporation(PPC). All parties (public and private) involved in developing great infrastructure projects come to an agreement on to collective risk control.

2.6 References


3 Decision Analysis

3.1 Introduction
Decision Analysis is a term for a process that is able to produce solutions for decision problems after indicating the complexity of the precise nature of the decision situations. It provides a structured way of thinking about decisions. Modeling the nature of a decision can be described as the modeling of the essential elements of the problem boundaries, objectives, alternatives and uncertainties. The overall strategy is to decompose a complicated problem into a framework of smaller parts that can easily be analysed and understood. Decision Analysis also consists of a tool kit of different techniques for dealing with difficult decisions [ADA according to Clemen, 1999]. Most of these tools can be explained by decision theories. Therefore this chapter first handles a theoretical approach on decision making before pointing out the common structure of a Decision Analysis. To perform Decision Analysis different kinds of software are available. This chapter analyses two kind of software compared to decision making theory and techniques described in the previous chapter.

3.2 Theoretical approach on decision making
Several theories on handling complex problems are known. Scientists as Michael Pid, Paul Goodwin and Robert Clemen all produced their view on creating a structure in handling problems. Clemen points out that decision problems often are influenced by a web of objectives (several parties), attributes (several stake holders), a lot uncertainties etc. that the decision maker is not able to oversee is problem. Therefore these paragraph describes the approach Clemen propose in order to create structure in these situations.

3.2.1 Elements of a decision problem
Given a complicated problem, how should one begin? A critical first step is to identify the elements of the situation (see [Clemen]). We will classify the various elements into (1) values and objectives, (2) decision to make, (3) uncertain events and (4) consequences. These four terms are discussed briefly below.
1. Value and objective
   Value is a term that refers to things that matters to the decision maker.
   Objective is a specific thing the decision maker wants to achieve.
2. Decision to make
   Each specific decision situation calls for specific objectives. The setting in which the decision occurs is called the decision context. Values, objectives and decisions go hand in hand. Identifying the decision context and the immediate decision to make is a critical step in recognising the situation and the elements of the problem.
3. Uncertain events
   Many important decisions have to be made without knowing exactly what will happen in future or exactly what the ultimate outcome will be from a decision. Only uncertain events that have effect on the objective(s) are relevant.
4. Consequences
   If the decision context requires consideration of multiple objectives, the consequence is what happens with respect to each of the objectives. It is important to determine the dimensions of the consequence. In many cases it will be possible to work in terms of monetary values but in some cases it is difficult to determine exactly how the different objectives should be traded off.

3.2.2 Structuring Decisions
Having identified the elements of a decision problem, how should one begin the modelling process? Creating a decision model requires three fundamental steps (see Cooke).
1. **identifying and structuring the values and objectives.** Structuring values requires identifying those issues that matter to the decision maker. Fundamental objectives and means objectives are separated and the ways to accomplishment of the objectives must be specified.

2. **Structuring the elements of the decision situation into a logical framework.** Used in conjunction with a carefully developed value structure, a model of the decision that shows all the decision elements: relevant objectives, decisions to make, uncertainties and consequences is required.

3. **The refinement and precise definition of all the elements of the decision model.** Although many consequences are easily measured on a natural scale, other non-quantitative objectives such as increasing health or minimising environmental impact are more problematic.

### 3.3 Concept and Techniques of Decision Analysis

#### 3.3.1 General

The concept on which the Decision Analysis based is practically similar to the decision making theory in the previous chapter. Most of the tools Decision Analysis provides are based on mathematical and business/commercial approaches on decision making. When handling these tools there will be referred to other chapters in this report that describes these approaches.

The concept on which Decision Analysis is based on can be represented by Figure 3—1.

![Decision Analysis Process Diagram](image)

*Figure 3—1 The Decision Analysis process [ADA\(^3\) according to Clemen, 1999]*

This figure shows the three main phases of the analysis. Framing, Modelling & Data Collection and Evaluation is a cyclic process. After evaluation of outcomes, framing and modelling will be fit to the new ‘knowledge’ of the decision maker. When the decision maker accepts the model and quality of the data that has been processed, the decision can be taken. This paragraph is a more detailed description of this concept and provides several used techniques.

#### 3.3.2 Framing

The purpose of the framing phase is to specify the scope, objectives and issues to be considered in the decision. It is essential to identify the right problem and to focus on the important aspects. An important aspect is to create a manageable problem by identifying the participants of the decision making process. Three parties can be recognised in this process; the decision maker, the analysis conductor and information experts who provide inputs on alternatives and uncertainties [ADA\(^3\) according to Clemen, 1999]. These three parties combined with. Figure 3—2 gives the schedule below.

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\(^3\) Applied Decision Analysis (ADA) is a subsidiary of PriceWaterhouseCoopers and serves as a management consultant. The examples presented in their lecture are derived from "Making hard decisions", by R.T. Clemen[3].
Figure 3—2 Interaction in each phase of the analysis [ADA, 1999]

Providing a frame requires a clear defining and scooping of the decision problem by four aspects: 1. Boundaries, 2. Objective, 3. Alternatives and 4. Uncertainties resulting in decisions(1 and 3), uncertainties(4) and values(2). Tools for framing these aspects are:

1. Decision Pyramids
2. Value hierarchies
3. Strategy Tables
4. Brainstorming

Figure 3—3 Tools for framing [ADA, 1999]

These four tools make it easier to answer four important questions during the framing process.

<table>
<thead>
<tr>
<th>Question</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the level and scope of the decision?</td>
<td>Create decisions and boundaries.</td>
</tr>
<tr>
<td>2. Which value is intended to achieve? What ‘sub-values’ make it worth to achieve an objective?</td>
<td>Structure the objectives.</td>
</tr>
<tr>
<td>3. Structure the objectives.</td>
<td>Multiple dimensions of the decision.</td>
</tr>
<tr>
<td>4. Multiple dimensions of the decision.</td>
<td>Brainstorming.</td>
</tr>
</tbody>
</table>

Table 3-1 Actions for framing [ADA according to Clemen, 1999]

The last step in the framing phase of the Decision Analysis is to create a clear overview of all decisions, uncertainties in values. This overview will be produced in a diagram that displays relationships among the components of a problem, the so-called influence diagram.

Influence Diagram

General

A Influence diagram describes the correlation or relation between decisions and uncertainties within a decision problem and connects this to a objective function which has to be optimised. An influence diagram is built up by rectangles, circles, rectangles with rounded angles and arcs that connect these figures. From here these figures are called nodes and can be described as[Smith]:

1. The Decision node that represents choices that must be made among various alternatives.
2. The change node that represents events or numerical values whose state is unknown to the decision maker.
3. The value node that represents measures with which the decision will be evaluated.
4. Influence arcs that represent the dependence of different elements. 
The arcs are the most important part of the diagram because of their changing function within one diagram. The function of an arc depends on the order, the decision-making, and the type of nodes that are connected by one arc.

The following figures show the components of an influence diagram, the total figure and the explanation of the components.

Figure 3—4 Components of an Influence diagram [ADA, 1999]

Figure 3—5 Example of influence diagram [ADA, 1999]

a. An arc into a chance node represents probabilistic dependence

Example 1:
b. Arcs into value nodes indicate deterministic dependence

\textit{Example 2:}

\begin{center}
\begin{tikzpicture}
  \node (chance) {Chance node} ;
  \node (r&d) [below of=chance] {R&D Investment} ;
  \node (profit) [right of=r&d] {Profit} ;
  \node (market) [below of=profit] {Market result} ;
  \node (profit_text) at (profit.east) {Profit is determined by R&D costs and market result} ;
  \draw [->] (r&d) -- (profit);
  \draw [->] (profit) -- (market);
\end{tikzpicture}
\end{center}

\textit{Example 3:}

\begin{center}
\begin{tikzpicture}
  \node (chance) {Chance node} ;
  \node (r&d) [below of=chance] {R&D Investment} ;
  \node (technical) [right of=r&d] {Technical Success} ;
  \node (commercial) [right of=technical] {Commercialisation decision} ;
  \node (technical_text) at (technical.east) {In this example we will make the R&D investment and know the technical success before we determine whether or not to commercialise the technology} ;
  \draw [->] (r&d) -- (technical);
  \draw [->] (technical) -- (commercial);
\end{tikzpicture}
\end{center}

\textit{Objective function}

This function gives a value on consequences of decisions. These values represent the relative preference of the decision maker. By connecting probability distributions on uncertainties to these values the expected objective function can be calculated. An optimum decision or combination of decisions can be chosen that the expected objective function is optimised[Smith].

\textit{Time influence}

It is noticed that time plays an important role in the decision making process. Therefore Decision Analysis provides a tool to scheme the 'activities' in decision making in time. The schematic decision tree accompanies influence diagrams to show chronology. The schematic tree for example c. is shown below[ADA].

\begin{center}
\begin{tikzpicture}
  \node (r&d) {R&D Investment} ;
  \node (technical) [right of=r&d] {Technical Success} ;
  \node (commercial) [right of=technical] {Commercialisation decision} ;
  \node (time) [below of=r&d] {Time} ;
  \node (no) [below of=time, xshift=-1cm] {No} ;
  \node (yes) [below of=time, xshift=1cm] {Yes} ;
  \node (nominal) [below of=technical, xshift=-1cm] {Nominal} ;
  \node (low) [below of=technical, xshift=1cm] {Low} ;
  \node (high) [below of=technical] {High} ;
\end{tikzpicture}
\end{center}

\textit{Figure 3—6 Precedence explained by a decision tree [ADA according to Clemen, 1999]}

---

\textsuperscript{4} Theoretical approaches on the decision will be issued in Chapter 4.
In which:

![Decision Tree Diagram](image)

**Figure 3—7 Explanation of elements decision tree**

All examples are general strategy problems on analysing the sale of products. In the constructor's world, besides profit of constructing a product, other design and construct strategy objectives like reducing pollution, reducing the use of surface or as in Risk Management minimising the change of failure and minimising the consequences. These and other objectives in Design and Construct projects will be issued in the Chapter ###.

As you can see framing lays the groundwork for the rest of the Decision Analysis therefore this part influences the major part of the Final result of the process.

3.3.3 Modelling and Data Collection

The Decision Analysis models can be categorised by their treatment of uncertainty. The following split is created based on a difference in input treatment.

1) models with deterministic input
   - The model treats all input if they were certain
   - The model gives a single output for a single set of inputs

2) models with probabilistic input
   - The model treats chance variables by assigning probability distributions
   - The model returns a distribution on the outcomes reflecting the uncertainty in the inputs.

In order to understand the relation between deterministic and probabilistic modeling within Decision Analysis a phased approach decision problem is given in the following model[ADA, 1999].

![Phased Approach Diagram](image)

**Figure 3—8 Phased approach on modelling phase**

This approach will be explained by an example based on the following influence diagram.
Figure 3—A new influence diagram used for following example [ADA, 1999]

Example: We have a reliability problem: and we have three alternatives (policies) for dealing with it:
1. No action (policy1)
2. Backup equipment (policy2)
3. Reliability program (policy3)

Deterministic model
A Deterministic model assigns a value to a single setting of decision and chance variables. The model is used to quantify decision maker’s values, to determine how decisions impact the measures of the value and to guide the development of the probabilistic model. The most common types of deterministic models are:
- Tables
- Simple Equations or Spreadsheets (Profits = Revenue - Costs)
- Complex Simulation or Optimisation Models (Linear Programming)

A often used type of technique to help the decision makers trade off multiple values to create single measures is the MultiAttribute Utility Analysis (MAUT). This analysis was explained in chapter 3.

Sensitivity Analysis
A sensitivity analysis investigates how changes in the models input affect the output. A variable of the model is called sensitive for two reasons:
1. It causes the optimal decision alternative or policy to change (decision sensitivity).
2. It has a large effect on the measure of value (value sensitivity).

Furthermore the sensitivity analysis can be used for getting insight into the deterministic model. It provides help in determination which variable should be set to their nominal values and which should be modelled probabilistically. It also shows which alternative can be removed from further consideration or if it is necessary create more or less detail in the deterministic model.
To achieve this insight the following steps show how to conduct a sensitivity analysis.
1. Establish nominal inputs and ranges for uncertain variables.

<table>
<thead>
<tr>
<th></th>
<th>Low(10th percentile)</th>
<th>Nominal (50th percentile)</th>
<th>High(90th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Costs</td>
<td>f 100,-</td>
<td>f 550,-</td>
<td>f 600,-</td>
</tr>
<tr>
<td>Backup Costs</td>
<td>f 300,-</td>
<td>f 400,-</td>
<td>f 600,-</td>
</tr>
<tr>
<td>Replacement Costs</td>
<td>f 75,-/day</td>
<td>f 100,-/day</td>
<td>f 125,-/day</td>
</tr>
<tr>
<td>Failure Duration</td>
<td>1 day</td>
<td>4 days</td>
<td>6 days</td>
</tr>
</tbody>
</table>

2. Determine optimum policy with all variables set at nominal
   a. No action; f 400,- (replacement cost*failure duration)
   b. Backup Equipment; f 600,- (0.5*failure duration*replacement cost) + backup cost
   c. Reliability program; f 550,- (program cost)
So Alternative A is the “nominal” policy
Run the model with each variable set at low and then high, leaving all others nominal

<table>
<thead>
<tr>
<th>Total Cost</th>
<th>A. No Action</th>
<th>B. Backup Equipment</th>
<th>C. Reliability Program</th>
<th>Decision sensitive?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Costs</td>
<td>400</td>
<td>600</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>Program Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low = 100</td>
<td>400</td>
<td>600</td>
<td>100</td>
<td>Yes</td>
</tr>
<tr>
<td>High = 600</td>
<td>400</td>
<td>600</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Replacement Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low = 75</td>
<td>300</td>
<td>550</td>
<td>550</td>
<td>No</td>
</tr>
<tr>
<td>High = 125</td>
<td>500</td>
<td>650</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>Failure Duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low = 1</td>
<td>100</td>
<td>550</td>
<td>550</td>
<td>Yes</td>
</tr>
<tr>
<td>High = 6</td>
<td>600</td>
<td>650</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>Backup Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low = 300</td>
<td>400</td>
<td>500</td>
<td>550</td>
<td>No</td>
</tr>
<tr>
<td>High = 600</td>
<td>400</td>
<td>800</td>
<td>550</td>
<td></td>
</tr>
</tbody>
</table>

*All optimal policies are marked in this table*

3. Identify ‘deterministic’ dominance

*for example:*
If a particular alternative is inferior to any other single alternative in all scenarios, one should consider eliminating this alternative from further analysis.

4. Draw a tornado diagram (subparagraph 3.3.4) and identify sensitivity variables. Working with the 10\(^{th}\) and 90\(^{th}\) percentile gives us the same base for every variable. This makes the tornado diagram a reliable technique.

5. Set non-critical uncertainties to nominal

**Probabilistic modeling**
After analysing the deterministic model it is possible to perform the probabilistic model in order to (1) compare the expected return of decision alternatives, to (2) examine the risk of the decision alternatives and to (3) determine how much it is worth to reduce uncertainty or control events. Decision Analysis uses the decision tree for probabilistic modeling.

In Decision Analysis probabilities are obtained from experts. They may be based on data, judgement, or both. These probabilities serve two purposes in decision making.
- They provide a common language to describe uncertainty
- They facilitate the analysis of decisions involving uncertainty.

Experts describe the probability in probability density functions. Important issues in assessing expert opinions are discussed later. The density functions, produced by experts, are easy to use and helps the decision maker to produce the decision tree.
for example:

![Discrete probability density represented on decision trees](image)

**Figure 3—10 Discrete probability density represented on decision trees**

![Cumulative Continuous probability distributions represented by decision trees](image)

**Figure 3—11 Cumulative Continuous probability distributions represented by decision trees**

Discretization is the most common way of representing a continuous probability distribution by decision trees.

**Probability assessment: Expert Opinion**

The influence of the kind of assessment on probability is often an underestimated part of the Decision Analysis. The probability assessment is a quantitative representation of a person’s knowledge. The personal involvement of the expert influences the expression of this knowledge. The biases that occurring can be divided in [ADA according to Clemen, 1999]:

a) Motivational biases (personal involvement).
   - suppression of uncertainty to appear more “expert”
   - High estimate of probability of success by project manager
   - Being conservative in fear of later being accused of ‘underperformance’

b) Cognitive biases
   - Anchoring: focusing on a specific number
   - Availability: focusing on a dramatic/recent event
   - Overconfidence: overestimating what is known
   - Coherence: overestimating the likelihood of an event because there is a good supporting story.
   - Hidden assumptions: conditioning estimates on unstated assumptions about the outcome of influencing events.

To ensure that assessed probabilities are authentic, decision analysis has developed formal procedures.

- Interview techniques to control biases
- Encoding devices to simplify quantitative assessment of uncertainty
- Methods to assess multiple experts and resolve differences in opinion

These techniques will not be described. The use of quantitative techniques for probability assessment in infrastructure projects is described in the thesis report of [Willems]

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3.3.4 Evaluation phase
The purpose of the evaluation phase is to gain insight into how the alternatives will perform under various scenarios and assumptions. Working with output controlling methods gives us a clear view on the (probabilistic) model. The four key analytical outputs are [Clemen, 1995]:
1. Risk Profiles
2. Expected values
3. Sensitivity Analysis
4. Value of information

ad.1 The risk profile is calculated by “rolling forward” the decision tree. The forward rolling takes place by calculating, from left to right, the expected value at each chance node from the tree. It produces an outcome table with values ordered from lowest to highest, indicating probabilities and cumulative probabilities.
Table 3-2 (next page) shows an example of a risk profile for policy 1 of the example in the previous subparagraph.

<table>
<thead>
<tr>
<th>Total Cost</th>
<th>Probability</th>
<th>Cumulative probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.1250</td>
<td>0.1250</td>
</tr>
<tr>
<td>300</td>
<td>0.1250</td>
<td>0.2500</td>
</tr>
<tr>
<td>400</td>
<td>0.5000</td>
<td>0.7500</td>
</tr>
<tr>
<td>500</td>
<td>0.1250</td>
<td>0.8750</td>
</tr>
<tr>
<td>13.8</td>
<td>0.1250</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 3-2 Fictive risk profile of policy 1
Risk profiles are used to compare the risk of different policies. The figure below shows the risk profile of Table 3-2.

Figure 3—12 Fictive risk profile of a profit policy

ad.2 The expected values are determined by “rolling back” the decision tree. The “back rolling” takes place by calculating, from right to left, the expected value at each chance node from the tree. In most organisations, the “best” alternative is the one with the highest expected value.

ad.3 Same as described after deterministic approaching models. It uses techniques like rainbow diagrams to illustrate sensitivity to quantities and probabilities. A tornado diagram shows on what conditions whether one has to chose for a certain policy. The following tornado diagram is in accordance with the example in Table 3-1.
Figure 3—13 Tornado diagram

In this case policy 2 will not lead to an optimum combination of the variables. This is in accordance with Table 3-1.

ad.4 In any decision problem there are “unmodeled” alternatives. Therefore there are advanced techniques available to indicate the perfection of the information. Decision makers are used to say that the value of perfect information is the maximum you should pay for information.

3.4 Decision Analysis Software

As a result of the increasing complexity of the decision situation an application of software that refines the decision making process is desirable. Therefore it is necessary to point out features of different software applications supporting the decision making process.

In order to qualify the features of an application it is necessary to determine criteria for suitable software application for Decision Analysis\(^5\) based on the Figure 3—1[Nieman].

Figure 3—14 Illustration of parts in a complete software package

1. Problem solving capacity; the calculating speed of the application must be sufficient.
2. Complexity of input; the application must be used for commercial purposes. Also note academic people must be able to use the application.
3. Uncertainty complexity; uncertainties often do not come alone. Dependency relationships are not always easy to specify. When an application is able to handle dependency this would be an advantage.
4. The application must be easy to use; therefore it must work on a windows95 platform and it must have a clear user interface.
5. Output; Output must give the opportunity to handle the model results in an easy way.

\(^5\) These criteria are based on [Gallant] and [Nieman]
3.4.1 Microsoft Excel

Microsoft Excel is a spreadsheet application. Spreadsheets provide a great environment for creating deterministic models. Spreadsheets combine ease of use with a high library of mathematical functions that serve as building blocks for decision models[Gallant]. Getting results from a spreadsheet-based deterministic model is easy. Just enter all of the input values you want, recalculate the spreadsheet, and look at the cells containing the output values.

Using spreadsheets to generate results for a probabilistic model can be a challenge. Inputs consist of probability distributions rather than single values. These distributions can represent several till millions of possible values. Determining the output distributions requires calculating the results of the original deterministic model for every combination of input values. Recalculating the model for all these values may not be possible.

The great calculating power of spreadsheet programs makes them suitable for performing 'If-Then-Analysis'. By changing input variables of a calculating model one is able to see the influence of the change on the final result. This is called Scenario Control.

This Scenario tool can solve Optimisation problems in Cost-Benefit Analysis and decision problems with not too many input variables.

Via macro's one is able to repeat a particular action on a set of input variables. After the decision maker has changed is input he is able to repeat the same calculation as on the original values. Microsoft Excel is able to produce Tornado Diagram and outcome distributions by assigning complicated macro's on set of input variables.

3.4.2 DPL(Decision Programming Language)

Computational features
DPL(Decision Programming Language) provides the decision maker to generate a set of output values based on a probabilistic model, deterministic described in an Excel spreadsheet. The approximate of the input distributions forms the key difference between the algorithm in DPL and other the algorithm in other software applications[Gallant]. How many points and which points must be used to represent the input distribution.

DPL selects its points by constructing a new, discrete, distribution that matches key characteristics - called moments- of the original distribution. Moments are special statistics of a probability distribution that provide information about what the distribution looks like. The mean, the variance and the skewness are all examples of the moments of a distribution. DPL designs the new approximate distribution to precisely replicate the moments of the original continuous distribution. Because moments involve information about both probabilities and values, DPL's technique of "moment-matching" develops a set of points that take into account asymmetries, long tails and spikes in the distribution.

After defining a discrete approximation for each continuous input distribution, DPL builds a probability tree. Each path through the tree represents one possible combination of the states of input distributions, and is called a scenario. The probability of a scenario is the product of the probabilities of these individual branches or the joint probability of each particular branch occurring.

DPL leaves the decision maker free to make his choice for different multicriteria approaches. When a decision problem asks for multi attribute functions de decision maker must perform the weighting process before running the Decision Analysis. The difference between decision supporting techniques were described in paragraph 3.4.

Problem structuring and communicating features
DPL provides, beyond computational assistance, an entire problem structuring, modelling, and communication environment. Using its influence diagram and decision tree interface, the analyst frames the decision problem by specifying decisions, uncertainties, value measures; how they influence one another, and the chronology of events that define the decision problem. As you can see DPL supports all concepts and techniques described in the previous paragraph Concept and Techniques.
Treatment of decisions
DPL considers decisions explicitly. The analyst can enter decision nodes into a DPL influence diagram or tree that identify the specific alternatives. Using its optimising rollback procedure, DPL will determine the optimal decisions at each stage in the tree.

3.5 Starting points further investigation
- Working with influence diagrams and decision trees provides the analyst and stakeholders a good environment in decision making processes.
- There are no software packages available that combines a multi attribute utility analysis with an Decision Analysis.
- The software packages that implement Analytical Hierarchy Process approach are available. It is described that AHP is not able totally describe the decision maker’s situation and therefore are not suitable for a Decision Analysis. AHP using software will not be a part of further investigation.
- The strength of DPL lies in its feature of being a communicating tool.
- DPL is proved to be a well performing tool in supporting Decision Analysis on general decision problems. Therefore it is chosen to investigate it’s performance in decision problems in early project phases of infrastructure projects.

3.6 Summary
Decision Analysis is a term for a process that is able to produces solutions for decision problems. It provides a structured way of thinking about decisions. Applied Decision Analysis[ADA] created a concept based on the following phases.
- Framing phase
- Modeling & Data Collection phase
- Evaluation phase
- Decision & Integration phase

In order to provide a good definition of the problem in the framing phase, several tools are available.
- Decision Pyramids
- Value hierarchies
- Strategy Tables
- Brainstorming

The base of the modeling & Data collection phase is an influence diagram, which consist of:
- Decision nodes
- Change nodes
- Value nodes
- Influence arcs

In order to model time influence one can use a decision tree as the representation of the problem.

The modeling & data collection phases consists of three steps.
1. Deterministic modeling
2. Sensitivity analysis of the deterministic model
3. Probabilistic modeling

A deterministic model assigns a value to a single setting of decision and chance variables It is used to quantify decision maker’s values.

In the modeling phase the sensitivity analysis can be used for getting insight onto the deterministic model. It provides help in determination which variable should be set to their nominal values and which should be modeled probabilistically.
The probabilistic model is used in order to:
• compare the expected return of alternatives;
• examine the risk of decision alternatives;
• determine how it is worth to reduce uncertainty or control events.
In Decision Analysis probabilities are obtained from experts. They may be based on data, judgement or
both.

The purpose of the evaluation phase is to gain insight into how the alternatives will perform under
various scenarios and assumptions. Four output control methods are available:
1. Risk Profiles
2. Expected values
3. Sensitivity analysis
4. Value of information

As a result of the increasing complexity of the decision situation an application of software that refines
the decision making process is desirable. Three applications are testes on the following aspects:
1. Problem solving capacity;
2. Complexity of input;
3. The application must be easy to use;
4. The application must be easy to use.

Microsoft Excel, DPL and Monte Carlo simulation software like @Risk are useful tools to help one
evaluate the effect of uncertainty on spreadsheet model. They differ primarily on the manner in which
they approximate the continuous one uses in the analysis.
Microsoft Excel needs a lot of samples, DPL’s calculating speed may be too slow, @Risk is not able to
handle all distributions. The most striking difference between DPL and the other two software is the
effort the decision maker has to make before running his Decision Analysis.
When the analyst is interested in expected values the moment-matching - precisely match of mean and
variance of original distribution - algorithm provides a good basis for making decisions. DPL does not
calculate weights on attributes itself. The analyst has to put the weights in the model.

3.7 References

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4 Decision Theory

4.1 Introduction

4.2 Mathematical approach

Compared to the theory in the previous chapter the mathematical approach show similarities in the identification of the elements of the situation (see [Bedford]).

This mathematical approach is based on the ‘(single attribute) subjective utility theory’. (see [Keeney & Raiffa])

1. Define actions that the decision maker has to choose.
2. The circumstances on which the action has to be performed. The decision maker has no exact information on the state of nature.
3. The outcome. The action and the present circumstances will determine the outcome. The decision maker tries to choose that action that provides him the most attractive outcome.

A numerical scale is created in order to measure the preference of the decision maker. This scale is called the utility. The kind utility function depends on the attitude and objective of the decision maker.

4.2.1 Model on decision problems

A decision problem model describes, in accordance with the theory in paragraph 3.2.1, the following elements (see [Bedford]):

1. A, collection of actions on which the decision maker chooses one action.
2. N, collection of possible states of nature.
3. Ω, collection of possible outcomes
   - \( f: A \times N \rightarrow \Omega \) is a function that determines on every action \( a \in A \) a state of nature \( \theta \in N \) and outcome \( \omega \in \Omega \), \( \omega = f(a, \theta) \).
   - \( \mathcal{U}: \Omega \rightarrow R \), is a function that determines for every outcome \( \omega \) the value of that outcome. If \( \mathcal{U}(\omega_1) > \mathcal{U}(\omega_2) \) \( \iff \) the decision maker prefers \( \omega_1 \) instead of \( \omega_2 \).

De collections A, N and Ω are continue or discreet. The value \( \mathcal{U} \) is often described as a function, the value function: \( \mathcal{U}: A \times N \rightarrow R \) written as

\[
(a, \theta) \rightarrow \omega \rightarrow \mathcal{U}(\omega) = \mathcal{U}(a, \theta)
\]

Definition 4-1

4.2.2 Utility functions

In this context value functions are used when there is no uncertainty over the state of nature. When there is uncertainty over state of nature, utility functions are used (see [Bedford, TU Delft]). A utility function is necessary to order all possible outcomes of the decisions on increasing preference. Most of the outcomes are put on a monetary scale to analyze the order of preference. Other cases forces the decision maker to put the outcomes of utility function on another numerical scale, like: capacity, weight, accuracy. Other outcomes like aesthetic value, comfort, curiosity value or protection of environment are more difficult to put on a numerical scale. Methods to represent outcomes on a numerical scale are discussed in paragraph 4.3.2. A new problem occurs when it is analyzed that outcomes are a mix of the different components. In that case the different aspects of a composite outcomes can be weighted in utility function. The preferences of the composite outcomes are presented as well. This decision maker’s individual preferences can be described in the utility function.
A decision tree is one of the most used techniques to represent the possible utilities on different actions of the decision maker. Because of probability on different states of nature the possible outcomes on an action can grow to more than a decision maker is able to handle. This technique creates a transparent view on often complex outcomes on different actions of the decision maker. shows an example of a decision tree where different actions leads to different utilities(see[Vrijling]).

![Decision Tree Diagram](image)

**Figure 4—1 Decision tree with finite amount of actions**

The choice of the utility function strongly depends on the individual approach of the decision maker. Therefore it is defined that the utility function only calculates the relative utility of the outcomes(see[Bedford]).

Problems occur when the decision maker’s context is to complex. It is not always possible to represent a decision maker’s situation with discrete possible actions. Especially is early phases of the project development in which the uncertainties are influenced by a web of involved parties⁶. In that case the decision can be represented by Figure 4—2.

![Decision Tree Diagram](image)

**Figure 4—2 (Analogue)Decision tree with infinite amount of actions**

Analogue forms of decision trees do not give a clear representation of problem. It loses it’s strength as communication tool. There are too many uncertain ‘states of nature’⁷ influencing a decision. This problem occurs when a failure level of a project has to be determined. The Bayesian decision theory from Chapter ### also provides a solution for this problem. Therefore the risk will be capitalised and compared to the needed investments to create an acceptable level of failure. The risks are considered on the period in which a project will be designed. Because of this time dependence of investments and risks it is important that project costs are considered in time.

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⁶ Duko Roeleven noticed this issue. Duko Roeleven is former Risk Analyst of BNE and is now working as Financial Engineer at BNI.

⁷ State of nature is determined as possible actions of involved parties. It is not easy to describe these actions with certain probability density.
This technique is often used as the Cost Benefit Analysis, which will be described in subparagraph 4.4.1 and compared to other decision supporting techniques.

### 4.2.3 Probability state of nature

It is hard to judge the probabilities on states of nature. It has to be noticed that the availability of information, the use of assumed mathematical models and the decision maker's objective has a great influence on the interpretation of the given state of nature (see [Bedford]).

The decision maker is able to collect information on different ways. Some possible ways to approach probabilities on the state of nature will be described in Chapter 5. In this context it is assumed that the decision maker is able to adapt his observations to an a-priori-probability distribution. In this theoretical approach the decision maker is expected to base his decision on the chosen a-prior-probability distribution. When one bases his decision on an a-prior-probability distribution that represents the state of nature, one makes a 'Bayes-decision'.

A 'Bayes decision' is an action that awards an expected value of the outcome based on state of nature.

\[
E\nu(a, \Theta) = \sum_{\Theta} \nu(a, \Theta) P(\Theta = \Theta)
\]

**Definition 4-2**

The collection of states of nature only contains discrete values

When the decision maker uses a utility function \( u \) the Bayes-action \( a^* \) is defined by

\[
Eu(a^*, \Theta) = \max_a \sum_{\Theta} u(a, \Theta) P(\Theta = \Theta)
\]

**Definition 4-3**

Creating probability distributions for these Bayesian priors is a often discussed subject in decision making processes. In this lecture this discussion will be passed. The following figure gives an insight in the distributions used in practice (see [Vrijling]).

![Figure 4—3 priors used in practice](image)

Paragraph 5.4 describes the determination of the priors at Ballast Nedam.

### 4.2.4 Utility of outcomes

To make explicit which criteria are used in evaluating the preference between two outcomes, a multi attribute function can be used. This combines several criteria values to a single value representing
preference. The mathematical approach on this subjective part of the analysis is described in the following five steps.

1. The least preferred outcome is awarded with low utility value and the most attractive outcome gets an high utility value. For example weighing tree outcomes:

\[ u(\omega_3) = \frac{u}{u} \text{ in which } u \text{ and } \overline{u} \text{ are real values and } u \leq \overline{u} \]

\[ u(\omega_2) = \overline{u} \]

2. \( \omega_1 \) is more attractive than \( \omega_3 \) but less attractive than \( \omega_2 \). Therefore the outcome \( \omega_1 \) has to get an utility value bigger than \( u \) but smaller than \( \overline{u} \). Suppose:

\[ u(\omega_1) = \alpha u + (1 - \alpha)\overline{u} \text{ in which } \alpha \text{ is a value that has to be determined between } 0 \text{ and } 1. \]

3. To determine \( \alpha \) the decision maker has to choose between two alternatives \( L_1 \) and \( L_2 \).

   \( L_1 \): Choose the certain outcome \( \omega_1 \)

   \( L_2 \): A lottery that gives outcome \( \omega_3 \) with a probability of \( \alpha \) and gives \( \omega_2 \) with a probability of \( 1 - \alpha \).

4. For lower values of \( \alpha \), the decision maker will prefer \( L_2 \). The higher values of \( \alpha \) creates a preferences for \( L_1 \). Testing different values of \( \alpha \) gives a value of \( \alpha \) that the decision maker will be indifferent neither for alternative \( L_1 \) nor \( L_2 \).

Problems occur when it is not possible to put the different criteria on alternative in an uniform scale. Several methods to create a suitable scale are available.

### 4.3 Quantitative approach on outcomes

#### 4.3.1 Definition of quantification

The term quantification seems to be the point of discussion in several decision problems. The definition 'to express in value' is not suitable for identifying the different forms of quantification. Therefore measurement theory (see [Roberts]) is used. This theory describes a function \( f \) that awards a value to the variable that has to be quantified. The application of \( f \) is called the measurement of the variable and the function \( f \) is called the measurement scale. Different types of measurement scales can be used.

<table>
<thead>
<tr>
<th>Type of scale</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td>Counting</td>
</tr>
<tr>
<td>Ratio</td>
<td>Mass</td>
</tr>
<tr>
<td></td>
<td>Temperature on Kelvin-scale</td>
</tr>
<tr>
<td></td>
<td>Relative Time</td>
</tr>
<tr>
<td>Interval</td>
<td>Temperature in degrees Fahrenheit, Celcius</td>
</tr>
<tr>
<td></td>
<td>Calendar time</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Preference</td>
</tr>
<tr>
<td></td>
<td>Quality of air</td>
</tr>
<tr>
<td>Nominal</td>
<td>Numbering of Alternatives</td>
</tr>
</tbody>
</table>

*Table 4-1 Fundamental measurement scales*

The following text explains Table 4-1.

- Absolute scale
  Only one way of measurement is possible. The reference point (zero) and unity are fixed points. An example is counting.
• Ratio scale
The reference point is fixed. It is often possible to choose this point by yourself, but variation is not possible. It is possible to multiply the scale unity by a positive constant value. The name ratio scale is derived from the fact that the ratio of the values are important in use of the scale. Mass and expired time are examples. In case of expired time the start of a stopwatch can be chosen as reference point. The time following on this starting point can be measured in seconds, minutes or hours etc.

• Interval scale
The reference point and the scale unity can be varied. Examples are calendar time and the temperature on Celcius and Fahrenheit. These last two scales for temperature differ in reference point and scale unity but the represents the same temperature.
On interval scale the ratio's are of non importance but the differences between two values are often discussed. For example one can say that in the year 2000 a new millennium starts 1000 years later than the last one started. But it is wrong to say that that is twice as late.

• Ordinal scale
At this scale only the order of elements is described. Ratio's and differences are of non importance on this scale.
For example the quality of air is described in priority codes by giving the values 1,2,3,4 and 4. The values 1,3, 3, 5, 6, 7, 9 and 9.1 make no differences because they do not change the order. They are suitable too.

• Nominal scale
In this case there is no order. It is only important to give elements numbers to distinguish them from another element. The values are arbitrary chosen and are suitable to be exchanged. Examples are numbering of alternatives.

The values on the nominal scale can be replaced by characters, colours or symbols. In case of absolute scale, ratio scale or interval scale it is not possible to replace the values because of their importance.

4.3.2 Use of measurement scales
This paragraph shortly describes the application of measurement scales. It is important to recognise calculations on values of the different scales.

Taiwan High Speed Rail, risk inventory in absolute scales
by: Ballast Nedam Engineering

This cases shows how to quantify risks by giving the risks a probability. A probability distribution is determined for each uncertainty. A Triangular distribution based on expert opinions is elicited. The Triangular distribution consists of a minimum value, a top value (highest probability) and a maximum value. These values form the input for a Monte Carlo simulation in order to simulate from a probability distribution.
Subjective probabilities like the values described above can be considered as measurements on the Absolute scale because of the fixed reference point and a fixed unity.
It is noticed that only technical risks can be determined on a absolute scale. The non-technical risks like political risks(procedures), social risks(strikes) and economical risks(bankrup) are mentioned (qualitative analysis) but are not easy to quantify. Therefore these kind of risks are put on the nominal scale.

Arno Willems describes the following issues about measurement on ordinal scales performed by Bouwdienst RWS.
The combination of measurements on ordinal scales gives often a lot of difficulties on interpretation of the values. The experts(provider of the values) often do not explain the differences between the values. Therefore it is advised to choose similar differences between the values, after informing the experts about the differences. Only a clear view on the significance of the values gives us the possibility to multiply different values on ordinal scale. Outcome on the multiplying now have more sense.
4.4 Decision Support Techniques

Arithmetic operations are meaningless on an ordinal scale. Therefore different techniques and aids are developed in order to support the decision making process. Which of these techniques is the most suitable depends on the nature of the problem and the objective of the decision. Techniques can be used for different kind of problems. In this paragraph four kinds of techniques will be issued.

4.4.1 Cost Return Analysis

The base method of a Cost Benefit Analysis (CBA) is to evaluate alternatives on only one objective: the minimal expected costs or the maximal return (see [Nas]). CBA is a so called single trade off technique. Figure 4 — 4 Optimum costs shows a graphical representation of this analysis.

![Figure 4 — 4 Optimum costs]

This representation can be compared with the representation of the Bayesian approach on decision problems with infinite actions described in subparagraph 4.2.2.

The CRA seems to be a good working tool for financial optimisation issues or dimensioning problems. Both are easy to describe on a Ratio scale and therefore easy to handle. On the same hand it is not possible to use two different objectives in this analysis. Everything is represented in a monetary value and will be compared on monetary basis. In some cases market values are use as good representation of society’s value judgements. The CBA prices out non-monetary costs and benefits and the aggregates them. This issue caused critique on CBA’s. Some of them are describe below.

Time influence and influence of uncertainties on decision making process does not play a role in this technique. Expectations are defined in a monetary value without giving any judgement on uncertainties. The time effect on the magnitude of uncertainties and consequences is not analysed here. The influence of discount rates on time trade off’s is also not analysed [Kaldor-Hicks] So a technical issues like comparing construction methods is not easy to perform with this tool.

According to [Payne], Cost/Benefit analysis, views choice of strategy in decision making as a conscious process. Benefits could include:

the probability that the decision strategy will lead to a correct decision, the speed of making the decision, and its justifiability. Costs might include the information acquisition and computational effort involved in using strategy. Decision rule selection would then involve consideration of both the costs and the benefits associated with each possible strategy.

4.4.2 Multi Criteria Analysis

A Multi Criteria Analysis (MCA) produces a table per alternative. The alternative are evaluated on several criteria. The table shows the value per criteria of each alternative. This procedure is used for
quantitative and qualitative judgements on realisation of several (conflicting) objectives (see [Keeney & Raiffa]).

Objectives become explicit by transforming them to measurable quantities [Pidd]. Frequently used implementations of MCA assume that the overall score of an alternative equal the weighted sum of criterion scores. The determination of the weights forms the essential aspect in this procedure. After determining the weights the utility of the different alternatives will be calculated on a scale from 0 to 1. This forms the base of determining a total score for each alternative; the alternative with the highest score is the ‘best’ alternative. Table 4-2 gives an example of a quantitative MCA on an environmental design of installation.

<table>
<thead>
<tr>
<th>Alternative A:</th>
<th>Weight (W)</th>
<th>Judgement</th>
<th>Score (Utility, u)</th>
<th>Criterion score (=W x u)</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>0.47</td>
<td>fl. 10.000.000,-</td>
<td>0.90</td>
<td>0.42</td>
<td>Innovation</td>
</tr>
<tr>
<td>environmental effects</td>
<td>0.30</td>
<td>5% No, exposition</td>
<td>0.60</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>0.16</td>
<td>50 year</td>
<td>0.40</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Construction time</td>
<td>0.07</td>
<td>8 year</td>
<td>0.90</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>1.00</td>
<td></td>
<td></td>
<td>0.73</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-2 Decision table
The following steps are taken in an additive MCA [Keeney & Raiffa]:
1. Identifying of the alternatives
2. Identifying judgement criteria
3. Define a measure for each judgement criterion (Attributes)
4. Determine the weight of each criterion
5. Determine the score for each alternative

Point three and four are point of discussion on several decision making processes. Therefore two different approaches on determining weights are discussed below. The AHP (Attribute Hierarchy Process) analysis and the MAUT analysis (Multi Attribute Utility Technique). AHP:
The multiplicative AHP is concerned with ratio’s of intervals on the dimension of desirability [Lootsman]. This techniques is based on pairwise comparisons of alternatives and the criteria, so that the decision maker’s judgement is rather fragmented. The base of this structure is the use of a geometric scale to quantify human comparative judgement, and with a multiplicative structure: logarithmic regression to calculate the impact scores of the alternatives at the first evaluation level, and a geometric-mean aggregation rule to calculate the final scores at the second level.

The linear model used after determining $W_i$ and $s_i$:

$$\text{overall benefit} = \sum W_i s_i$$

in which:

$W_i$ weight of attribute

$s_i$ score on attribute

The AHP has been criticised for the following reasons [Bedford & Cooke]:
a) for the fundamental scale to quantify human judgement,
b) because it estimates the impact scores of the alternatives by the Perron-Frobenius eigenvector [Barzilai], and
c) because it calculates the finals scores of the alternatives via the arithmetic-mean aggregation rule
Overall concluded it is said that this technique is not transparent (black-box-method). It does not show how the weights of attributes can be representative for the decision maker’s opinion.

MAUT:
The MAUT analysis uses a measurement technique for determining order and weights on attributes that is called the ‘swing weighting’ technique [Keeney & Raiffa]. This is not the only method to assess weights on attributes, but it is a popular often used technique. All attributes are put on the lowest possible value and the decision maker is asked to pick one attribute if he was asked to maximise only one attribute. After this the technique is repeated for the other attribute and so on.
The weight on a criterion is determined by the comparison of the attribute to the least important or most important attribute. All criteria are put on their lowest score and the decision maker is asked which criterion he would choose if he was asked to maximise one criterion. This criterion will be put out the list of criteria and the same question has to be answered again until the list is empty [Keeney & Raiffa]. The following mathematical approach illustrates this technique based on Table 4-3 that sets out the performance measures of alternative actions on Attributes.

<table>
<thead>
<tr>
<th>Mathematical approach MAUT Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attributes</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td><strong>Lowest (min ( X_i ))</strong></td>
</tr>
<tr>
<td><strong>Highest (max ( X_i ))</strong></td>
</tr>
</tbody>
</table>

Table 4-3 Performance profiles on attributes

In which:
* \( A_i \) possible action
* \( X_i \) chosen Attributes (example: Quality, Costs, Time to completion etc....)

Objective: Determine the \( \lambda_j \)'s of the total value function

\[
\varphi(x_1, x_2, x_3, x_4) = \sum_{j=1}^{4} \lambda_j \varphi_j(x_j)
\]

**Definition 4-4**

For the \( j \)th attribute let \( w_j \) represent the worst value and \( b_j \) the best value. Then for positively oriented scales we would have \( w_j \leq x_j \leq b_j \). Let \( I \) be the set of attribute indices; in this example \( I = \{1, 2, 3, 4\} \). Let \( T \) be a subset of \( I \) and \( \overline{T} \) be the complementary set to \( \overline{T} = I - T \).

Let \( x^T \) be that profile where all the component \( x_j \)'s are equal to \( b_j \) for \( j \in T \) and equal to \( w_j \) for \( j \in \overline{T} \). Thus, for example of \( T = \{2, 3\} \) then

\[
x^T = x^{(2,3)} = (w_1, b_1, b_2, w_4)
\]

since \( \varphi_j(w_j) = 0 \) and \( \varphi_j(b_j) = 1 \), we know that

\[
\varphi(x^T) = \sum_{j \in T} \lambda_j
\]
This technique suggests a first step in ranking the profiles \( x^{[2]} > x^{(1)} > x^{(4)} > x^{(3)} \). This would imply that for the decision maker

\[ \lambda_2 > \lambda_4 > \lambda_3 > \lambda_1 \]

Now the decision maker starts comparing \( x^{[2]} \) versus \( x^{(1,3,4)} \); for example the comparison between attribute 1 and attribute 2.

We start looking for the levels of \( x_i \) vs \( x_4 \) until the indifference (see paragraph 4.2.4 weight on outcomes step 4). This in accordance with Table 4-3 Performance profiles on attributes

\[
\begin{align*}
\nu(2.0,350,15,1350) &= \nu(9.0,200,15,1350) \\
\lambda_2 \nu_2(350) &= \lambda_1
\end{align*}
\]

When the component \( \nu_2, \nu_1, \nu_4, \nu_3 \) functions has already been assessed, a combination like \( 0.6\lambda_2 = \lambda_1 \) can be found for each comparison between the attribute values. The weighing factors of the analysis are determined.

One of the fundamental concepts of the multi attribute utility theory is that of utility independence (see [Keeney & Raiffai, page 224]).

### 4.4.3 Weighing process

After identifying different uncertainties it is important to quantify the state of nature influencing the decision. The performance on this quantitative analysis is discussed in Chapter 2 Theory of Risk Management. The problems occurring in quantifying decision situations form the central issue in this paragraph. The general approach of the assessment of alternatives is based on the following `three-step`:

1. Create a metric scale for the scalar assessing each alternative, \( i, j, u_j \)
2. Transform each metric scale onto a value function
   for example:
   \[
   \nu_j = \frac{(u_j - m_j)}{(M_j - m_j)} \text{ in which } M_j \text{ and } m_j \text{ are the maximum and minimum bounds of } u_j
   \]
3. Construct of weighted average \( \nu_i = \sum_{j=1}^{M} \lambda_j \nu_j \)

Subparagraph 4.3 and 4.3.2 focus on the first step. The next paragraph handles the main issue of this chapter the use of decision supporting techniques in order to control step 2 and 3 mentioned above.

### 4.5 Starting points further investigation

This chapter gave an insight in available decision supporting techniques based on the utility theory described in paragraph 3.1 and 4.2. Following from the text the statements pointed out below are done:

1. Cost Benefit Analysis (CBA) is often used in financial optimisation problems. But CBA gives problems when monetary values are given on intangible aspects.

2. Multi Criteria Analysis (MCA) is a proved method to make a good judgement on different alternatives and thereby taking into account that the decision maker has more than one objective and therefore has to weight the alternatives on more than one attribute. In this case it can be concluded that:
   - The Attribute Hierarchy Process (AHP) uses the ‘paired comparison’ method in order to create hierarchy in the attributes. This method is not able to represent the complex decision situations.
The Multi Attribute Utility Technique (MAUT) seems to be a reliable method to represent conditioned weighing on multiple attributes in complex decision situations.

The description of the complex decision situation is of main importance at big infrastructure projects. Responsibility over time and money influences the decision maker's attitude on the decision problem. Therefore it is stated that the attribute weighing process may take time in order to get a good qualitative result. In this case the energy and time that has to be taken for the performance of a MAUT, at weighing attributes at decision processes for infrastructure projects, is accepted.

## 4.6 Summary

The theoretical approach on decision making processes is based on Clemen.

Given a complicated problem one can recognize the following elements of the decision situation:
- Value and objective;
- Decision to make;
- Uncertain events;
- Consequences.

After identifying the modeling of the modeling of the problem is important and separated in the following steps:
- Identifying and structuring the values and objectives;
- Structuring the elements of the decision situation into a local framework;
- The refinement and precise definition of all the elements of the decision model.

The mathematical approach is based on the 'single attribute subjective utility theory' that recognizes three elements in a decision problem:
- Decisions that the decision maker has to choose.
- The circumstances on which the action has to be performed. The decision maker has no exact information on the state of nature.
- The outcome. The outcome will be determined by the action and the present circumstances. The decision maker tries to choose that action that provides him the most attractive outcome.

The mathematical model analyses the possible actions in order to achieve the objective of the decision maker.

A decision tree is a often used tool to give an insight in the structure of the decision maker's problem. By discrete the possible actions one is able to create a value or utility on every actions by using the following model:

1. \( A \), collection of actions on which the decision maker chooses one action.
2. \( N \), collection of possible states of nature.
3. \( \Omega \), collection of possible outcomes

- \( f : A \times N \rightarrow \Omega \) is a function that determines on every action \( a \in A \) a state of nature \( \theta \in N \) and outcome \( \omega \in \Omega \), \( \omega = f(a, \theta) \).
- \( \nu : \Omega \rightarrow R \), is a function that determines for every outcome \( \omega \) the value of that outcome. If \( \nu(\omega_1) > \nu(\omega_2) \) \( \iff \) the decision maker prefers \( \omega_1 \) instead of \( \omega_2 \).

De collections \( A, N \) and \( \Omega \) are continue or discreet. The value \( \nu \) is often described as a function, the value function: \( \nu : A \times N \rightarrow R \) written as

\( (a, \theta) \rightarrow \omega \rightarrow \nu(\omega) = \nu(a, \theta) \)

The decision can be made following the Bayes theorem.
Bayes: A rational decision is the choice for the action with the expectation of the biggest utility value. The theory is based on subjectivity.

Quantification of the aspects of the mathematical model can be performed by using measurement scales.
- Absolute scale;
- Ratio scale;
- Interval scale;
- Ordinal scale;
- Nominal scale.

In order to support the decision making process the following techniques can be used.
- Cost Benefit Analysis (CBA)
  The CBA only uses monetary values. This gives problems on comparing intangible aspects of the problem with monetary aspects of the problem.
- Multi Criteria Analysis (MCA)
  MCA is based on the utility theory. It is able to give utility values to possible actions based on probability of state of nature and determining weights on attributes.

Two approaches on determining weights on attributes are discussed:
- The Attribute Hierarchy Process (AHP)
- The Multi Attribute Utility Technique (MAUT)

The most important difference between AHP and MAUT is the algorithm on calculating weights. AHP is a controversial method where the calculating is based on paired comparison. It does not necessarily give representative output for the decision maker’s situation.

The ‘swing weight’ technique is, used in MAUT, a more transparent technique because of the clear way of interviewing the decision maker on his preference for criteria.

MAUT allow a more general form. The decision maker has to make up his mind what his opinion is on the criteria. The AHP does not ask an a-priori way of thinking form the decision maker before he determines the weights on criteria (see [Bedford&Cooke]).

4.7 References
[Vrijling] “Kansen in de Civiele Techniek, CUR rapport”, Prof.drs.ir. J.K. Vrijling e.a.,


5 Risk Management at Ballast Nedam

5.1 Introduction
The application possibility of Decision Analysis at Ballast Nedam depends on several things. Ballast Nedam disciplines has a changing character per project. This implies that every project is unique and that it’s difficult to create a standard view on Ballast Nedam projects. Therefore this Chapter describes the organisation and the features on subsidiaries and working procedures.

5.2 Ballast Nedam Organisation
Ballast Nedam covers thirteen subsidiaries (see OR). Five of these subsidiaries are involved in developing big infrastructure projects. Each subsidiary participates in different phases of the project and therefore has its own character. Figure 5-1 shows the Ballast Nedam holding covering these five subsidiaries.

![Organisational Chart Ballast Nedam](image)

**Figure 5-1 Organisational Chart Ballast Nedam**

In which (see [internet]),
Ballast Nedam Engineering (BNE) is specialised in design engineering of architectural, civil technical and hydraulic construction. As the technical hart of the Ballast Nedam concern, BNE performs as a multi discipline subsidiary for the other subsidiaries.
Ballast Nedam Developing (BND) has a team of specialists who combine the necessary knowledge for integral developing of the built environment. This subsidiary focuses on initiating and developing of integral area development in which all Ballast Nedam disciplines, like infrastructure, house-building and utility construction, can be used.
Ballast Nedam International (BNI) performs world wide. The activities of BNI focuses on the project management and the preparation and construction of projects in concrete and hydraulic construction, utility construction and house-building.
Ballast Nedam Grounds and Roads (BNGW) is active in the preparation and construction of infrastructure projects. BNGW provides a large scale of works in removal of wet and dry grounds.
Ballast Nedam Concrete and Hydraulic Works (BNBW) is specialised in the construction of infrastructure projects, industrial securities and facilities for air and marine ports.

These subsidiaries are independent operating businesses with their own features. Features of projects performed by these subsidiaries has an influence on the decision maker’s strategy when solving problems or choosing alternatives.
Ballast Nedam Dredging (BND) perform in dredging projects world-wide. This is an subsidiary working on its own and often not participating in projects concerning the subsidiaries mentioned above. Therefore BND will not further be issued.
The next subparagraph describes the subsidiaries on four points influencing the decision maker’s status when solving a problem.

5.2.1 Features on subsidiaries
In order to get a clear and not too extensive description of features on subsidiaries it is chosen to focus on three groups of subsidiaries. This focus is based on joint features that can be seen as decision properties in the decision making process. These properties are:
1. source; What is the source of the problem? How strict is the information?

---

4 Mr. Armand Verweij noticed this in a conversation about the Ballast Nedam structures and working procedures.
2. decision maker; Who is the decision maker?
3. Objective(s); What are the most important objectives in decision making processes?
4. Time perspective; Whether the time window of action is long term or short term, strongly influences the decision

Figure 5—2 points out the structure of the project phasing and the participation of the subsidiaries during this process. The subsidiaries are set out vertically, the project phases are set out horizontally. When a subsidiary participates in a project phase the joint cell is filled with an ‘X’.

<table>
<thead>
<tr>
<th></th>
<th>General</th>
<th>Initiative/ acquisition</th>
<th>Design/ Development</th>
<th>Contracting</th>
<th>Work preparation</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNO</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNGW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNBW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNI</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Strategy decision points
Design & Construct Decision points

**Figure 5—2 Participation of subsidiaries in phases of project**

Following from Figure 5—2 and an interview with Armand Verweij a separation in accordance with ‘Table 5-1 classification of subsidiaries’ seems to be appropriate.

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNO; BNI</td>
<td>BNBW; BNGW; BNI</td>
<td>BNE</td>
</tr>
</tbody>
</table>

**Table 5-1 classification of subsidiaries**

Ballast Nedam Developing (BNO) and Ballast Nedam International(BNI) forms Group I. These subsidiaries operate in the first stage of the process. Funding- and developing uncertainties play a big role. The uncertainties are long term strategy uncertainties. Because of the increasing demand of participation of these subsidiaries (as preparation on Design & Construct projects) an insight in specific uncertainties is necessary. The identification of these uncertainties is performed in the next paragraph ‘Identification of uncertainties at subsidiaries’.

The subsidiaries in Group II do not perform in the initiative and acquisition phase of projects. Their participation starts in the design process. The shape of the projects is quite clear. Therefore one is able to have a more detailed view on uncertainties that can occur during design and construct processes.

Ballast Nedam Engineering (BNE) only performs as an engineer and designer. Other contracting responsibilities play a role and therefore the decision maker at BNE has to manage different sorts of uncertainties. BNE’s plan developing section serves BNO in its approach on developing project plans. Uncertainties in that stage of design, differs from the uncertainties BNE’s other sections have to deal with in later stages of design.

**5.3 Identification of uncertainties at subsidiaries**

The general (theoretical) classification on uncertainties was described in Chapter 2. This paragraph describes shortly how the inventory and processing of the uncertainties take place at BNE.

**5.3.1 Inventory**

At Ballast Nedam Engineering the Risk Analyst produces, together with the project team, an inventory list of source of uncertainties. This can be done by a brainstorm session. The normal uncertainties are on an existing checklist. The special uncertainties follows from the brainstorm session and interviews with so-called experts.
The inventory of risk sources is followed by the qualitative analysis (see Chapter 3) that put all results from the previous phase on a Risk Item List [BNE2]. This lay-out of this list is shown in Figure 5—3 and it consist of the presented subjects.

<table>
<thead>
<tr>
<th>Risk Item List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project:</td>
</tr>
<tr>
<td>Part:</td>
</tr>
<tr>
<td>Aspect</td>
</tr>
</tbody>
</table>

*Figure 5—3 Risk Item List*

### 5.3.2 Expert Opinion

After the determination of Risks the quantification of uncertainties often takes place by interviewing experts (see also [RISMAN]). This paragraph first describes a theoretical approach on collecting risk values. After this it will be describe in what way Ballast Nedam quantifies uncertainties.

#### Classic approach

The uncertainty about a scatter is represented by asking an expert to give three values for a certain variable. The first scattering is the value of which he expects the realisation will be higher than this value with a chance of 95%. The second scattering is the value of which the expert is indifferent whether the value will be higher or lower than the given value. The third scattering is the value of which the expert expects the value will be lower than this value with a chance of 95% [Willems]. These values result in a triangular distribution of possible values of the uncertain variable. Because there will be only one input value for the risk analysis all scatters have to be combined to one. Several models are used in order to perform this combination. The Classic model is model based on the capability of the experts to represent their own uncertainty on the values they provided. These method is described in [Willems].

Goodwin & Wright noticed that groupthinking processes often helps the recognition and quantification of risks in phases where the uncertainty on the further process of a project is bigger.

#### Practice at Ballast Nedam Engineering

Processing and quantification of uncertainties of normal events differs from the processing of special events. The expert is asked to give the most likely value with an almost (95%) highest and almost (5%) lowest value for the normal events. Working with triangular distributions helps the risk analyst to translate the expert opinion into probability density function. A division is made in [BNE2]:

1. Uncertainty in time
2. Uncertainty in price
3. Quantity uncertainties
4.

*Normal uncertainties (known activities)*

- time
- price
- quantities

*Figure 5—4 Quantification of types of uncertainty.*

For special events (2a. in paragraph 2.1.3) the expert is asked to estimate the chance of occurrence of the event in a discrete value. These estimates are provided by different experts. These estimates are combined to one new estimate which will be used as input for the next step in quantifying uncertainties.
Figure 5—5 Quantification of events

The risk analyst combines the probability distributions, provided by different experts. The provided triangular densities of a variable are combined by determine the average. This combined distribution represents the believe of experts in the uncertainty of a variable. In order to perform a good simulation of the overall model the risk analyst searches for a triangular distribution or an uniform distribution that represents the believe of the experts. Such a distribution is called a fit on the combined distribution [Klaveren].

At BNE two techniques of fitting are used:
1. The 'Triangular fit'
   *A Triangular fit that has the same modus*, 5% en 95% values as the combined distribution.
2. The Moment fit
   *A Triangular fit that has the same mean value and expectation as the combined distribution. The variance of the fit is also equal to the variance of the distribution, except all cases that an under or upper border will be deleted by this calculation.*

5.4 Cases at Ballast Nedam

This subparagraph will describe two cases at Ballast Nedam which describe the identification of uncertainties at big infrastructure projects. Interviews with responsible persons on BNE and BNO provides insight in the used a technique in order to come to decisions in the variant analysis.

I. ‘Maasvlakte in rustig water, het binnenmeerconcept’

*by: Ballast Nedam Engineering*

A consortium of Ballast Nedam, ING Bank and Euro Combined Terminals (ECT) presents the design of the development of ‘Maasvlakte 2’ by characterising it as a concept in which uncertainties are handled carefully. Carefully handled uncertainties focuses on:

- Do we have reasonable expectations about the demand for a extra harbour?
- This kind of expansions has a duration of more than 10 years. Especially uncertainties about the speed of political decision making. How are we able to avoid political rules.12

Therefore this case is chosen to analyse it’s decision making process on: Risk recognition(A), attribute weighing(B), - application and scaling(C) and choice making(D) based on scores. Here the case will be set out in accordance with decision making structure in paragraph 3.1. Figure 5—6 Flow Diagram Variant Design shows a stream diagram of the activities of the division plan developing of BNE.

---

9 Modus: Central value of a datas et

10 Ir. Jan Willem Rohring is Head Engineer at Ballast Nedam Engineering Plan Development

11 Ir.Duko Roeleven is financial engineer of Ballast Nedam International

12 This was noticed by Jan Willem Rohring.
Figure 5—6 Flow Diagram Variant Design

In which:
- RWS: Dutch Department of Waterway construction
- GHR: Municipal Harbour Company
- SM2V: Consortium Variants for 'Maasvlakte 2'

Decision profile
1. Base: 'Startnotitie PKB + MER Maasportontwikkeling Rotterdam'
2. Objective: Design a development plan for expansion of harbour activities in Mainport Rotterdam that satisfies the government purposes in Mainport development.
3. Decision to make: Choose a design concept for expansion of harbour activities in Mainport Rotterdam.
4. Uncertainties/Risks recognition: Table 5-2 presents the located risk in the plan development phase of this 'Maasvlakte 2'-project. Details on this table can be found in Appendix E. Risk Item List of 'Maasvlakte 2'.

<table>
<thead>
<tr>
<th>Risk Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal Risks</strong></td>
</tr>
<tr>
<td>Management Risk</td>
</tr>
<tr>
<td>Project Organisation</td>
</tr>
<tr>
<td>Contracting Personnel</td>
</tr>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Design Risks</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table 5-2 Risk Recognition

^13 This report is a formal base for decision making procedures on area development

45
5. Attributes/criteria
   - possibilities in economic development
   - Development of nature (morphological acceptance)
   - hindrance on environment
   - employment
   - hindrance on shipping (present nautical situation)
   - trade off of variants
   - turn around time of terminals

A) Risk quantifying
Risk quantifying is very difficult. The project is unique in itself so routine based estimates of risks is necessary. In this case the decision maker did not quantify the risks. The project team based it's choice on a qualitative risk approach:
   - Experience in funding infrastructure projects
   - Analysing posterior morphological data of Coastal Projects (Location risks)
   - posterior figures of similar Distripark project (Market Risk)
   - Recognising design and management risk during design process

B) Attribute weighing
The concept plan has been developed based on interviews with the parties involved. These parties are shown in Figure 5—6 on the previous page. In these interviews no quantitative attribute weighing took place. Evolution on the attributes and their influence on the design were issued in this meetings. After the meeting it was determined what has to change on the present concept variant. So only qualitative weighing of attributes took place. These most important attributes issued in the concept of the 'Binnenmeer' are:
   - Nautical accessibility.
   - Morphological justified
   - Harbour site linked on market demand
   - As much as possible 'soft' coastal defence
   - ECT wants a straight wharf construction of no less than 7 kilometres.

C) Scaling
In this case the 'Maasvlakte 2 project team' did not scale the used criteria. All five bullets above were issued as main attribute in developing a concept. No hierarchy in criteria was used.

Own interpretation:
It is noticed that criteria and attributes have the same meaning. When variants are judged they are judges on several criteria. The variant's attributes (qualities/features) are expected to meet the criteria of the decision maker. So in fact attributes are a feature of the variant and criteria are features of the decision maker.

D) Decision
The concept presented by the consortium creates a 'Binnenmeer'. This is an tranquil area behind a 'ringdike' where the criteria mentioned under b) can be fulfilled in time.
The proposal of the Ballast Nedam-ECT-ING Bank consortium focuses on the partly unknown development of Rotterdam mainport. Starting with construction of a 'ringdike' the proposal foresees in the acute need for space for container activities. The 'binnenmeer' concept gives space for ecological development en special chances for development of nature. By proposing a PPS-form of contracting this concept helps to create social acceptation.
II. BOT\textsuperscript{14} contract structures at BNI

by: Ballast Nedam International

The following part describes the structure of Projects at Ballast Nedam International (BNI). The general activities of BNI were described in paragraph 5.2. Because cases at BNI are classified the work methods are presented in accordance with BNI presentation sheets.

\textit{Base:} Initiative of international party to develop a project.

\textit{Objective:} To create a corporation in which participating parties come to the development (build, operate and transfer) project.

\textit{Decision to make:}
Projects of BNI are divided in 6 phases in which BNI manages three different roles. BNI has three roles in the whole process.

A. Developers role
B. Contractors role
C. Equity providers role

The figures below illustrate the connection between the different roles and the project phases.

![Diagram of project phases with roles A, B, and C, and financial close milestone]

\textit{Figure 5—7 Project phasing at BNI and important decision moments}

In accordance with Figure 5—7 BNI performs in the initiative phase as a developer and contractor. In pre-feasibility phase BNI produces conceptual budgets and makes preliminary approaches. The equity provider’s role is represented in an investment advising task. After this first study a ‘Go-No Go decision’ has to be made.

When it is decide to ‘go’, BNI continues in the feasibility stage by producing a more detailed form of preliminary price(s), design & estimate. The ‘development manager’ now takes over the development process responsibilities of the portfolio manager. Also investment advice is performed by BNI.

The fourth phase is closes the financial phases. The development process is finished by negotiations on contract, construction, basic engineering and investment. When all involved parties come to an agreement the construction of the project may start; there is a so-called ‘financial close’. The developers role of BNI stops. BNI proceed in the contractors role and the equity providers role. During construction and the operations the following chart can describe Ballast Nedam International.

![Diagram of organisational structure with Development Group, Mondial portfolio managers, Financial Engineers, and Developing Managers]

\textit{Figure 5—8 Organisation BNI}

The Mondial managers are working around the world in order to collect and prepare projects. When projects are financial feasible (work by financial engineers), the developing managers take over the role and does the management until the end of the project.

\textsuperscript{14} BOT: Build Operate and Transfer projects
It has to be noticed that the negotiation phase has the longest duration because of the fact that all parties involved has come to an agreement. Figure 5—9 (next page) gives an insight in the parties involved in BNI projects during the whole process.

Figure 5—9 BOT contract structure at BNI

In this phase the uncertainties are big and very hard to quantify. Discretisation of external risks is hard. For example: finding a discrete value for the chance that an government will create a delay by not giving permission to build is an external factor that is hard to control. In fact BNI has to control other organisational risks. The ‘state of nature’ will be hard to predict by experts.

Uncertainties/Risks recognition:
The risk that are recognised at BOT projects are:
- Political/legal risk
- Construction risk
- Operating risk
- Input risk
- Revenue risk
- Environmental risk
- Economical risk/financial risk
- Development risk

An example for risk allocation at BOT projects by BNI could as shown in the following table(BNI presentation sources):

<table>
<thead>
<tr>
<th>Risk</th>
<th>government</th>
<th>Equity providers</th>
<th>Debt Providers</th>
<th>Contractor</th>
<th>Operator</th>
<th>Users</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political/legal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eco-financial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5—10 Risk allocation Table at BOT projects (BNI)
5.5 Starting points on further investigation

- Ballast Nedam has little experience in quantifying plan uncertainties.
- The base of applicability of Decision Analysis at Ballast Nedam depends on the quantification of the ‘Decision Profile’ at a Ballast Nedam subsidiary:
  - **Objective:** Is it possible to express the Ballast Nedam objectives in non-monetary values?
  - **Uncertainties:** Is it possible to quantify uncertainties by interviewing experts in the same way the analysis process is performed now?

- Problems occur when the risk item list contains items which are not easy to quantify. Therefore the investigation will focus on the phases of the project process where these items play a role.
- The subsidiaries in Group I (BNO, BNI) perform in the early phases of the process where these items play a role. The investigation focuses on these two subsidiaries.
- The investigation will focus on the application of Decision Analysis at big infrastructure projects. Public and Private influences will play a role.

5.6 Summary

Ballast Nedam covers thirteen subsidiaries. Five subsidiaries are involved in developing infrastructure projects:
- Ballast Nedam Engineering (BNE)
- Ballast Nedam Developing (BNO)
- Ballast Nedam International (BNI)
- Ballast Nedam Grounds and Roads (BNGW)
- Ballast Nedam Concrete and Hydraulic Works (BNBW)

Based on the features on these subsidiaries a classification (in groups) seems to be appropriate:

<table>
<thead>
<tr>
<th>Group I</th>
<th>BNO; BNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>BNBW; BNGW; BNI</td>
</tr>
<tr>
<td>Group III</td>
<td>BNE</td>
</tr>
</tbody>
</table>

A theoretical approach on classification of uncertainties describes three classes of uncertainties:
1. uncertainties involving normal events
2. uncertainties involving special events
3. plan uncertainties

Ballast Nedam Engineering has procedures describing identification and quantification of normal uncertainties and special uncertainties. There is little experience in quantification of plan uncertainties.

The quantification of uncertainties often takes place by interviewing experts. When it is necessary groupthinking processes like brainstorming is used.

Working with triangular distributions helps the Ballast Nedam risk analyst to translate the expert opinion into probability density functions. Having special uncertainties (events) the expert is asked to estimate the chance of occurrence in a discrete value.

The probability distributions of different experts are combined by the risk analyst. This combination takes place by fitting. Two techniques are available at Ballast Nedam.
1. The Triangular fit
2. The Moment fit

Cases at Ballast Nedam provides insight in the uncertainties play a role at big infrastructure projects. Because of the web of involved parties it is very hard to create an overview on the influences on decision making processes.
The involved parties often are:
• Prime Contractor
• Government
• Users
• Operators
• Founders
• Equity providers
• Public parties
• Environment

Attributes and criteria that play a role often are:
• possibilities in economic development
• development of nature
• hindrance on environment
• employment
• trade off of variants
• operating quality.

5.7 References

[Vrijling] “Kansen in de Civieke Techniek, CUR rapport”, Prof.drs.ir. J.K. Vrijling e.a.,

[Vrijling2] “Probabilistisch ontwerpen in de waterbouwkunde”, Prof.drs.ir. J.K. Vrijling


[OR] Organisational reports of Ballast Nedam subsidiaries


[Internet] www.ballast-nedam.nl


Appendices
Appendix AA Logical model on Risk Management

- Public Private Corporation
- Compensation systems
- Risk Allocation
- Project Phase
- Sources
- Approach
- Strategy

Risk Management
# Appendix BB

## Features of Risk Identification Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Objective</th>
<th>Procedure</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Checklists</td>
<td>Delegate knowledge of former projects</td>
<td>Creating list by personnel and specialist</td>
<td>1. Possibility to describe a large number of risks 2. Efficient method as first insight 3. Describing risk at a detailed level</td>
<td>1. Does not stimulate thinking. 2. Adjustments are necessary. 3. Subjectivity 4. Does not give insight in the accuracy of the form</td>
</tr>
<tr>
<td>2. Introducing of important project parties or external experts</td>
<td>Get knowledge on risks of special techniques or types of construct</td>
<td>Conversation between risk analyst and involved persons</td>
<td>Interviewing on subjects makes it possible to deepen parts of projects</td>
<td>1. Interviewed person must have time. 2. Depends on qualities of the person being interviewed.</td>
</tr>
<tr>
<td>3. Brainstorm of the project team.</td>
<td>Combine multidiscipline knowledge and create creativity in the project team.</td>
<td>Unstructured group conversation.</td>
<td>Big freedom in association is possible. It provides abnormal and new risks.</td>
<td>1. Quality depends on knowledge of group. 2. Not easy to determine completeness</td>
</tr>
<tr>
<td>4. Fault Trees</td>
<td>Determine undesirable situation</td>
<td>Designing a structured reproduction of causes of consequences.</td>
<td>1. Structured method to describe a complex process; it helps to understand the process. 2. This method shows to weakest link in an activity. This helps to identify risks.</td>
<td>1. In an early stage of the project a lot of information is necessary. 2. labour intensive work</td>
</tr>
</tbody>
</table>
Appendix CC Subjects on Decision Making

- Decision Making
- Consequences
- Uncertainties
- Decision to make
- Value and objective
- Mathematical approach
- Used Model
- Strategy
# Decision Profile

**Risk Analysis**

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase: Plan development</td>
<td>Political/juridical decision making</td>
<td>Not getting permission to build decision making process</td>
<td>special event</td>
<td></td>
<td>End of work</td>
<td>Intensive consultation about program of demands</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unpredictable political strategy</td>
<td></td>
<td>special event</td>
<td></td>
<td></td>
<td>Convincing government of necessity of harbour expansion and perspectives 'Binnenmeer' concept.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slow decision making process</td>
<td>Control decision making process</td>
<td>normal event</td>
<td></td>
<td>Delay Project. Construction planning too little.</td>
<td>Decision making procedures in contracts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interaction between governments</td>
<td>Country, provinces and cities do not communicate their plans.</td>
<td>Special event</td>
<td></td>
<td>Program of demands bound. conditions not clear. Delay of project. Extra Costs</td>
<td>Stimulate government to decision making processes and taking a clear strategy</td>
<td></td>
</tr>
</tbody>
</table>
# Decision Profile

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project organisation</td>
<td>Interests of consortium parties are not linked</td>
<td>Clear organisation process for every party of the consortium.</td>
<td>Special event</td>
<td></td>
<td>Extra Costs, delay. Conflicts in organisation. No uniform concept.</td>
<td>Uniform definition of different starting points and objectives in consortium.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more consortium members do not put enough effort in creating an organisation</td>
<td></td>
<td>special event</td>
<td></td>
<td>Stagnation of progress project. Insufficient means for realisation of a good concept plan.</td>
<td>Definition of Strategy of the consortium as a whole. Priorities and responsibilities.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategy of GHR is not clear for consortium</td>
<td>GHR has a clear strategy</td>
<td>special event</td>
<td></td>
<td>Tensions in consortium. Conflicts.</td>
<td>Stimulate GHR to make its own strategy.</td>
<td></td>
</tr>
</tbody>
</table>
## Decision Profile

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase: Plan development</td>
<td>No experience in PPS contracts: What is the role of the government</td>
<td>Create an insight in PPS contracting</td>
<td>special event</td>
<td>Wrong interpretation of contract, conflicts, claims and division of project risks.</td>
<td>Deliberation between involved parties, definition of functions, starting points, responsibilities.</td>
<td>Know the law</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incomplete legislation of PPS contracts</td>
<td>Definition of rights and obligations, responsibilities on duties.</td>
<td>Special event</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One of the parties leaves the consortium and is bankrupt</td>
<td>Keep the consortium complete</td>
<td>special event</td>
<td>Delay, extra costs</td>
<td>Contracting new involved party</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commitment and responsibilities are not fixed in the contract</td>
<td>Definition of procedures and clear structures of organisation in a contract</td>
<td>special event</td>
<td>Conflict situations, delay, extra costs, tensions in consortium</td>
<td>Definition of responsibilities regarding to works</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No directives on tendering document. There is a possibility the concept will be tendered over Europe and the consortium will be taken out of control because too much knowledge</td>
<td>Getting the project</td>
<td>special event</td>
<td>Tendering of projects goes to another consortium</td>
<td>Make agreements with government on tendering procedures and financing plan development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Appendix DD**  
Decision Profile
## Decision Profile

**Risk Analysis**

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase: Plan development</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Financing</td>
<td>Founders are not willing to invest in the project or parts of the project. Especially for risk full and not profitable parts</td>
<td>Create an attractive concept for founders or stakeholders</td>
<td>special event</td>
<td></td>
<td>insufficient financing of the project</td>
<td>financial feasibility study Contracting founders by create an alternative that is more attractive for founders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No agreement about financing of profitable parts of the project</td>
<td>Agreement in consortium about financing plan</td>
<td>special event</td>
<td></td>
<td>making compromises contracting new founders</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Output of exploitation is insufficient compared to the prognosis</td>
<td>sufficient exploitation</td>
<td>special event</td>
<td></td>
<td>shortage in financing</td>
<td>studies on development sea ports. Alternative filling in of port area</td>
<td></td>
</tr>
<tr>
<td>GHR does not link present harbour area and ‘Maasvlakte 2’</td>
<td>Full connection between present infrastructure and Maasvlakte 2</td>
<td>special event</td>
<td></td>
<td>Separate Maasvlakte 2; financial (invest) risks are high</td>
<td>definition of procedures with government.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncertainties on application of Selective Investment settlements</td>
<td>Uniform strategy for all involved parties</td>
<td>special event</td>
<td></td>
<td>Extra Costs</td>
<td>Definition of strategy and making agreements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private founder goes bankrupt.</td>
<td>Create sufficient financial capacity</td>
<td>special event</td>
<td></td>
<td>Extra Costs, delay, financial shortcomings</td>
<td>Definition financial capacity of founders</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Appendix DD**

Decision Profile
# Decision Profile

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial feasibility of container terminal ECT on '2nd Maasvlakte'</td>
<td>Expansion of container market is less than expected</td>
<td>Get a clear insight in market development on container transhipment</td>
<td>normal event</td>
<td></td>
<td>No needs for harbour expansion in Rotterdam</td>
<td>Performing a study on container transhipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expansion surrounding harbours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capacity expansion in present harbour area caused by:</td>
<td>Get a clear insight in development on present harbour area</td>
<td>normal event</td>
<td></td>
<td></td>
<td>Performing a study on harbour development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• free harbour basins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• optimal use of present harbour areas</td>
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<td></td>
<td>• smaller storage needed by growing technical development</td>
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<tr>
<td></td>
<td>Uncertainty on willing to invest in ECT Terminal of external parties in</td>
<td>Insight in way of funding the project</td>
<td>normal event</td>
<td></td>
<td>No insight in way of funding of Maasvlakte 2</td>
<td>Communicate with potential founders.</td>
<td></td>
</tr>
</tbody>
</table>
## Decision Profile

### Risk Analysis

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>General Risk</th>
<th>Objective</th>
<th>Uncertain event (classification)</th>
<th>Quantification</th>
<th>Effects</th>
<th>Measure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase: Plan development</strong></td>
<td></td>
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<tr>
<td>Environmental activists</td>
<td>Opposition by environmental activists</td>
<td>Good communication with environmental activists</td>
<td>normal event</td>
<td></td>
<td>construction of Maasvlakte 2 will be delayed or will be stopped</td>
<td>Communication with activists about boundary conditions</td>
<td></td>
</tr>
<tr>
<td>Coastal development</td>
<td>The coastline develops in a different way than expected</td>
<td>Get insight in coastal development</td>
<td>normal</td>
<td></td>
<td>extra costs coastal management</td>
<td>Study on coastal development (preventive) Sand supplementary and dredging (corrective)</td>
<td></td>
</tr>
<tr>
<td>Influence on environmental development different than expected</td>
<td></td>
<td>normal</td>
<td></td>
<td></td>
<td>Claims from environmental organisations</td>
<td>Study on effects on environment</td>
<td></td>
</tr>
<tr>
<td><strong>Design Maasvlakte 2</strong></td>
<td>little experience in designing</td>
<td>Create a reliable design</td>
<td>normal</td>
<td></td>
<td>Wrong interpretation of conditions</td>
<td>Communication with involved parties</td>
<td></td>
</tr>
<tr>
<td><strong>Design ECT Terminal/connection with present infrastructure.</strong></td>
<td>Connection from ECT on railways etc. is insufficient</td>
<td>Create a good working logistic system</td>
<td>normal</td>
<td></td>
<td>transit speed is insufficient or not optimised</td>
<td>Study on logistics) or adapting internal infrastructure</td>
<td></td>
</tr>
</tbody>
</table>

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**Appendix DD**  Decision Profile
Appendix EE General Risk Listing

Internal Risks
Product developing
Sensitivity on economic situation
Image building

Management Risks
Fault decision
Communication
Knowledge-management
Quality management

Financing Risks
Invest
Invoice-system
Liquidate
Insurance

Operational Risks
Quality of working procedures
Teambuilding/People-management
Emergency procedures
Planning risks
Technical failures
Engineering
Availability & reliability applied structures

Location Risks
Soil investigation risks
Environmental effects

Political/Juridical Risks
Contracting
Legal responsibility

External Risks

‘Force majeure’ Risks
Big accidents
Natural disasters
Earthquakes
Fluid streams.

Market Risk
Fusing
Marketing strategy
Acquisition strategy
Public Relations