

Using the concepts of the Real Options Approach for valuing (infrastructural) investments at Hallmark Events Case study: Dutch Grand Prix at Zandvoort



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Image on the cover:

Al vroeg druk op de weg naar Zandvoort en Castricum, (NHNieuws, 2019)

Executive summary

Using the concepts of the Real Options Approach for valuing (infrastructural) investments at Hallmark Events

Hallmark Events are events with a diverse function from regional to (inter)national with a number of visitors up to 1 million people. If an event becomes this big, it is likely to make necessary investments in transport infrastructure to ensure that all visitors can reach the event. Access roads, parking places, public transport upgrades are just a few of the bigger infrastructural investments that might be needed to deal with the demand of visitors. The different solutions are often compared on net present value (NPV), which is a summation of all costs and benefits of a project. Benefits for infrastructure are often gained over time and with high costs for infrastructure a break even point can be found years from the investment moment (Renes, G. Romijn, 2013). Imagine a break even point for the costs and benefits in five years the NPV becomes positive from year five on. In the case of a Hallmark Event it is unknown how many repetitions there will be and if the event is stopped after three years the investment will never be earned back. This specific type of uncertainty that comes with a Hallmark Event is not included in the traditional CBA nowadays.

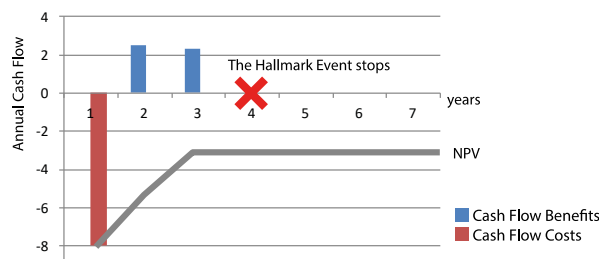


Figure 1: Uncertainty at Hallmark Events with unknown number of repetitions

In the stock trading market the real options approach (ROA) is a commonly used method to validate potential investments. The method is able to identify not only future outcomes, but also the moments in time where decisions can be made. This introduces the possibility to apply flexibility to the investments by being able to know when crucial decisions need to be made (Centraal_Planbureau, 2017; Triantis, 2003; van Aarle, 2013). The application of this method at Hallmark Events has not been found in literature, which is unfortunate since the uncertainty might be captured with this method. Where the CBA just checks the NPV of an investment the ROA also calculates which investment moment is financially most profitable or identifies the moment when a decision needs to be made. The potential of this method has not been researched and therefore the following main question is asked throughout the report:

To what extent results applying ROA for valuing infrastructure projects at Hallmark Events into useful decision-making information?

By using the theories the ROA and CBA a new method for valuing investments at Hallmark Events is developed. The methodology is based on a step wise approach similar to a methodology made by Centraal Centraal_Planbureau (2017). Centraal Centraal_Planbureau (2017) implemented ROA features into a CBA for valuing water construction in the Netherlands. The method is specified for Hallmark Events by also implementing a queuing theory part for determining solutions within the networks for different

modalities at the Hallmark Event (step 1,2). The ROA part was implemented by adding flexibility to the different solutions for the demand problem at a Hallmark Event. The types of flexibility distinguished are 'Waiting for Certainty' and 'Natural Flexibility' (step 3). The 'Waiting for Certainty' considered deferring an investment and wait for more knowledge or certainty about the future. The Expanded NPV can be calculated for different investment moments were each following decision moment is extended with more information about the future. The 'Natural Flexibility' is the type of flexibility that comes naturally with temporary solutions since they can be stopped at any moment and come without big investment costs. The determination of effects and monetizing of those effects came from the CBA (step 4,5). From ROA the decision tree in which all possible outcomes for the future could be presented was included. With each type of flexibility different decisions could be made at each decision moment. The 'Waiting for Certainty' option could be used to test different investment moments for the investment and with the 'Natural Flexibility' the decision moments could be used to stop the temporary solution at any decision moment. Step 6 is an important step in the methodology because it is used to identify the decision moments and give probabilities to the outcome of scenarios. This way

Furthermore it makes it possible to identify decision moments. These moments can be used to do an additional investment or to defer an investment to This way the method is able to identify the best investment moment by including these types of flexibility.

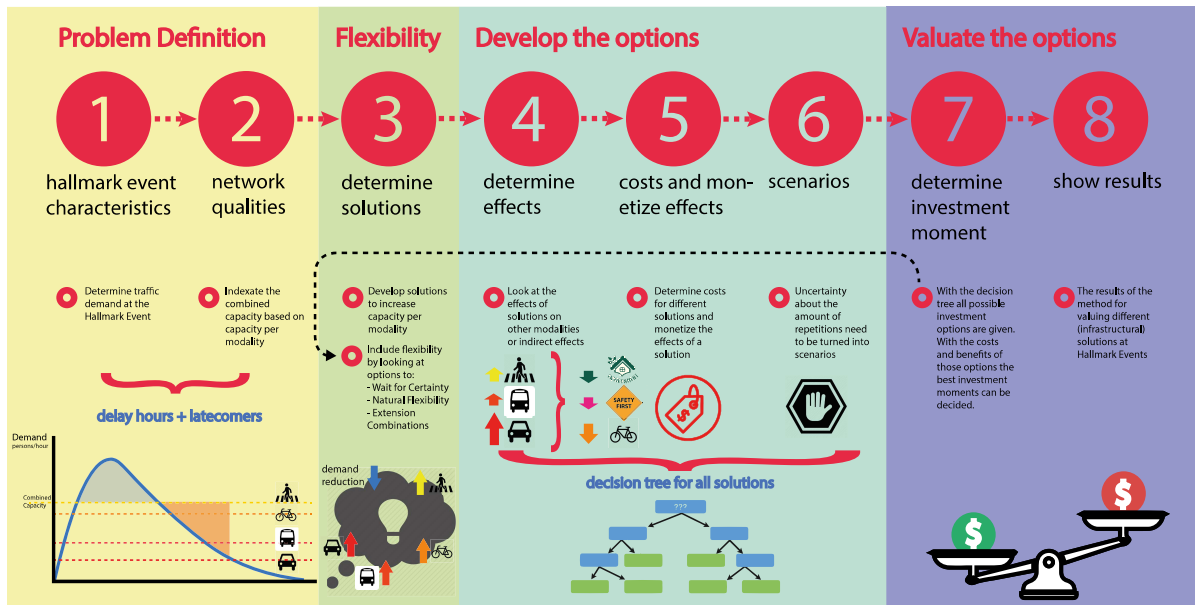


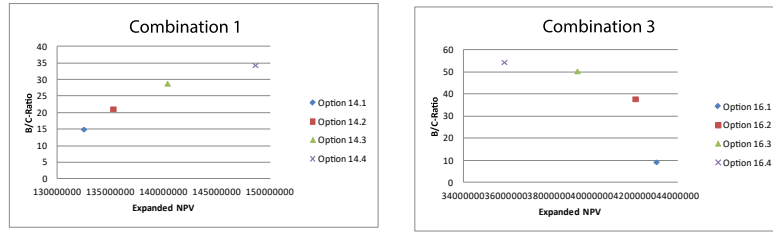
Figure 2: Methodology to deal with uncertainty of repetitions at Hallmark Events

In the coming years a few major events are held in the Netherlands. The Dutch Grand Prix is one of those big events, that can be called a Hallmark Event. The city of Zandvoort does not have a lot of capacity on the current networks towards the circuit, although 140 thousand visitors are expected (Organisation of DGP, 2019). The method is used in a case study to find practical outcomes for the DGP and general outcomes for the new methodology itself. The steps of the method were followed and a CBA is made with the ROA features. Using the queuing theory (step 1 and 2) it became clear that without any investments or temporary solutions there will be major delays on the networks and even visitors that will not make it on time. In step 3 for the modalities car, bicycle, train and pedestrian different solutions were developed to increase the capacities of the networks for those modalities or to reduce the demand. Thirteen different infrastructural and temporary solutions were developed to increase the capacities of the different networks. Flexibility was added with the options 'Waiting for Certainty' and 'Natural Flexibility'. Step 4 and 5 were based on the traditional CBA. Natural flexibility would be able to start or stop the solution at any time, which can be found in temporary solutions. Infrastructural investments were attached with the waiting for certainty option. These investments can be deferred, to gain more

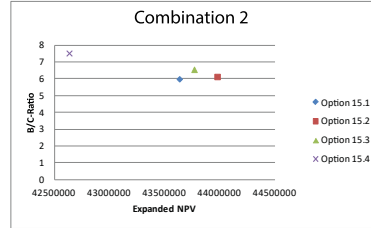
knowledge about the future over time. Effects were calculated and monetized to estimate overall costs and benefits for an investment. In step 6 the scenarios are developed together with the decision moments where potential investments can be made. This is the main difference with the traditional CBA, since the CBA would only consider the different future outcomes. The ROA also identifies the moments in time when an investment can be made or deferred. In step 7 the best investment moments are determined and step 8 is included to show the results in a way it is understandable for the decision maker.

The usage of the new methodology on the case study resulted in the best investment moments for the different individual solutions. Although best investment moments could be identified it became clear that it is not possible to solve the demand problem with only one solution. Therefore combinations of solutions were also made and this became an option in the methodology. This way combinations could be tested on Expanded NPV and B/C-ratio with the addition of altering individual solutions over the decision moments. This way optimal combinations with most beneficial investment moments for the individual solutions could be found. With the valuation of a combination of solutions it became clear that some of the individual solutions that were financially beneficial were better not made if a temporary solution could be used. The lengthening of the train station in Zandvoort turned out financially beneficial, but the overhead upgrade for electric trains not. There were however some solutions that had a best investment moment in the combination that was not the first year. The investment for car infrastructure again turned out financially beneficial in combination with other solution, but the best investment moment was not in the first year. And therefore deferring the choice to the next decision moment is an advise for the municipality of Zandvoort. Overall the infrastructural investment did not turn out to be very financially beneficial, since the uncertainty about the future high and also the costs for the infrastructural investments are high. However the station lengthening is financially beneficial and this is reasonable, since the main bottleneck of the networks could be found in the train network.

After this case study the generic results were discussed that were generated by the usage of this new methodology. For the practical usage of the method multiple outcomes were given for Zandvoort, but also generic outcomes could be given for this new methodology. The Expanded NPV and B/C-ratio were chosen as indicators. With the indicators on the x-axis and y-axis multiple outcome patterns could be identified, see figure 6.2(a,b,c). Patterns for a negative advice on the making of an investment were identified by the visualisation of a better score for both Expanded NPV and B/C-ratio every later investment moment (figure 6.2(a)). For the positive advice the later investment moment scored worse every next decision moment (figure 6.2(b)). The graphs used to visualise these patterns are therefore very useful, but compared with the traditional CBA not that interesting. This is because the same conclusions would be generated by the traditional CBA for the decision on an investment. The third pattern, see figure 6.2(c), became the most interesting one. This pattern did not show a best or worst case for the first or last investment moment, but could also point out the second or third investment moment as the best option. Therefore it became clear that the investment moment does matter for the estimation of financial benefits gained by an investment. With the knowledge that the new methodology is able to identify a best investment moment, that is not the first moment, by checking multiple investment moments it can be said that this methodology could give a broader insight in the possible options for investing.



(a) Shape: Don't make the additional (b) The additional solution solves infrastructural investment problems for a higher price



(c) Shape: Do another check next decision moment

Figure 3: Three outcome patterns

In a research like this the validation of the results might be the most important step. Therefore a sensitivity analysis was performed and two experts were interviewed on the topic. The new method comes with a way of scenario development from the ROA, but this means that new uncertainties appear. Assumptions were made on the amount of year that the event will continue for the case study, but in reality this information might be gained on other aspects. However the outcomes for the different investment moments were considered very useful and an addition to the traditional valuation methods by the experts. The major reason for a valuation methodology is to let a decision maker what the value of a potential investment is. This CBA is often misunderstood and the new methodology where even more information is added to the CBA will probably even be more difficult to understand.

In the end it can be concluded that the implementation of ROA features within a CBA is able to change the information that is given to a decision maker. For most of the outcomes there would be no difference with the traditional CBA, but some cases did show a different best investment moment. However some new uncertainties come into play once this method is used and those need to be researched to make this new methodology practically useful. This basically comes down to a more detailed scenario development with more certainty in the probabilities for future outcomes or multiple repetitions. Also decision makers need to be involved in the process of using this new methodology, since outcomes can be difficult to interpret. In theory this method is capable for finding the best investment moment as a form of flexibility to deal with the uncertainties at Hallmark Events.

Preface

In your hands or on your screen is the thesis that I wrote from September 2019 until March 2020. In this thesis I've tried to make something useful for society. The waste of public money is something that has actually always interested me. And with an event like the Dutch Grand Prix I always have the feeling money is not rationally spend. Not that I am in favor or an opponent of events such as Zandvoort, but because I want the tax money spend in an equal way. That is why I am happy to present a thesis for you that might make it easier for a policymaker to make the right choice.

I would like to thank my supervisors dr. Jan Anne Annema, dr. Victor Knoop and dr. Niels van Oort. Especially for the moments that I needed an extra critical look or even more for the moments that I needed some positive feedback to continue. I think the balance in the guidance was a perfect mix of motivational guidance and constructive critic. In this thesis not only literature was used, but also the knowledge of experienced experts in the field of valuation methodologies. Gerbert Romijn from Centraal Plan Bureau, Niek Mouter and Bert van Wee from TU Delft have helped me a lot with their insights. I'd like to thank them very much for the insight they provided, but also for the time and willingness to help me with completing my thesis.

Delft, March 2020

Rick Smits

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List of Abbreviations and Definitions

Abbreviation	Description
BOPM	Binomial Option Pricing Model
BCR	Benefit-Cost Ratio
BSOPM	Black-Scholes Option Pricing Model
CBA	Cost-Benefit Analysis
CPB	Centraal Planbureau
CF	Cash Flow
CPB	Centraal Planbureau
DCF	Discounted Cash Flow
DGP	Dutch Grand Prix
DRU	Dienstregeluur
LOS	Level of Service
MCA	Multi Criteria Analysis
NPV	Net Present Value
OAT	One-At-a-Time
RADT	Risk-Adjusted Decision Tree
ROA	Real Options Approach
SCBA	Social Cost-Benefit Analysis
TPV	Total Project Value
VOMO	Value of Missing Out
VOT	Value of Time

The methodology that is developed in Chapter 2 uses multiple definitions. The descriptions of these definitions can be found in the table below for a better understanding of the report, when this is not read completely.

Definition	Description
Repetitions	The amount of times that a Hallmark Event is held
Flexibility	The ability to make changes for future investments
Option	A type of flexibility to apply in a valuation method
Solution	An (infrastructural) investment that reduces delay hours and latecomers
Decision moment	The moment when a decision needs to be made for the investment
Investment moment	The moment an investment need to be made
Scenario	A possible outcome for the amount of repetitions for the event
Scenario combination	A set with probabilities for all the different scenarios

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Chapter 1

Introduction

World of Finance - (September 20, 2018)

Goldsmith (2018) wrote an article about the real costs for infrastructure in the World of Finance. The infrastructure that was considered involved the infrastructure that was needed for major sport events. Examples given considered Olympics in China (2008), London (2012), Russia (2014), Brazil (2016) and World Championship Football in Qatar (2022). The main prediction made the organizers of these events is the extra publicity for the tourists sector, however often these potential benefits are miscalculated. Unfortunately big investment costs in stadiums, hotels and also in infrastructure are made for prices unimaginable. Brazil's total investment costs came down to 13 billion dollar, Russia spent 30,8 billion dollars and China paid over 45 billion dollars on the total event. The main conclusion from the article came down to the following sentence. "*It's time politicians started being honest with the public about this, especially when taxpayer money is at risk*" (Goldsmith, 2018). For events like Olympic Games and World Championships it is known that the event will only last one time and a specified plan for investments can be made with that knowledge. What kind of investments should be done when the amount of repetitions is unknown to prevent big financial losses?

One-time occurring or limited occurring events with a regional or international function, such as Olympic Games or music festivals are called Hallmark Events (Hall, 1989). These kind of events can attract a huge amount of visitors. The type of events are known for generating external benefits, or benefits so widely distributed that the costs for the event can be seen covered (Arnegger & Herz, 2016; Hall, 1989; Madden, 2006). However, local people hardly seem to profit from these 'so-widely-distributed-benefits' (Cashman & Darcy, 2008; Chalip, 2006; Matheson, 2004; Roche, 1994; Scandizzo & Pierleoni, 2018). The studies together researched over 30 years and concluded that these big events are attracting a lot of tourists, but hallmark events are rarely beneficial for the local people. Furthermore there is often need for new infrastructure that is needed for the event to facilitate all the tourists that are attracted by the event. The finance for infrastructure is mostly covered by the (local) government and is therefore not beneficial for the local people since other infrastructural investments might be postponed. Also the local companies in the area of an Hallmark Event will not benefit since bigger companies profit from the fact that they have the possibilities to play a part in organizing the event and be main suppliers of goods and supplies (Dunn & McGuirk, 1999; Faulkner, 2003; Sun et al., 2013).

The most interesting aspects to know for an organizer of a Hallmark Event, or for the local government involved, is the value of an (infrastructural) investment. It is desirable to create infrastructure that is aligned with the need for the event while still be beneficial in the long term for daily transport activities. Especially since the local governments have a budget for road maintenance and infrastructural investments and once they invest in infrastructure for the Hallmark Event they might have less budget for the other (planned) investments in their municipality. Preferably the future value of an investment needs to be given, but with big uncertainties this is difficult. The common methodology used for comparing projects is the cost-benefit analysis (CBA). The main problem with Hallmark Events is, like said before, that there is no guaranty that it will be repeated for a specified amount of years (Brent Ritchie, 1984; Hall, 1989; Quinn, 2009). This is an uncertainty for the potential benefits, since those benefits are most of the times expressed in travel time reduction, for all the travellers involved over the life time of a project (van Oort

N, 2017). With infrastructural investments the benefits are gained over multiple years and uncertainty in the amount of repetitions can bring a big risk for the potential benefits (Pereira, Andraz, et al., 2013). For that very reason it would be interesting for the decision maker if there would be valuation method that is able to cope with the uncertainties that a Hallmark Event brings. This way high infrastructural costs might be saved.

In the coming years a few big Hallmark Events are scheduled in the Netherlands. The Eurovision Song Festival is coming in 2020 and the DGP (Dutch Grand Prix) is planned to be held at the original F1 circuit at Zandvoort (Noord-Holland) in the summer of 2020 as well. For these Hallmark Events the same problems might appear that are mentioned above. Therefore it is interesting to value solutions with a method that can include the specific type of uncertainty that occurs at a Hallmark Event. There may be a big difference in the approach of finding the right solution for an event in the city (Eurovision Song Festival) and events in a more rural area (DPG), and therefore a deviation in Hallmark Events might be needed. The scientific gap that this thesis will cover is the method that is missing on the valuation of potential infrastructural projects at Hallmark Events and the process of investing. The Hallmark Events come with an uncertainty in the number of times that the event is repeated. Therefore making it difficult to predict the amount of visitors that benefit from the new solution. A methodology for dealing with this type of uncertainty is therefore needed.

1.1 Objective

The number of repetitions for some Hallmark Events are very uncertain. The current way of valuing (infrastructural) solutions is not capable to handle this uncertainty. The objective therefore is to develop a methodology for finding economically efficient solutions for dealing with the big amount of travelers at a Hallmark Event while cope with the uncertainty of the amount of repetitions.

Another part of the objective is to see if this methodology is of any practical value at a Hallmark Event and therefore a case study is preferred. In this case study the method can be tested and even further developed. At the end of the report a tested method can be presented with all the pro's and con's of the methodology.

1.2 Research Questions

Looking at the introduction of the literature gap and the general problem for valuing infrastructural designs at hallmark events it raises the following main questions:

To what extent results applying ROA for valuing infrastructure projects at Hallmark Events into useful decision-making information?

To answer this question in a structural way a few other question will be answered throughout the research to give a clear view on the total scale of the problem:

1. To what extent can the ROA be an addition to the current valuation methods to develop a potential valuation method relevant for Hallmark Events?
2. How could the potential method be performed at a case study, taking into account the uncertainties of repetitiveness?
3. What is the experts point of view on the new proposed methodology for dealing with uncertainty at Hallmark Events?

1.3 Methodology

The methodologies used in to answer the different questions are explained throughout this section. According to Yin (1994) there are three types of research strategies: exploratory, descriptive and explanatory studies. Looking at the type of main question Yin (1994) would argue this is best translated

into an exploratory research. Exploratory research can be seen as qualitative research to clarify the nature of a problem. Such researches can be executed in different ways and one is the use of a case study, which will be used in the second sub question. However, firstly this research looks into existing researches and knowledge in the field of dealing with uncertainties in the valuation methods. At the end a reflection will be given on the results and the usage of the new developed method to answer the main question. In the following section the methodologies are explained more extensively for each of the research questions:

1. To what extent can the ROA be an addition to the current valuation methods to develop a potential valuation method relevant for Hallmark Events?

The first question will be answered by looking at commonly known valuation methods. Those methods have their advantages and disadvantages when it comes down to dealing with uncertainty. The main focus will be on traditional CBA and ROA and the differences that can be found between the two approaches in terms of dealing with uncertainties. From the literature study it is known that not a lot of studies or case studies could be found for the usage of ROA with the valuation of infrastructural investments. The literature study will focus on the limited literature available on the combination of ROA and infrastructure investments.

All the findings on the valuation methods and their way of dealing with uncertainty will be taken into account to develop a potential valuation method for the infrastructural investments at Hallmark Events. The potential new method will be discussed with dr. Gerbert Romijn who is an expert in CBA. He also developed a method for adding flexibility in the traditional CBA for water constructions in the Netherlands. His expertise on developing a method with features of ROA will be used to give more insight in the way the method should be developed.

The results will lead to knowledge about the valuation methods. Most important is the information on CBA and ROA for taking flexibility into account together with the clear definition of Hallmark Events. Furthermore a methodology based on the research for dealing with uncertainty when investing infrastructure was developed.

2. How can the new method, for valuating (infrastructural) solutions at Hallmark Events, be tested at a case study, taking into account the uncertainties of repetitiveness?

Zandvoort is currently making plans for the Gran Prix that will be held in May 2020. The current infrastructure is not able to handle the amount of visitors for this Hallmark Event (Organisation of DGP, 2019). It is likely that the municipality has a budget and with this budget limited possibilities are available to develop infrastructure to deal with the capacity problems at Zandvoort. Because of the uncertainty of repetitions for the DGP at Zandvoort and the limited budget it is a good example for an event that can benefit from a method that deals with these factors. For different modalities multiple potential infrastructural solutions are developed within the new methodology. The different options for implementing flexibility were used to calculate the added value of the investments proposed. Flexibility was implemented with the different investment options to see what the difference is with the traditional CBA.

The case study will be performed by executing the developed method from the previous sub question. A CBA spreadsheet will be built with the features that came out as usable by sub question one. This way flexibility can be integrated into the spreadsheet to deal with uncertainty. Multiple different solutions will be developed and compared with the new methodology to see if there would be differences with the traditional CBA. In the end specific solutions for the municipality of Zandvoort are presented.

3. What is the experts point of view on the new methodology for dealing with uncertainty at Hallmark Events?

After the case study a reflection will be given on the methodology and generic outcomes are presented to draw generic solutions for the main question. A sensitivity analysis will be performed by using the visualisation method scatter plot to interpret the changes to the outcomes by changing variables.

Eventually the results will be discussed with experts in the field of valuating infrastructural investments. Prof. dr. Bert van Wee and Dr. mr. Niek Mouter were interviewed on the topic and results were presented to these experts. The unit of analysis in this case are the experts that have experience with valuation methods. Again an important aspect for performing the interviews was the way the units were picked. This was done by 'purposive sampling'. The purposive sampling technique, also called judgment sampling, is the deliberate choice of a participant due to the qualities the participant possesses. It is a

nonrandom technique that does not need underlying theories or a set number of participants. Simply put, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience (Etikan et al., 2016). The experts need demonstrable experience in conducting or investigating ROA, and have some experience of their own and added to science.

1.3.1 Scope

The scope of this research will be set in this section. Per question the scope will be mentioned to show what was taken into account and what not. Some limitations or scope related arguments have already been mentioned already in the methodology section. Below per sub-question the remaining constraints.

- The first question will look at the current ways of valuing infrastructural solutions and the potential of the ROA in this valuation. This will be done by looking at the literature and also by interviewing some experts. In the Netherlands CBA is mandatory and therefore interviews with Dutch experts seems more relevant.
- The method developed in Chapter 2 will only look at Hallmark Events with a uncertainty in the amount of repetitions.
- In the case study some simplifications were used in terms of different modalities. Only infrastructural solutions for the modalities: car, public transport and bicycle were included in the case study.
- The solutions in the case study are a set of most likely solutions, for duration and simplicity reasons.

1.3.2 Research approach

The research approach includes all the three sub-questions with the methodologies that will be applied to give an answer to the question. Also the different phases from preparation till conclusion and recommendations are visualised. In figure the visual representation of the research approach is given.

Phases	Progress on the report	Method
Phase 1 Exploration	Literature study on valuation methods	Desk Research
Phase 2 Specification	Developing a new methodology for Hallmark Events	Desk research & interview
Phase 3 Application	Case study Dutch Grand Prix Zandvoort	Case Study
Phase 4 Conclusions & Recommendations	Getting opinions from experts Reflection Conclusions & Recommendations	Sensitivity Analysis & Interviews

Figure 1.1: Research Approach

Chapter 2

Developing a potential method

Hallmark Events can be seen as events with a big uncertainty on the amount of repetitions and the spread of benefits as told in the first chapter. In this chapter the following question will be answered to develop a method on dealing with uncertainty of an Hallmark Event:

What valuation methods are available, how do they deal with uncertainty and how can they be made applicable for dealing with the uncertainty at Hallmark Events?

2.1 Hallmark Events

Before evaluating the different valuation methods it is interesting to get a clear view on what a Hallmark Event is, before considering the best valuation method. The term Hallmark event is one that was already used in the 1980s. An event like this is often carried out in the form of a large exhibition, cultural or sports event (Hall, 1989). The main function of a Hallmark Event is to create a place where a high-quality way of tourism can be achieved. One of the downside of the event is that both nationally and internationally high costs can be incurred socially and for nature. The standard definition of a Hallmark Event can best be given by Brent Ritchie (1984):

"Major one-time or recurring events of limited duration, developed primarily to enhance the awareness, appeal and profitability of a tourism destination in the short and/or long term. Such events rely for their success on uniqueness, status, or timely significance to create interest and attract attention".

A few years later Burgan and Mules (1992) did a research to the characteristics of a "Special Event" and identified some main characteristics for an event to be called a "Special Event".

1. The first characteristic of the event is that there is not one single attractor, but the event can also provide other services such as accommodation, food, transport and entertainment.
2. The demand for the event is condensed into a very short period of time. This can vary from a single day to a few weeks, but not much longer than that. The main problem is that it is not possible to spread out the demand based on the activities that come with the event.
3. The demand leads to a peak in travel movements and this influences the benefits of the event.
4. The benefits or net impacts for local funds are relatively small, not that they don't profit from the situation, but most of the profit is made by national operating funds from outside of the region.

Since a Hallmark Event can also be a local event there is a significant difference between a Special Event and a Hallmark Event. There are however even bigger events like Olympic games that are called "Mega-Events". These events are exceptionally large because of the size of the event and the different attractors that are included in the events program. These events attract a huge amount of visitors to the event location for example in Beijing with 400.000 hotel reservations on average per night (Byrne &

Ragin, 2009). A Hallmark Event can also be a local event with a more regional function and less tourists that come visiting the event. Hall (1989) already evaluated all the different type of events shown in figure 2.1.

Scale of impact	Description of event	Examples	Target Market	Major level of public Financial Involvement	Organisation and Leadership	Economic and Social Impacts of Event on Host Community
	Mega Event	Olympics World Fairs	International	National	Establishment of special authorities by government	International cooperate investment in event and facilities
	Special Event	Grand Prix America's Cup	International / National	National / Regional	Coordination between the various levels of government	Event may be used for urban redevelopment and tourism promotion
	Hallmark Event	Australia Games	National	National / Regional	Limited local involvement, leadership assumed by government	Leakage of profits from host community
		Festival of Perth	Regional	Regional / Local	Major role for regional tourism bodies, local business and government	Corporate investment significant for running of event
		Wellesley Apple and Butter Festival	Local	Local	Leadership and organisation provided from within host community	Economic benefits accrue to host community
	Community Event	Community Fetes and Street Parties	Event designed for local consumption	Minimal local government involvement	Local control	Strengthening of local identity

Figure 2.1: Characteristics of short-term staged events (Hall, 1989)

The Hallmark Event can be identified not only by the size but also by the regional function that the event might have. Where Special and Mega-Events cause a lot of international tourists to come and visit the event, Hallmark Event mainly focused on the local and regional function. The characteristics that Hall (1989) has identified can be found in figure 2.1 in the third, fourth and fifth row. The Hallmark Event has a wide spread when it comes down to the local, regional and national market. The main difference can be found in the Economic and Social Impact. The Special and Mega-Events have international impacts and direct effects on urban development, the Hallmark Event is on a lower level and has some local benefits or even none because of national influences.

Events, no matter how big they may be, are attractors of tourists on a local, regional, national or even international level. This might lead to big changes in the demand for road, train or public transport capacities, but depending of the period of time in which the demand and the amount of repetitions the need for infrastructural change different. The Hallmark Event is serving a group of tourists on a national/regional level with a limited amount of repetitions. The traffic problems or logistic problems that this might cause can therefore influence the decision making process of building new infrastructure or other solution that prevent these problems. The way this decision making process is performed and the methodologies used in the valuation of projects will be examined in the next sections. Eventhough the Hallmark Event is a concepts already mentioned in literature from the 80's there seems no specif valuation method for this type of projects. Therefore a search for a potential valuation method begins in the following sections.

2.2 Cost-Benefit Analysis

The CBA (cost-benefit analysis) is widely used for valuating projects, but is it able to cope with the uncertainty that is introduced by the Hallmark Event? In the world of valuation methods there are three main traditional approaches for valuing a future project. Mun Mun (2002) divided the traditional approaches in three main approaches. These approaches are:

1. Market Approach

The Market Approach tries to come down to an equilibrium for the value of a product based on other comparable products or assets. The producer will get insight when the value of their product is getting up or down or what to do with their prices, size of the firm, revenue levels, operational efficiency and more firm related aspects. The supply and demand is the main driver for the theory behind this approach.

2. Income Approach

The income approach looks at the future potential profit or free-cash-flow-generating potential of the asset and attempts to quantify, forecast, and discount these net free cash flows to a present value.

3. Costs Approach

The costs approach included all the costs that a company has to make to keep their business running or to change their assets to make them future proof. Although this methodology presents itself as one that can handle multiple options, which would make it applicable for flexible option, this is not the case for real flexible options in terms of strategic investing.

Basically the traditional approaches come down to finding the net value of their profit or losses. Many approaches that are made over the years are combinations of one or more of the earlier mentioned approaches. The CBA (Cost-Benefit Analysis) can be seen as a combination of the earlier mentioned approaches. This approach uses the NPV (Net Present Value) for calculating the potential value of an infrastructural solution. The incomes and costs are input for the calculation of the NPV, but this method also take non-monetary values into account by giving a value to aspects like noise, value of time, safety, ect. The whole theory also relies on the DCF (Discounted Cash Flow) which will take care of the devaluation of money over the years (Mun, 2002).

The Centraal Planbureau made a general approach for executing a SCBA (Social Cost-Benefit Analysis) in the Netherlands that can be used for the mandatory CBA at large projects. In figure 2.2 the steps are shown that need to be made for executing the (S)CBA in the proposed way that the CPB made. In the road map the first three steps are called the preparation phase. In the preparation phase, the policy question is translated into a CBA.

1. The problem analysis

The problem analysis part analyses the problem that will arise without the government interfering. The problem analysis is not a part of the valuation, but shows the seriousness of the problem. It is important that the CBA compiler make sure that the problem analysis offers sufficient starting points for a meaningful CBA.

2. The formulation of the zero alternative

The zero alternative is the first step that introduces valuation in the CBA. The effects of doing nothing and let the problem appear is what is valued in this step. The zero alternative is primarily determined by the development of exogenous factors. In addition, the zero alternative policy includes planned measures (at least, if the execution is virtually inescapable) and smaller interventions that it partly solve or mitigate the problem but do not constitute a policy alternative.

3. The formulation of policy alternatives

The combination of policy alternatives and zero alternative must be chosen in such a way that their SCBA provides an answer to the policy question. A policy alternative is defined as the smallest possible collection of interdependent measures that are feasible economically, financially and technically.

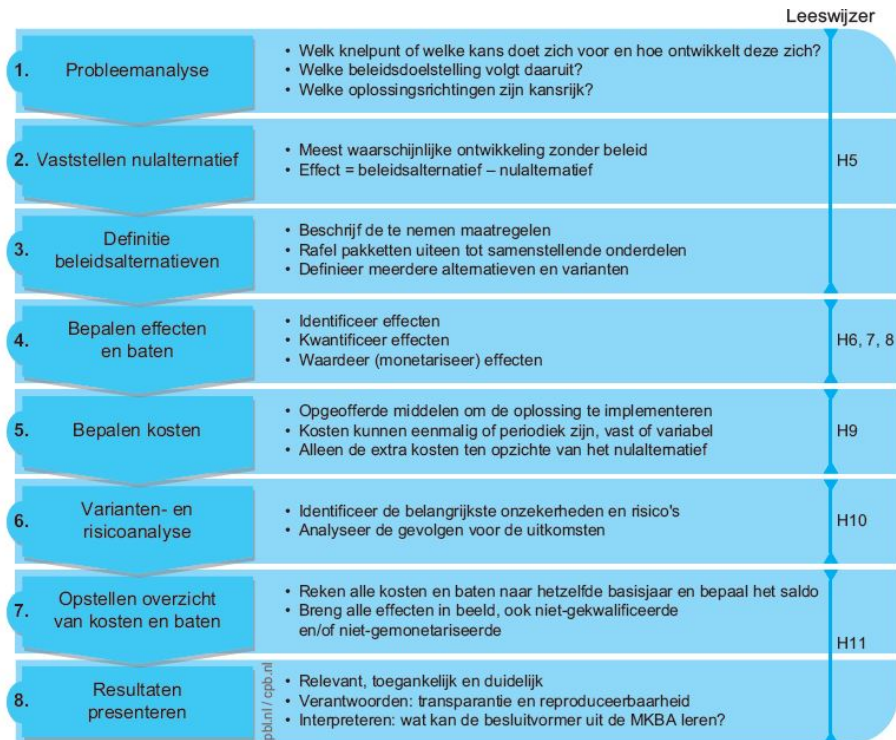


Figure 2.2: Road map for constructing a social cost-benefit analysis (Renes, G. Romijn, 2013)

The preparation phase is now complete and the actual valuation will begin from the fourth step. All direct and indirect effects will be estimated and monetized to be able to compare the chosen alternatives in step 3.

4. Determine effects and benefits

The most important methods for determining the effects are behavioral models, business cases, empirically determined price elasticities, experiments and key figures. The requirements that come with impact assessment in a CBA to the application of the methods are:

- The method must be scientifically verified and must be repeated regularly validated.
- The method must be focused on the effect to be investigated.
- The more important an effect is for the outcomes of the CBA, the more it requires detailed investigation.
- Knowledge uncertainties in applying a method must be named and analyzed.

5. Determine costs

The costs of a measure consist of the costs of the resources needed to complete an investment and the costs to maintain this measure. The costs are defined in a CBA based on welfare-economic principles which tries to monetize all found detriments and benefits.

6. Alternatives and risks

The Centraal Planbureau also mentions limitations with the approach and explained them in further detail (Renes, G. Romijn, 2013). The (S)CBA has a hard time dealing with future changes which is something that is actually a big uncertainty at Hallmark Events. The future is uncertain and so are the estimates of the costs and benefits of measures. This uncertainty means that ex ante estimates of benefits and costs are not accurate but have an uncertainty bandwidth. The longer the time period, the greater this bandwidth. The Centraal Planbureau distinguishes three forms of uncertainty:

- knowledge uncertainty

- policy uncertainty
- future uncertainty

The first two types of uncertainty are mapped with a sensitivity analysis with regard to the uncertain knowledge and if there are important policy uncertainties. Future uncertainty is especially important for long-term effects. This is shown by using scenarios for possible future developments and a apply a general risk surcharge to the discount rate. Uncertainty and risks can also be included in the decision-making process by define policy alternatives that respond to a greater or lesser extent to uncertainty future developments. For example, by considering the benefits of postponing measure, by examining the consequences of phasing a measure or by redesigning the measure in different future circumstances. Renes, G. Romijn (2013) call this adding flexibility to the alternatives and this flexibility itself can also have a value for preventing a unnecessary investment.

7. Overview on costs and benefits

An overview need to be made to make it clear what major costs and benefits occur in the realisation of a specific alternative. This can be seen as showing the NPV (net present value) of the alternative to be able to compare this with other alternatives.

8. Present the results

A CBA may have been performed so well, but if the reporting about it is not in order, the obtained insights lack their effect on policy preparation and can decision makers are being misled. A good SCBA report is sufficient following requirements:

- The results are presented in a clear and accessible way responsible.
- Readers find building blocks for answers to the questions in the MKBA report are important to them in decision-making.
- The report must interpret the results of a CBA: what can the decision-maker do? learn from the CBA?

This approach for developing a CBA that the CPB made is a very elaborate one that is used as a guideline for making a CBA in the Netherlands. In step 6 however the methodology mentions the uncertainties that need to be tackled. The first two uncertainties can be covered with a sensitivity analysis, but the future uncertainty is the one that needs attention. A few approaches for dealing with future uncertainty are mentioned but a real systematic way is not proposed. If this is the case it is imaginable that the CBA is not that usefull for dealing with very uncertain future perspectives. It is therefore interesting to see what the actual usage of the CBA is.

2.2.1 Criticism on the CBA

The most common way of valuing a project or (infrastructural) investment is done through a CBA. Within the Netherlands there is even an obligation to do a CBA when a project has a certain size or impact (Annema et al., 2017). Even though this methodology is mandatory to use in the valuation of solutions it is not mandatory to take the outcomes of the CBA into account in the actual decision making. Annema et al. (2017) found that there was not a significant relation between the high valuation that a project got in the cost-benefit analysis and the actual decision made by the politicians. Some years earlier Mouter Mouter (2012) did a research after the pro's and con's that decision makers identified in their experience with the CBA. He found that the main characters interviewed think that many assumptions must be made when creating a CBA. "According to respondents two essential assumptions need to be made to make the CBA work. Firstly the assumptions for demographic and economic development, because the CBA tries to model the future. Secondly the CBA calculates the effects for a specific project, but those effects are often based on standard models and standard key figures. According to respondents, these assumptions ensure per definition for uncertainty and the correctness of calculations. There is according to the respondents both future uncertainty and knowledge uncertainty"(Mouter, 2012).

Aside from the assumptions that are uncertain there are more cons with the execution of the CBA. It is up to the researcher that creates the CBA to show the calculations of all the different monetized

aspects and this can be done in a way the protagonist will not understand the outcomes (Mouter, 2012). Also travel time gains or travel time delays are calculated different every time and often considered very inaccurate (Flyvbjerg et al., 2008). A respondent of Mouter mentions that travel time calculations are hard to understand and that it is easier and more satisfying to work in a country with less developed networks so the results are more accurate.

When looking at these those mentioned researches it is understandable why CBA is not used that much among decision makers or politicians. The reasons therefore might be political, but by seeing the results of Mouter (2012) it is imaginable that the way CBA is dealing uncertainty is not accurate enough for the decision makers who need convince other adherents in their party. Also the travel time calculations need to be more clear for the decision maker. With that information and the practical approach of the CBA to deal with uncertainty it is almost undeniable that the CBA is not the best way to deal with uncertainty by itself.

2.3 Real Options Approach

The main problem with the Hallmark events that was discovered in the first section of this chapter is the uncertainty for the future regarding the number of repetitions that the event might have. In the Netherlands the CBA is a mandatory valuation method for large scale projects to measure the effects of different solutions, but the outcomes of the CBA are often ignored by decision-makers (Annema et al., 2017; Mouter, 2012). Another downside of the methodology is the way the CBA deals with future uncertainty which cannot be captured in a systematic way. It is possible to build durable infrastructure that can still accommodate uncertain future modifications. Infrastructure strategies based on this observation can be called flexible or responsive strategies. Numerous historic examples show that strategies of this kind have been used for a long time (Fawcett et al., 2015).

The main theoretical approach in the mentioned studies are based on the ROA (Real Option Approach). This method comes from the economic field of research that was mainly focused on the uncertainty in the stock trading business. In Appendix B a more elaborate explanation, of the various applications the theory has, is given there. An actual project that used the full real options approach to value the possible solutions at a project have not been found (Bos & Zwaneveld, 2014). Within big companies the method has been used, but for governmental investments this is not the case. However the flexibility has been used within CBA's, but the value of the actual flexibility was not found by Bos and Zwaneveld (2014). Even though the Real Options Approach (ROA) has not been used fully within infrastructural projects it is a methodology that takes care of uncertainties by developing flexible options for possible scenario outcomes.

The ROA is not applicable for every project and this can make it hard to figure out the added value of a ROA within the CBA. In 2004 Adner and Levinthal (2004) made a general approach for deciding if a project is suitable for applying the ROA. In figure 2.3 the two indicators are given on the axes, which are Uncertainty and Irreversibility. For the infrastructural solutions that we are looking for in this project the value for irreversibility becomes high, for the fact that infrastructure is often realized for a longer period of time. And the uncertainty is high for the number of repetitions of the Hallmark Event itself.

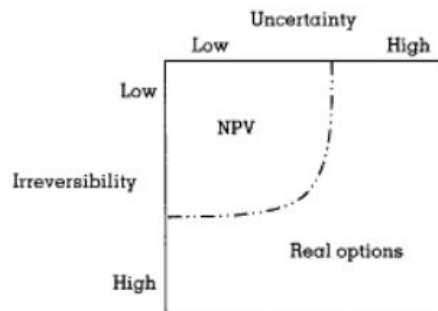


Figure 2.3: Boundaries of Applicability for Net Present Value or Real Options, (Adner & Levinthal, 2004)

The origin of this valuation method comes from the economic sector and has been developed as a decision tool for defining the right moment for buying or selling an obligation (Zhao & Tseng, 2003). The right for buying or selling is called an option. The theory behind this economic valuation is a simple one. Imagine a stock that can be bought for a price K at time T . Then the profit that a stock buyer makes depends on the selling price $S(T)$, once this price is lower than K there will be no profit at all. The buyer will probably wait for a better moment to sell the stocks, but due to the discount rate the value of the stock will decrease over time. The discount rate r decreases the value of the stock over time t as it increases.

$$\text{Expected Option Payoff} = E_{\delta} \max[S(T) - K](1 + r)^{-(T-t)} \quad (2.1)$$

This financial real options approach is the most obvious or simple way to think of the ROA. Over time multiple types of the ROA have been developed to be able to apply it on more fields than only the economic one. Triantis Triantis (2003) wrote a book on the ROA with the applications in the economic field, but also described the other types of ROA that were used in other fields to give a broad vision on the different possibilities with the ROA.

Table 2.1: Different options in ROA (Gijzen, 2016; Triantis, 2003)

Option category	Description	Fields of application	Type of flexibility	Publications
Option to defer	Possible future conditions may be preferable comparing with the present situation. This option exists when management is able to leave an open door to investment opportunities, deferring the investment waiting for a better opportunity to capitalize.	Natural resource extraction industries, real estate developments, agricultural industries, paper products	Upside potential	Tourinho (1979); Titman (1985); McDonald and Siegel (1986); Paddock et al. (1988); Ingersoll and Ross (1992); Anderson (2000)
Option to abandon	When market conditions take an unfavourable turn, the company can terminate its operations, sell the project, and realize the residual value.	Capital intensive industries, financial services, new product introductions in uncertain markets	Upside potential	Myers and Majd (1990); Berger et al. (1996); McGrath (1999); McGrath and Nerkar (2004)
Time-to-build option, staged investment sequential option	There is an option to abandon the project while it is in progress in case the new information is deemed as unfavourable. The commencement of the individual phases is conditioned on the success of the previous phase. It can be interpreted as a series of successive options.	All the R&D intensive sectors, especially the pharmaceutical industry; capital-intensive projects calling for long-term development (e.g. large-volume construction works, power plants); startup of risky enterprises	Upside potential and downside protection	Majd and Pindyck (1987); Carr (1988); Trigeorgis (1993); Kemna (1993); Perlitz et al. (1999); Loch and Bode-Greuel (2001); Lint and Pennings (2001); MacDougall and Pike (2003)
Growth options	An earlier investment is regarded as the precondition of another project. The success of the initial investment can open up new, future investment options for the company.	Infrastructure-based or strategic industries: especially high-tech, R&D, where there are complex product generations; strategic acquisitions; multinational activities; organizational capabilities	Upside potential and downside protection	Myers (1977); Kester (1984); Trigeorgis (1988); Pindyck (1988); Brealey and Myers (1991); Kester (1993); Borissiouk and Peli (2001); Tong and Reuer (2006); Brouthers and Dikova (2010)
Option to alter	Under favourable market conditions, the company can extend the lifecycle of the project, increase the size of series production or accelerate resource utilization. On the other hand, in unfavourable situations, the company may cut back production, or even suspend production temporarily in justified cases.	Natural resource extraction industries (e.g. mining); design of equipment and construction in cyclic industries; fashion products; consumer goods; commercial properties	Upside potential and downside protection	McDonald and Siegel (1985); Brennan and Schwartz (1985); Trigeorgis and Mason (1987); Pindyck (1988); De Neufville (2003); Chung et al (2010)
Flexibility option, option to switch, input and output	Under conditions of production flexibility, in case there are changes in the prices or demand, the management of the company can change the output structure, product structure (production flexibility) or make the same products with the use of different types of inputs (process flexibility).	Output changes: In the case of products that are sold in small volumes, or attract fluctuating demand (electronics; toys; automobile parts) Input changes: electric power; agricultural crops; chemicals; raw materials requiring mechanical processing, pending opportunities	Downside protection	Margrabe (1978); Kensinger (1987); Kulatilaka (1988); Kulatilaka and Trigeorgis (1994); Lieblein and Miller (2003); Mol et al (2005)
Compound option	Options or option chains associated with other options. Because of the mutual dependencies, the values of	Most of the real projects in the above-mentioned industries.	Upside potential and downside protection	Brennan and Schwartz (1985); Trigeorgis (1993); Kulatilaka (1994); Schwartz

From the literature seven types of ROA have been identified, but these types only represent the different types of options that might occur in a project. The different options that are shown in the first column of table 2.1 are more or less likely to be used within a specific paradigm. For infrastructure the

time-to-build and the growth options are the most interesting to look at within the table. One major point of attention is the technique for calculating the value of flexibility within a ROA. The theoretical or mathematical framework to calculate a value for a specific option is not yet discussed. Multiple researchers found a few types of ROA's that can be seen as the main techniques of the ROA. Bos F. and Zwaneveld (2016), Martins et al. (2013), Mun (2002) found the same three main techniques within the ROA. The techniques are:

- Black-Scholes Option Pricing Model
- Binomial Option Pricing Model
- (Risk-Adjusted) Decision Tree

In Appendix B the techniques are described, but these theories are based on valuating stocks for the stock trading business and consider options that are unavailable for infrastructural investments. Also a lot of economic variables are used within the different options that cannot be determined for an infrastructural investment. For example the option to abandon is something that cannot be done with an infrastructural investment, because once it is build maintenance is needed and a government cannot simply stop spending money on it. "There are still major obstacles in the application of the real option analysis in the context from MKBA. For this reason, we do not recommend this method as standard practice." (Renes, G. Romijn, 2013). However there are some options that can be used within the traditional valuation methods. The following options from the table of Gijzen (2016), might give some extra flexibility within the traditional valuation methods.

Option to defer

- Delay. This can be done when it is likely that more knowledge about the future scenario is obtained at later period in time.
- Small adjustments. By taking small steps at a time improvements can be made on the status quo with lower costs.
- Combinations. Small adjustments can be made, but with the possibility of introducing a more expensive solution at a later moment.

Growth option

- Different scale. If a reconstruction is needed and it is expected that the demand will increase in a few years the new (infrastructural) solution can already be built for that period.
- Different form. The majority of the visitors might come by car, but overall there is a need for better bicycle infrastructure then the bicycle network can be built with the possibility for cars to use it during the Hallmark Event.
- Space reservation. Space can already be prepared for a possible construction or be reserved for a possible solution.

Option obtain extra knowledge

- Gathering information. This can be information on specific solutions that have been introduced. This might include information that is not focused on the time savings but on the environment or traffic safety.

If the different solutions are introduced it is now possible to add flexibility for the solutions that are not flexible naturally, which temporary solutions are already.

2.3.1 Practical usage in valuing infrastructure

The ROA has been used by various companies since the 1990s for strategic investment decisions (Bos & Zwaneveld, 2014). However, the real option approach is still not widely used by a lot companies and this is mainly due because the practical applicability and relevance turned out to be less than was first expected. According to the new Dutch guideline for social-cost-benefit analysis (SCBA), the real option approach is promising in theory, but the practical applicability is still a problem. In some Dutch CBA's in the field of infrastructure and energy attention was paid to incorporating flexibility into the investment alternatives, but a value for flexibility was not made. Therefore in 2014 the Dutch Rijkswaterstaat gave the assignment to the Centraal Planbureau to do a research after the practical issues that come into play when the ROA is applied to infrastructural projects. Their approach for valuing infrastructural solutions will be explained in this subsection.

In the table below (table 2.2) some Dutch infrastructural projects are given that took flexibility into account, but non of them executed a full ROA. The combination of infrastructure and ROA is one that has not been applied much. The following reports did an attempt for applying ROA or ROA fundamentals to value flexibility within infrastructural projects. A few of them consist of researches from master-student which is most interesting, but the actual value of such a research is not that easy to indicate.

(S)CBA	Problem	Value of flexibility	Conclusion	Source
Sea entrance in Ijmuiden	How can the entrance of the Noordzeekanaal towards the sea be improved?	Not just analysis of by project organization selected alternatives, but also for five years postponement of one of the alternatives and four others according to SEO 'interesting' variants.	The SCBA balance for the "Major" variant Lock 'is negative. Other variants score clearly better; the most favorable is the postponement variant: the CBA balance included 30% indirect benefits is positive; on top of that there may be the benefits of reduced risk of failure Noordersluis.	Rosenberg en koopmans 2004
Afsluitdijk	Should the Afsluitdijk be maintained or replaced and how?	A flexible alternative (An innovation before a new building process) has been taken into the analysis separately	The benefits of the flexibility can be measured, but depend on the scenario. The bandwidth of the value of these benefits is limited. The flexible alternative was 'no-regret' which had the best overall score.	(Grevers en Zwaneveld, 2011)
Wind energy on land	What are the NET benefits of extra investments in wind energy on land	Postponing the investment is included as a separate alternative.	Additional investments in wind energy have a potential positive return, but this differs per province. Delay by 5 years increases the benefits in all provinces. However, more delay does not seem favorable. Phased construction depending on the future energy price development is the best investment strategy	(Verrips et al, 2013)
Maasvlakte 2	How should the port of Rotterdam be expanded?	Simulation models that were made per social-economic scenario were used to estimate the best timing for investing.	A flexible and phased construction is the least expensive and avoids more risks	(CPB, NEI en RIVM, 2001)
KEA DPIJ	How should the water safety be maintained and keep the water sweet in the IJsselmeer	Short and long-term option are chosen after a good problem analysis and based on a mathematical economic model for required dyke improvement.	For water safety, pumping is among all scenarios more favorable than drains and dykes elevation. The freshwater buffer can be increased significantly in the short term at limited costs.	(Bos et al. 2012)
Safety regarding water in the 21st century	What is the optimal height of dikes in the Netherlands?	A Monte-Carlo analysis was preformed based on statistics for calculating costs and benefits.	This Monte Carlo analysis indicates that the confidence interval around economically optimal probability of flooding is high. Also could an analysis be used for a better estimate of the optimum dyke height.	(Kind et al. 2011)

Table 2.2: Flexibility in Dutch (S)CBA's (Bos & Zwaneveld, 2014)

In table 2.2 the different methods for applying flexibility within the valuation of solutions are shown. Like said before there is not one of those projects that uses a fully executed ROA. This might be caused by the disadvantages that can be found in the literature regarding dealing with the ROA. Although the ROA is a theoretically perfect method for dealing with uncertainty and giving a value for flexibility within solutions it is not always understandable and has some other limitations. Gijzen (2016) gave an extended summation of all the advantages and disadvantages of the ROA based on an extended research and multiple papers written about ROA.

Advantages

- Flexibility has a value within the method. This makes the choice for building or not building at all not always the best solution.
- In figure 2.3 the ROA is applied when the cost for irreversibility is high. The ROA takes care of the risk for irreversible choices.
- The feasibility of a project becomes higher because of the future options that the ROA indicates.

- The ROA can be adjusted per project and therefore has a free format.

Disadvantages

- The traditional decision-making tools/methods are already complex and the addition of the ROA within the existing methods can make it even more difficult to understand.
- The ROA has multiple forms (see table 2.1) and therefore there is not a standardised method for executing the ROA.
- The variables that are needed for the calculations can be hard to find or need to be estimated, which again leads to a less transparent calculation.
- The method is relatively new and not much experience is shared about its applications.

One of the most important disadvantages of the method at this point is free format which makes comparisons of multiple projects very difficult. This is even worsened by the fact that it is a relatively new method that is not used much at all. For this reason the ROA can be very difficult to understand and to validate by using other ROA projects.

To make the ROA more understandable and comparable the Dutch 'Centraal Planbureau' made a general approach for the ROA. The Centraal_Planbureau (2017) wrote a new paper on how to deal with flexibility in CBA's by using ROA features. And mentioned that the infrastructure in the Netherlands is one of the best and is also not that expensive (only 1.3% of the BNP). This is mostly due to the MIRT (Meerjarenprogramma Infrastructuur, Ruimte en Transport) that ensures that infrastructural projects developed over several years. One main disadvantage of the MIRT in the Netherlands is that decisions are made far in advance and are difficult to adjust, as later the circumstances or insights change. A more flexible infrastructure policy, for example by more step-by-step investing and more small measures can then have benefits. They mention that they will make use of the traditional CBA. Cost-benefit Analysis can support flexible infrastructure policies in two ways. First, by analyzing the costs and benefits of flexibility for a specific investment project or policy measure. And secondly by helping to identify new forms of flexibility. In practice, there will often be an iterative process between analysis of costs and benefits, the choice of more or less flexible alternatives and the problem analysis.

They mention the different forms of flexibility which they divided into three main variants of flexibility:

- Different timing
- Different form or (urban)planning
- Invest with extra knowledge

When looking at the first variant 'Different timing' an extra sub-categorisation is made to divide the flexible options within this form. The first option when using a different timing is option to postpone or to build the infrastructural solution in multiple phases. With postponing the actual demands that are changing over time can be captured and a more effective solution can be made. The second option is to do small adjustments or apply mitigating measures. This approach is a smart idea when uncertainty is high. The last one is a combination of the two earlier mentioned approaches. It aims to create combinations of small measurements over time. In figure 2.4 the steps are shown that need to be taken to include flexibility in the traditional CBA.

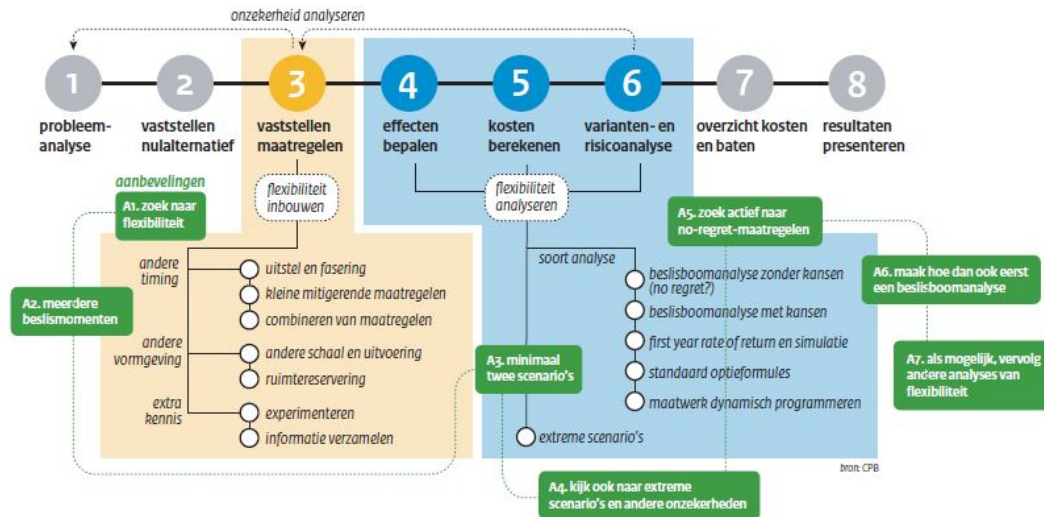


Figure 2.4: Creating flexibility into CBA with 8-step approach, (Centraal_Planbureau, 2017)

The 8-step approach in figure 2.4 is based on the earlier method of the traditional CBA made by Renes, G. Romijn (2013). The steps in the methods are similar but more elaborated to be able to cope with uncertainty by adding flexibility into the valuation method.

2.4 Developing a new methodology using ROA features for Hallmark Events

In the previous sections an extended research have been performed after the valuation methods that can be used for dealing with uncertainty and applying flexibility. For the Hallmark Events, with a limited amount of repetitions, the main uncertainty is the amount of repetitions. In the text box below the problem will be explained in a more practical way to explain what is needed for this type of events in a valuation method.

Hallmark Event needs for flexibility

In the traditional valuation methods different projects are valued on the net present value (NPV). The NPV is a cumulative representation of all costs and gains. In a normal NPV calculation the NPV is cumulative where it usually starts negative with the investment and over time becomes profitable because of the benefits that are generated over time, see figure 2.5. The red bar represents the investment costs, which are 8 million euro in this example. Every year 2,5 million euro is gained by the investment, these benefits are discounted over the years. This means that the value of one euro this year is worth less money every coming year, this is explained in section 2.5. In figure 2.5 it is clear to see that the investment becomes profitable after 5 years.

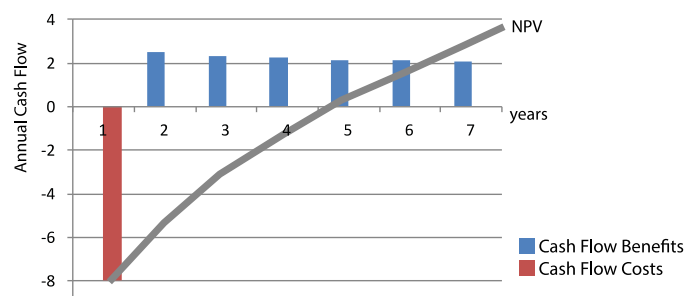


Figure 2.5: NPV example for investment

In the case of the Hallmark Events the uncertainty lies in the fact that the amount of repetitions is unknown. Figure 2.5 could be an example of a Hallmark Event with investment costs for an additional road towards the event, with time travel savings as gains over the years. It could be the case that the event stops after 3 repetitions, see figure 2.6. In this case the same investment is made, but the event stops after 3 repetitions which leads to a negative NPV. This is an outcome that is not preferred, since the investment will then cost more than it gains. Working with temporary solutions or wait for more information about future repetitions can be a way to prevent a government from making a wrong investment. This type of flexibility is needed for this type of events.

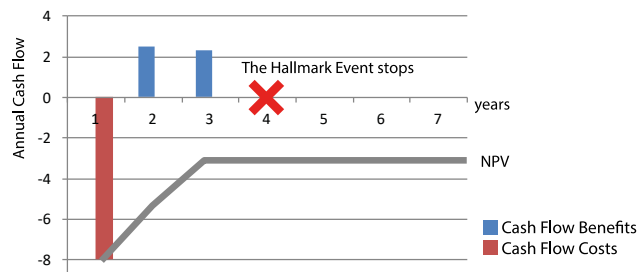


Figure 2.6: NPV example for investment

Hallmark Events can differ in terms of size, duration and repetitions. In the introduction there were two Hallmark Events mentioned; Eurovision Song Contest and Dutch Grand Prix. The first one, Eurovision Song Contest, has a few differences in comparison with the DGP. The uncertainty is way less since it is unlikely that the Eurovision Song Contest will be held in the same country for multiple years. The DGP in Zandvoort will be held in May, with a high probability of more repetitions, but the real amount of repetitions is unknown. Also the location of the Eurovision Song Contest, in Rotterdam, has some advantages because this is an urban area with a lot of transport facilities already in the city, whereas Zandvoort does not have all those facilities. Since Hallmark Events in urban areas already have advantages with available infrastructure the method will only cover the **Hallmark Events in the rural area with an unknown amount of repetitions.**

In the next sections the method will be explained. The method is based on all the findings in the previous sections. In figure 2.7 the new methodology is shown with the steps that need to be taken to apply flexibility in the valuation method for (infrastructural) investments at Hallmark Events. The method is strongly based on the methodology made by Centraal_Planbureau (2017), but the parts are

specially furnished for dealing with capacity problems at Hallmark Events. The main differences in the methods are:

- Problem definition is specified for 'Delay hours and Latecomers' as indicator for the problem.
- Only flexibility options applicable at Hallmark Events are included for implementing flexibility, not all the options shown in table 2.1.
- A feedback loop is introduced, after the determination of the best investment moment of an individual solution, to optimize the combination of different solutions.

In the figure a visualisation is given of the approach because the usability for governmental workers is crucial, like mentioned before. All the steps are described in the section below and the value of flexibility is discussed, which is the main addition on the commonly used CBA.

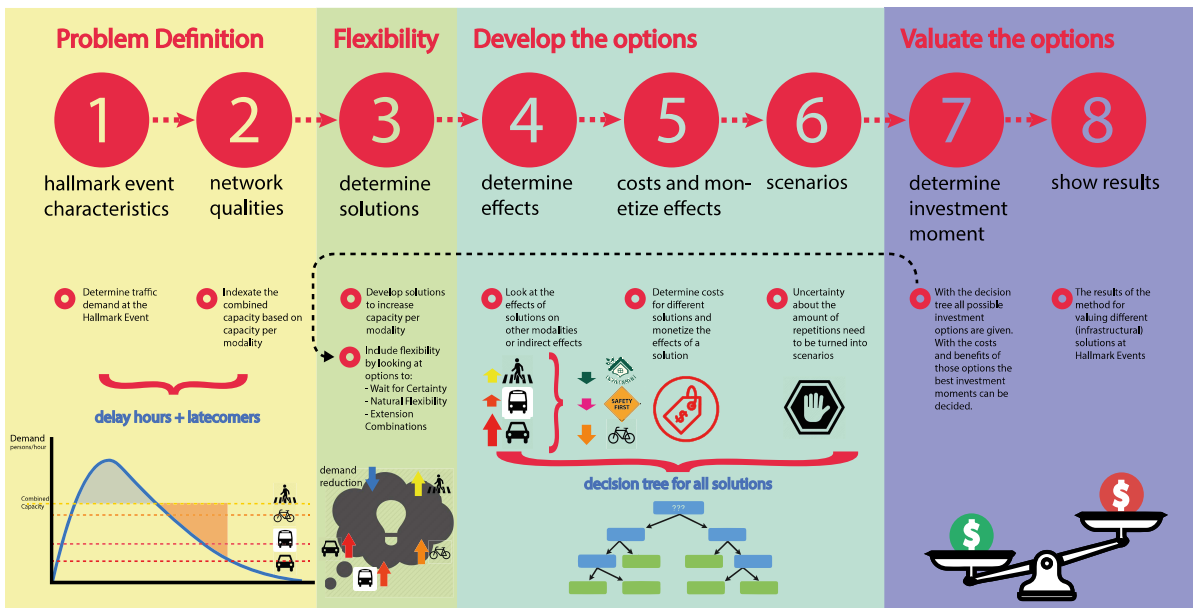


Figure 2.7: Methodology to deal with uncertainty of repetitions at Hallmark Events

2.4.1 Problem Definition

The Problem Definition combines the information about the incoming visitors (Hallmark Event Characteristics) and the Network Quality. This will lead to a demand curve for the inflow or outflow where the total delay time in the networks can be calculated together with the amount of 'latecomers'. Latecomers are those that try to visit the event, but do not get there in time because of capacity issues. The amount of delay hours and the amount of latecomers can be monetized and with those numbers a clear number can be given for the problem definition. In the sections below a clear explanation will be given.

1. Hallmark Event Characteristics

In section 2.1 previous Hallmark Event literature has been researched and one of the main problems was the high amount of visitors that arrive or leave at the same time. This demand might be higher than the capacity of the networks which leads to delay for the users of a network. The first step is to identify the size of the 'problem', the amount of visitors and their need of accessibility towards the event. The amount of visitors can be estimated based on the event and the surrounding activities that come with the event. The arrival rate of visitors is an important aspect for the problem definition, since a wider spread of visitors might lead to less delay at the bottlenecks.

2. Network Quality

The area of the Hallmark Event will probably have some qualities of its own regarding capacities of different networks. In section 2.2.1 it became clear that travel time calculation are often misunderstood or not understandable by decision makers (Flyvbjerg et al., 2008). Therefore a generic approach on calculating the travel time saving is preferred. This will be done by looking at the queuing theory.

In Appendix C the findings of a research after the queuing theory is given, which is used for calculations on travel time savings. The theory uses the cumulative curves that count the inflow and outflow every time step to find out how many people are stuck in the network. The outflow has a maximum of the capacity which causes vehicles to be stuck at a point when the inflow is higher than the capacity. Figure C.3 represents this theory with a demand curve (blue line) and a capacity (red line). On the right the cumulative curves are shown with the vehicle stuck in the network (black line) and the time that they spend there (purple line). The time is given on the x-axis and if there are still vehicles in the network at a specific threshold (or the moment the event begins) there are latecomers.

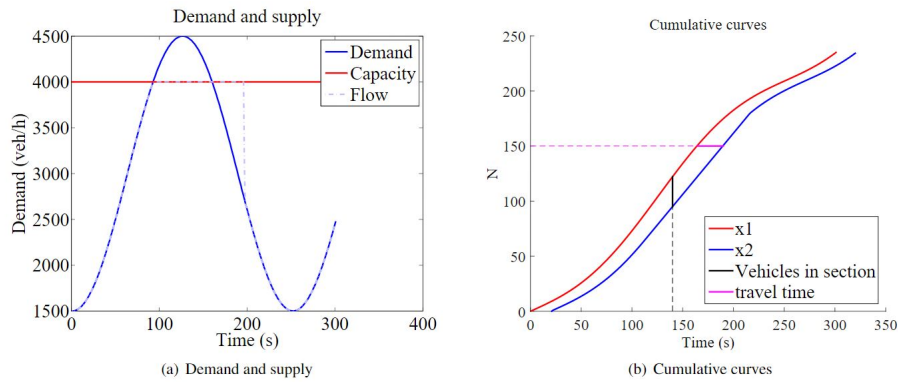


Figure 2.8: Demand and cumulative curves (Knoop, 2018)

The most obvious way to determine the travel time savings of the different networks is by looking at the main bottleneck in the specific network that reduces the capacity and causes delay. This might be found in the parking facilities, intersections, getting on or off a train and other parts in the network that might cause a major bottleneck for a specific network. By identifying those bottlenecks the capacity per network can be found, but the identification of those bottlenecks leads to possible solutions that can increase the capacity of that network for a modality. The solutions will come at a cost, but will increase the capacity by tackling a bottleneck. This way a clear view on the cost and the gains in terms of money and capacity is given. In figure 2.9 the increase of capacities is given with the demand and total capacity separately for all the networks.

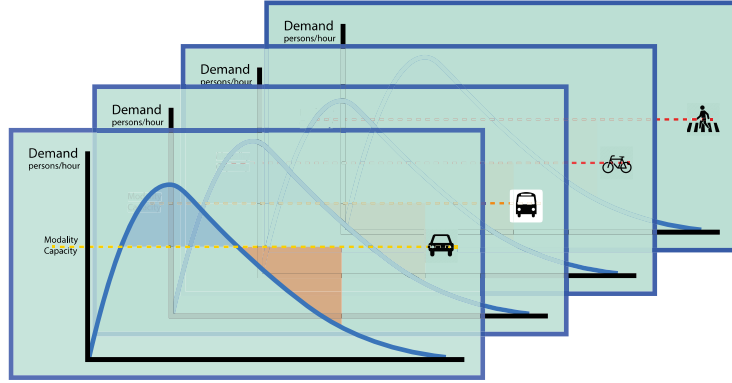


Figure 2.9: Capacities of different networks and occurring demand curve

The extended explanation is found in Appendix C, but this short version shows the way main bottlenecks can be used for the travel time calculation with the cumulative curves. With the Hallmark Event Characteristics and the Network Quality an estimation can be made of the delay that visitors encounter and the amount of latecomers.

2.4.2 Flexibility

This phase will be used to determine solutions and combine these solution with a form of flexibility, based on the flexibility options in table 2.1.

3. Determine Solutions

For all modalities involved it is imaginable to find a solution for the main bottleneck(s) of their specific network. In this step all those bottlenecks will be tackled and one or more solutions per network per modality will be made. In Appendix D, for all the different networks, characteristics have been found to use as input for potential solutions at the different networks. For example different type of trains with seat capacity are given or the capacity in vehicles per hour for different type of roads (cars and bicycle). Another important mindset is the spread of demand. This can be as important as the improvement of a network and therefore needs to be included in this step. A pre- or post activity could generate a spread of visitors at the inflow or outflow of the event.

Introduce flexibility

Flexibility in options for infrastructural investments can be defined by a specific benchmark: The options should have adaptability for unexpected developments compared to irreversible investments. By incorporating flexibility in the decision making and specification of infrastructure projects can respond to new developments. Also a distinction must be made between what must now be decided now and what decisions can be postponed. This can be seen in retrospect if unnecessary costs were avoided (Centraal_Planbureau, 2017).

A crucial aspect in this step is the identification of flexibility within the solutions. The ROA has an advantage over the traditional valuation technique by dealing with uncertainties and this is done by introducing flexible options. The flexibility can be implemented by looking at options that have been mentioned in table 2.1. The most interesting ROA options are: Options to defer (different timing) and Growth options (different form). Both these options are based on the possibility to do an investment at a later moment in time. For deferring the investment is just postponed, for the growth option the investment can be extended over time. The main thought is that at the next decision moment there will be more information available about the amount of repetitions. It can therefore be interesting to wait to do an (additional) investment. Moreover an interesting type of solution is a temporary measure. These

might not solve the problem fully, but is not irreversible. This temporary solution can be stopped at any moment which makes it a safe choice when the amount of repetition is unknown. For this method three types of flexibility are developed based on the literature and characteristics of Hallmark Events. For the types of flexibility a description is given in the paragraphs below. The main advantage of the ROA is the usage of decision trees (Renes, G. Romijn, 2013). For the different types of flexibility a decision tree is given and a full explanation is given in the text box.

Natural Flexibility

Natural Flexibility is the type of flexibility that comes with investment itself. Because the investment costs are low the operational costs become more important. Because of the low investment costs the investment can be executed and stopped at any time. In figure 2.10 the decision tree for this type of flexibility is shown. Every decision moment the investment can be stopped or introduced. If the event is stopped after 1 year (see figure 2.10), than it is wise to stop the measure. Since the temporary solution is designed to solve the problem on a cheap and temporary basis it is probably the case that it will be implemented from the first decision moment on till the event stops. The main characteristics are summed below:

- Natural Flexibility is found in what would be called a temporary measure.
- Natural Flexibility is found in solutions with low investments costs that can be cancelled at every moment.
- Benefits are usually low, but the solutions comes with low risks due to low investment costs.

Waiting for Certainty

In the 'Waiting for Certainty' option the flexibility is built in by the possibility to wait for another decision moment to do the investment. The main thought is that it is likely that information on the amount of repetitions will come at a later moment. Imagine an event that has a concession for one year, the municipality knows the event will have 1 or more repetitions, than after one year it is likely that the host will make a choice about the coming years. If the municipality invests in a car network in the first year the municipality has no choice anymore for deferring the investment. There is no option to add flexibility anymore, because there is no choice anymore about investing no matter the outcome of the future. However if the municipality would wait a year they have the choice to anticipate on the future situation. Than still all the possible investment choices are open and investment costs can be avoided. Below the main characteristics for the option 'Waiting for Certainty' are given:

- This form of flexibility will be used if there is no natural flexibility in the solution.
- If it is likely that there is more information in the future about the amount of repetitions of the Hallmark Event.
- The investment will be calculated for all decision moments. This means a calculation for costs and benefits when investing in the first year or investing in 10 years.

How to read a Decision Tree!

Throughout this report multiple decision trees will be shown. In this text box a reading guide for reading the decision trees is given. In this text box the decision trees for 'Natural Flexibility' and 'Waiting for Certainty' will be explained. The decision tree is made up out of different shapes and colors. These shapes represent:

- Decision moments (Blue Circles)
- Information about the future (text in the Blue Circles)
- Choice for a Infrastructural Investment (Green Squares)
- Choice for a Temporary Solution (Purple Squares)
- Choice to wait (Red Square)

Figure 2.10 the decision tree is given for 'Natural Flexibility'. At year 0 there is nothing known about the Hallmark Event, except the fact that it will be held one time. So the information we have about the future at year 0 is the fact that the Hallmark Event will have 1 repetition, but there could be more. At this year 0 there is a choice for a temporary solution or the choice to wait and don't do any investment. Both the paths lead to the next decision moment at year 1. At this moment there could be two possible outcomes: The event stops (only 1 year), or the event will go on for 4 more years (5 or more repetitions). With the knowledge about the future again a choice can be made for a temporary solution or to wait. If the future turns out to be negative for more than one repetition it is unlikely that a decision maker chooses for another temporary solution.

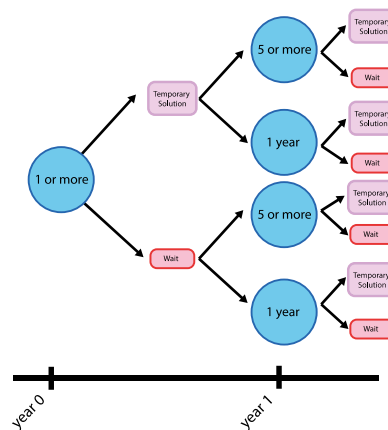


Figure 2.10: Decision tree of Natural Flexibility

In figure 2.11 the option 'Waiting for Certainty' is represented in a decision tree. Again the same decision moments with the same information is given. The main difference with this decision tree is the shape. The decision tree could be made in the same way as figure 2.10, but that would make no sense for an infrastructural investment. An infrastructural investment is a type of investment that is irreversible, because it is unlikely to build a road for one year and then tear it down to have the same choice set at the next decision moment. Therefore the choice for an infrastructural investment leads to a decision moment where the information does not influence the decision, since there is no choice to make. At the right side of figure 2.11 the actual decision tree is given for the 'Waiting for Certainty' option. The investment can be made, but then there is no choice anymore no matter the information given in the next decision moment. The way flexibility is built in, is by giving the choice to wait for the next decision moment and then make the same choice again with new information about the future.

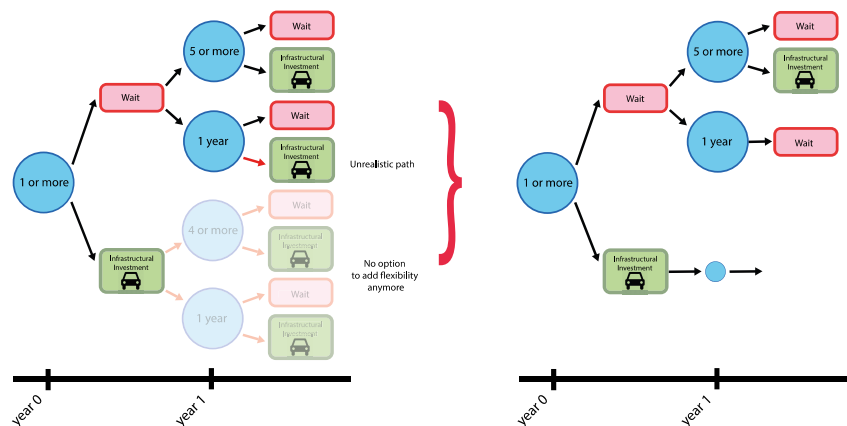


Figure 2.11: Decision Tree of Waiting for Certainty

Simplified Decision Tree

In the figures 2.11 and 2.10 two decision trees are given. At this step it is likely that the amount of repetitions is not yet defined. Therefore it can be sufficient in this step to just make a simplified decision tree. This simplified decision tree only has the solutions in the tree, with the choices that are available, and the new choice that is possible after choosing a direction. In figure 2.12 the simplified decision trees for 'Natural Flexibility' and 'Waiting for Certainty' are given. The shapes that are given in the simplified decision tree are:

- Choice for a Infrastructural Investment (Green Squires)
- Choice for a Temporary Solution (Purple Squires)
- Choice to wait (Red Squire)

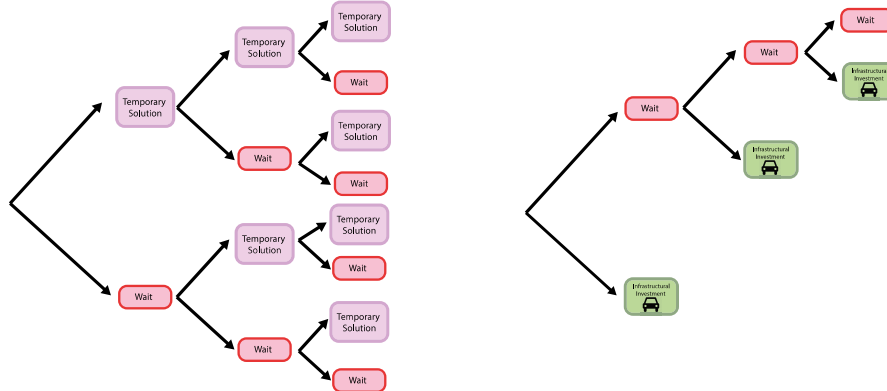


Figure 2.12: Simplified Decision Trees (left: Natural Flexibility, right: Waiting for Certainty)

Extension Combinations

The Extension Combination gives the option to make additional investments every coming decision moment or to combine solutions. It can be seen as a combination of both the options 'Waiting for Certainty' and 'Natural Flexibility'. Therefore it is not a completely new option, but more of a 'Extension Combination'. Investments can be made every decision moment to improve the networks, but avoid the risk of making all the investments at one moment. If the event stops it is likely that the decision maker will stop making additional investments. Therefore this is a specific choice, and definately not the same a the choice to wait. Since the choice to wait is made with the knowledge of the event going on. The choice to stop is made when the events stops. Below the main characteristics of this option are given:

- This form of flexibility is based on the growth option (table 2.1).
- It is a combination of solutions that are applied over time. Robustness is gained by improving the networks one by one.
- Investments start small and become bigger over the years. This will mean that once the event stops an additional investment in the future is prevented, but benefits are gained with a previous investment.

In figure 2.13 the simplified decision tree is shown for this option. The investor can make a choice for a specific investment and make another in a coming decision moment, but if the event stops the investments will also stop. The stacked solutions are not all done in a step, but a choice can be made for one or multiple of them. After an investment the investor can stop or do another investment. Waiting is also possible. In figure 2.7 the methodology is given with the steps to take. In step 7 the best investment moments will be generated. This can be input for this option 'Extension Combinations', because the right moments for different investments can be combined. This can be seen as the optimization step of the solutions determination.

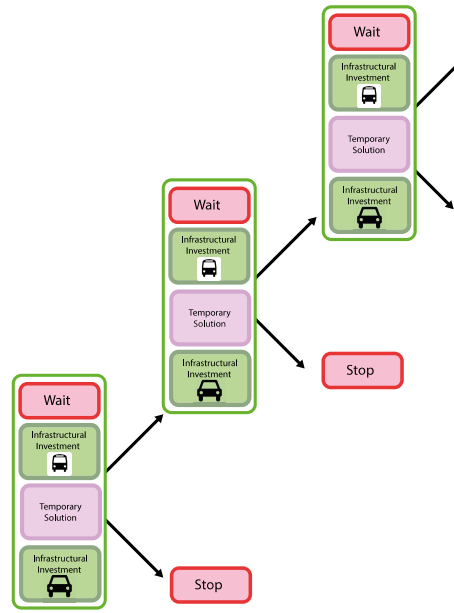


Figure 2.13: Simplified Decision Tree which of Extension Combinations

The three mentioned options to apply flexibility will be used to supplement the solutions. Depending on the solution a type of flexibility can be added. This way flexibility can be introduced in the development of the decision trees for the solutions.

2.4.3 Develop the Options

In this section the solutions are known together with the type of flexibility. From now on all the costs and effects are allocated to the solutions. Together with the scenarios all possible outcomes can be visualized and calculated.

4. Determine Effects

The determination of effects is an important part of this methodology. To value the solutions it is preferred to estimate the effects of a solution as detailed as possible. In the network quality part the queuing theory was introduced to calculate travel time effects, but also other effects might come into play. For example in figure 2.14 the improvement has been made for the network of pedestrians, public transport and cars. The arrows indicate the increase of capacities for an individual modality. On the right hand side the effects are shown: Negative effect for the environment and traffic safety, but also on the capacity of the bicycle network. This is just an example, but it is possible that the combined capacity is not that much better off with an improvement for just a specific modality.

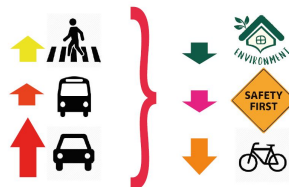


Figure 2.14: Effects of solutions (direct and indirect)

5. Costs and Monetizing effects

The costs for all the different solutions need to be estimated in this step. The monetizing of effects is one of the main aspects of the SCBA, where all the effects are estimated and monetized to compare the

solutions in an extended way. Investment costs, operational costs, maintenance and external costs need to be obtained for all the different solutions. Also the non-monetary values for aspects like traffic safety or environment need to be transformed into a monetary value to estimate the total costs of the solution. The effects that were estimated in the last step can be monetized by looking at key figures or recent researches to the effects.

For example the key figures for monetizing the environmental effects are given in table 2.3. Environmental effects are measured in the amount of pollutants that are produced by one vehicle kilometer. The value of these pollutants are calculated by van Essen et al. (2008) and given in table 2.3. These values will be used to calculate the monetized effects on the environment by the usage of the different modalities to enter the Hallmark Event. Changes in usage of vehicles due to the solutions will give different outcomes for environmental costs, but also for safety, travel time savings and other aspects that can be included in the valuation.

Modality	CO2	NOx	PM	SO2	Total €/km
Car	0.0045	0.0024	0.0087	0.0019	0.0175
Touring car	0.0318	0.0822	0.1657	0.0124	0.2921
Bus	0.0040	0.0030	0.0129	0.0020	0.0219
Bicycle	0.00	0.00	0.00	0.00	0.00
Pedestrian	0.00	0.00	0.00	0.00	0.00
Train (electric)	0.0005	0.0002	0.00	0.0002	0.0009
Train (diesel)	0.0022	0.0068	0.0560	0.0009	0.0659

Table 2.3: Emission costs per kilometer, (van Essen et al., 2008)

In Appendix D all types of tables, numbers and key figures are given. This input is used to monetize the effects that come with a solution. The more detailed the effects of the solution the fairer the comparison will be. The effects should therefore be estimated with as much detail as possible for the solutions at the Hallmark Events.

6. Risks and Scenarios

In step 6 the risks and uncertainties need to be taken into account. In case of the Hallmark Events the amount of repetitions is the main uncertainty for these events. Scenarios can be made based on other events with similar characteristics. This can be turned into a scenario for 1 repetitions and 5 repetitions for example. Multiple scenarios can be made that differ in the amount of repetitions and probability to occur. A similar approach for applying scenarios has been used by Bos and Zwaneveld (2014) by using high or low growth as scenarios. With the scenarios also decision moments can be made. For a better understanding of this development of scenarios, by using a scenario tree, the text box below is given.

Scenario Trees and Scenario Development

The scenario trees are made up out of a few shapes and characteristics:

- Decision Moments (Blue Circles)
- Information about the future (Text in Blue Circles)
- Year indication of the decision moments (Time moments at the x-axis)
- Probability (p) for having multiple repetitions
- Probability (1-p) for having no more repetitions
- Scenario outcomes (Dotted Squares with scenario indication)

The scenario tree can be made by identifying the decision moments. These moments are the moments when information about the future becomes available, in figure 2.15 these are year 1 and year 5. At these moments the decision maker will know if the event will stop or go on for a number of repetitions.

With the identification of the decision moments the decision maker also knows when the possible moments are that the event will stop. These possible stop moments are the scenario outcomes. By looking at figure 2.15 there is a decision moment at year 1 and at this moment the decision moment knows that the event could stop. Therefore the first scenario outcome is 'one repetition'.

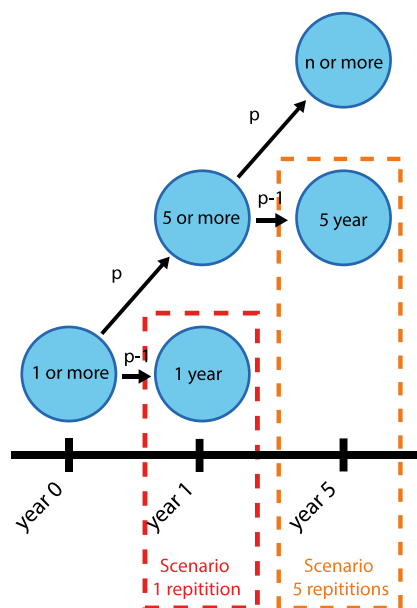


Figure 2.15: Scenario Tree

The probabilities for the scenarios can be given by looking at the ROA and their usage of the decision tree in Appendix B. This is done by picking a probability for a specific future outcome. In case of the Hallmark Events this is the probability p for more repetitions or the probability $(1-p)$ that it stops. By picking a value for p (between 0% and 100%) a scenario combination is generated.

For example: Giving p the value 20% leads to a scenario combination of 80% chance for having only 1 repetitions and $(p \times (1-p) =)$ 16% chance for having 5 repetitions and $(p \times p =)$ 4% chance for even more repetitions. Choosing a set of outcomes for the scenarios without using p is also possible, for example both 1 and 5 repetitions have the chance of 50% for happening. Then the scenarios are independent of probability p .

For the calculation of the costs and benefits the scenarios will be used. 1 Repetition is an outcome for a scenario and if there is only 1 repetition there is no chance of getting another one. The costs and benefits will be added up for only the first year, with the exception of ongoing fixed maintenance costs. This is all relative to the zero solution where no investment is made. So if a solution is postponed with the option to 'Wait for Certainty' the outcome for scenario 1 is zero, since there is no relative difference with doing nothing. If the outcome is '1 or more years' a new pair of possible outcomes appears. The event can now stop after 5 repetitions or have even more repetitions. The outcome of a scenario with five repetitions will add up all costs and benefits for a solution for 5 years, together with ongoing fixed maintenance.

Decision Tree and Value Of Flexibility

With all the steps taken so far a decision tree can be made. Two examples have already been shown in

figure 2.10 and figure 2.11. In this decision tree all the aspects are included that have been gathered in previous steps. These aspects are:

- Decision Moments (Blue Circles)
- Information about the future (Text in Blue Circles)
- Infrastructural Investments with 'Waiting for Certainty' option (Green Squires)
- Temporary solutions with 'Natural Flexibility' (Purple Squires)
- Year indication of the decision moments (Time moments at the x-axis)
- Probability (p) for having multiple repetitions
- Probability (1-p) for having no more repetitions
- Scenario outcomes (Dotted Squires with scenario indication)

In figure 2.16 a full decision tree with all possible aspects is represented. This is the same decision tree that is used in the case study in the next chapter. This decision tree is for the 'Waiting for Certainty' option. A brief explanation will be given, but for a full explanation of this decision tree the previous text boxes must be read. The decision maker has a choice to make at every decision moment, but depending on the outcome of the future some choices become irrelevant. For example if an infrastructural investment has been made some decision moments will appear over time, but there is no choice anymore, since an infrastructural investment is irreversible. Another example is the choice to stop, which is not really a choice since there are no revenues to be gained if it becomes clear in the decision moment that the event will not continue. Every time a decision maker does decide to wait the flexibility is maintained, which means that he/she has still two options at the next decision moment. The value for this flexibility can be positive, but also be negative (see next paragraph).

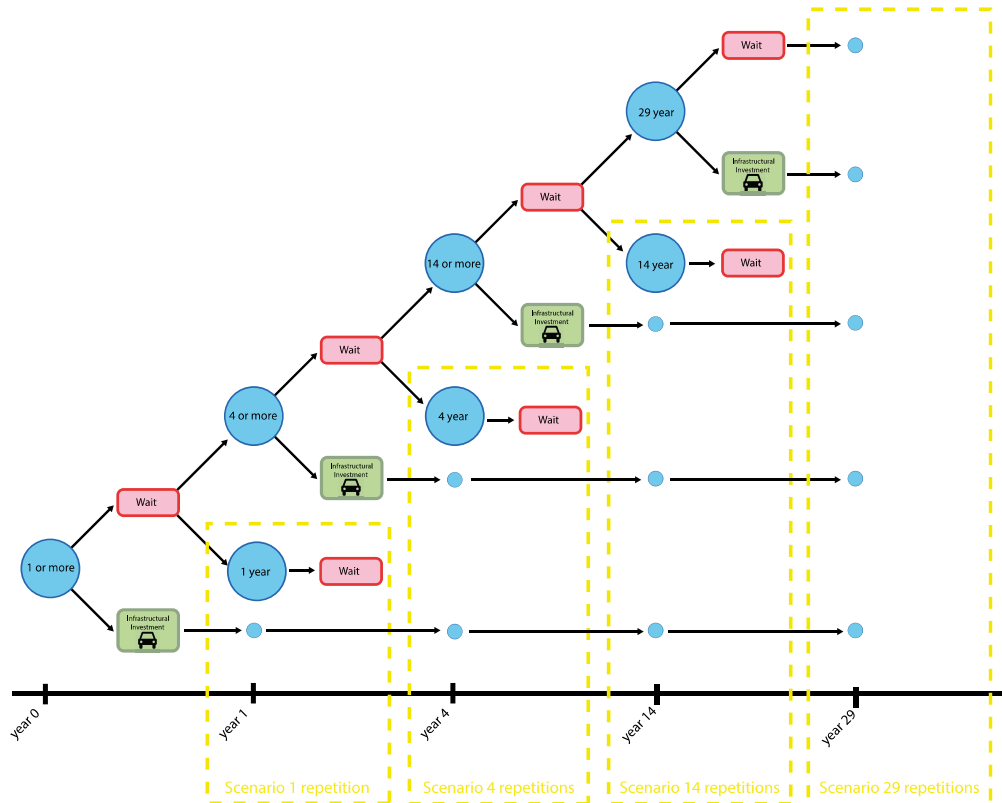


Figure 2.16: Decision tree example

2.5 Expanded NPV and Value of Flexibility

The classic financial valuation method is the calculation of the net present value (NPV), which is commonly used in the CBA. A brief explanation has already been given in the first text box in section 2.4. The net present value is in its simplest definition just the value in euro's (or dollars, ect.) that the investment has in a specific year or at the end of its lifetime. The outcome of the NPV is dependent on the cash flow (CF) per year. This CF includes all the costs and gains in a specific year. The value reduction of money should be included, which is called the discount rate. The discount rate is usually a percentage between 2 and 4 percent for developed countries (Harrison, 2010). This implies that the value of one single euro decreases every year by 4%. In Appendix D a more extensive explanation of the discount rate is given. The formula to calculate the NPV for every year is the following:

$$NPV = CF(t)/(1+i)^t$$

NPV = Net Present Value
CF(t) = Cash Flow for t
i = Discount rate
t = specific year

Centraal_Planbureau (2017) made a methodology for including ROA-features into a regular CBA. A more theoretical approach has been made by van Aarle (2013) who did a research in which he mentioned all the possible ways to use ROA as an add-on component for other valuing methods like CBA. To value flexibility or to add the value for flexibility to the total project value (TPV) a few possible approaches are given that were identified by van Aarle (2013). Multiple options that were given in table 2.1 made by Gijzen (2016) were discussed in his report and how the value of flexibility can be calculated for the different options. The most convenient method for Hallmark Events is the Expanded NPV method. This Expanded NPV can include time to build and growth, which are part of the 'Waiting for Certainty' option, presented in step 3. The formula for this Expanded NPV is shown below:

$$\text{Expanded NPV} = \text{Passive NPV} + \text{Option premium} + \text{Strategic Value}$$

The passive NPV is the NPV without flexibility included. This is the value that the earlier discussed NPV would be in a specific year. The Option Premium can be seen as the true value for flexibility in the calculation for the Expanded NPV. The Option Premium can have many forms, but in case of the Hallmark Events it can be the value for deferring an investment to the next decision moment, to be explained later on. The Strategic Value can be seen as a competitive aspect in terms of investments for companies. If company A invests earlier than company B it might have positive effects for having a head start with respect to company B (van Aarle, 2013). The strategic value is left out of the calculations and this is because of the lack of information on this value. In case of Hallmark Events this value can be seen as very low, by looking at events like the World Championship of Football or Olympic Games. This is because there is a chance of getting an event because a country already has a perfect infrastructure for hosting an event. However there are multiple examples of countries that got the concession for hosting an event, like the Olympic Games, that did not have a proper infrastructure at all (Hall, 1989). This strategic value could also be added as an effect for making an investment and therefore included in step 4.

The scenarios play a big role in the Expanded NPV for an investment moment. If there is a high chance for the event to have 1 repetition, say 75% then there might be a 25% chance of the event having 5 repetitions. Then the Expanded NPV for a solution per scenario can be multiplied with their chance of happening. The probabilities for this combined scenario is described in the 'Scenario Tree Text Box'. Below is the formula that is used in the spreadsheet to determine the expected revenue for a combination of scenario probability and Expanded NPV per solution.

$$\text{Expanded Revenue for decision moment (i)} = \text{Expanded NPV for scenario(j)} \times \text{Probability for Scenario (j)}$$

In the text boxes below a more practical example will be used to explain the concept in more detail.

Traditional Valuation of an investment

Imagine an event where the amount of repetitions is unknown. There is a chance for having the event 1 time, 5 times or 10 times. It is very likely that the event will happen only once, say 50% and to lesser extend that the event will happen 5 times, 30% and even less likely that it will happen 10 times, 20%. The investment costs for an infrastructural investment are €100 and every year €20 is gained on travel times savings, emissions and other monetized effects, see step 5. Furthermore a discount rate of 2% is expected for the devaluation of money over time. In the table below the investment costs and CF are presented for the years.

Year (t)	1	2	3	4	5	6	7	8	9	10
Investment costs (€)	-100	-	-	-	-	-	-	-	-	-
Cash Flow (€)	20	19.61	19.22	18.85	18.48	18.11	17.76	17.41	17.07	16.74
Net Present Value	-80	-60.39	-41.17	-22.32	-3.85	14.27	32.03	49.44	66.51	83.24

With the probabilities that have been mentioned before this leads to the following expected revenue for the investment. The total revenue with the expected probabilities is €-24.51, which is the sum of the Expected Revenues from table below. The table indicates the probability p for every scenario and multiplies this according to the formula given above the text box.

Scenario	1 repetition	5 repetitions	10 repetitions
Scenario Probability p	50%	30%	20%
Net Present Value (€)	-80	-3.85	83.24
Expected Revenue (€)	-40	-1.16	16.65

The traditional valuation method would not recommend the investment, because the average NPV for all the scenarios is negative.

Expanded NPV and Option Premium

With the new methodology it becomes possible to 'Wait for Certainty', which can be done by deferring the investment. If the investment is deferred to year 2 the decision maker will know that the Hallmark Event stopped or that it continues. With this option the Expanded NPV comes into play with the value for the Option Premium. Therefore the table below gives the option in which the investment is deferred to the second year. The Option Premium is €80, because €100 is saved by not doing the investment, but €20 is lost because no monetized effects are gained. The Option Premium is not a value that is added again, but it is made visible for showing what the effect is of deferring an investment. By waiting a year €80 is saved and knowledge is gained for the next four years.

Year (t)	1	2	3	4	5	6	7	8	9	10
Investment costs (€)	-	-100	-	-	-	-	-	-	-	-
Cash Flow (€)	-	19.61	19.22	18.85	18.48	18.11	17.76	17.41	17.07	16.74
Option Premium (€)	80	-	-	-	-	-	-	-	-	-
Expanded NPV	-	-80.39	-61.17	-42.32	-23.85	-5.73	12.03	29.44	46.51	63.24

The expected revenue for this deferred investment becomes now positive because the investment costs for the first year are saved. These costs for investment came with high risk, because it was uncertain if the event would continue or not (a 50% chance). With less uncertainty calculations can be made for the scenario 5 repetitions and 10 repetitions. This comes down to a profitable outcome of €0.38.

Scenario	1 repetition	5 repetitions	10 repetitions
Scenario Probability p	50%	30%	20%
Expanded NPV (€)	-	-23.85	63.24
Expected Revenue (€)	-	-7.16	12.65

However it is not the case that deferring is always a better choice. When the decision maker would wait for year 6 the Option Premium becomes negative for multiple years, because monetized effects are not gained. Although the first year still has a positive Option Premium the years 2 til 5 will miss out on a lot of benefits.

Year (t)	1	2	3	4	5	6	7	8	9	10
Investment costs (€)	-	-	-	-	-	-100	-	-	-	-
Cash Flow (€)	-	-	-	-	-	18.11	17.76	17.41	17.07	16.74
Option Premium (€)	80	-19.61	-19.22	-18.85	-18.48	-	-	-	-	-
Expanded NPV	-	-	-	-	-	-78.04	-60.28	-42.87	-25.80	-9.06

This leads to a negative Expected Revenue of €-1.81. Therefore all different investments should be tested for different investment moments to know which one is the financial most attractive one.

Scenario	1 repetition	5 repetitions	10 repetitions
Scenario Probability p	50%	30%	20%
Expanded NPV (€)	-	-	-9.06
Expected Revenue (€)	-	-	-1.81

In the last table below the Expanded NPV outcomes for the different investment years are shown. In this example the second year has a higher Expanded NPV than year 1 and year 6. Therefore it is not said that the investment should be done in the 2nd year, but at least that the decision maker should wait a year before investing. At that moment there will be more certainty about the future.

Investment year	year 1	year 2	year 6
Expanded NPV	-24.51	0.38	-1.81

2.5.1 Value the Options

The last two steps are all about maintaining transparency for the decision-makers and policy-workers. The method may be executed in a perfect way, but if it is not clear how the results are found the new valuation method has no added value. The cumulative curves will make the travel time savings more understandable, but the way the results are shown will also depend on the actors involved and there main interest for the investment.

7. Determine Investment Moment

For the determination of the best investment moments for the individual solutions a cost benefit-analysis

will be made with the Option Premium that is added as a value for flexibility to the different solutions. The eventual valuation is done by looking at the Expanded NPV, but also other measures are possible. For the case study in this report also the B/C-ratio is included. This ratio gives the efficiency of an investment by giving a ratio that indicates how much euro revenue is generated by investing one euro (Dhondt et al., 1991). In the text box below the practical usage of such extra valuation aspect is described.

The solutions that have been developed for the Hallmark Event are supplemented with one of the forms of flexibility. This flexibility means that the investments can be made at three decision moments, in this example. These moments can be compared on multiple aspects and for the comparison of different solutions not only the Expanded NPV is an interesting outcome. This Expanded NPV might be a large number for bigger investments if the amount of repetitions is high. Temporary solutions might be less beneficial, but because no big investments are made these solutions might score high on B/C-ratio. This value is the outcome of all the benefits divided by all the costs that the solution comes with. By definition the ratio should be higher than one, because for values lower than 1 the costs are higher than the benefits (Dhondt et al., 1991). By using this value as an indicator for the best solution it is more likely that also temporary solutions can become interesting.

Comparing the investment moments

To illustrate the B/C-ratio the example of the previous text box will be used again. The table for the outcome of the Expanded NPV for the investment in year 2 is again shown. The B/C-ratio is dependent on the scenario. For scenario 1 repetitions there is no ratio, because no money is spend. For the scenario 5 repetitions the positive cash flows are divided by the investment costs. In the table below the B/C-ratio is shown per scenario. And this comes down to a combined B/C-ratio of 0.48, which means that every euro invested will generate only 48 cents. Therefore it is possible that a positive Expanded NPV is combined with a B/C-ratio lower than one.

Scenario	1 repetition	5 repetitions	10 repetitions
Scenario Probability p	50%	30%	20%
Expanded NPV (€)	-	-23.85	63.24
Expected Revenue (€)	-	-7.16	12.65
B/C-ratio	-	0.76	1.63

In the case of a temporary solution the B/C-ratio can be a better indicator for a good investment. In the case of a temporary solution there might be no investment costs. The operational costs might be there that are lower than the investment costs, but also with a lower positive CF. The advantage of such an solution is the possibility to stop when the event stops.

Year (t)	1	2	3	4	5	6	7	8	9	10
Operational costs (€)	1	0.98	0.96	0.94	0.92	0.91	0.89	0.87	0.85	0.84
Cash Flow (€)	2	1.96	1.92	1.88	1.85	1.81	1.78	1.74	1.71	1.67
Expanded NPV	1	1.98	2.94	3.88	4.80	5.71	6.60	7.47	8.32	9.16
B/C-ratio	2	2	2	2	2	2	2	2	2	2

In the table below it can be seen that the Expected Revenue is lower but the B/C-ratio is positive which indicates a positive return of every euro invested. Therefore the temporary solution comes with a higher B/C-ratio and with lower risk because the solution can be stopped at any time, as can be seen in step 3.

Scenario	1 repetition	5 repetitions	10 repetitions
Scenario Probability p	50%	30%	20%
Expanded NPV (€)	1	4.80	9.16
Expected Revenue (€)	0.5	1.44	1.83
B/C-ratio	2	2	2

8. Show Results

At this point the decision maker is at his first decision moment and needs to make a choice for what investment he/she needs to make at this very moment. In the previous step the best investment moments for the solutions is determined. If there are solutions that do not have their best investment moments in the first year, these solutions can be left of the results. Or a clear separation must be made between financial beneficial and financially unprofitable solutions.

The solutions will have score on Expanded NPV. This is the most common way of presenting the solution in a CBA. This can be a good way for showing which results are best, but also benefit cost ratio

(B/C-ratio) is a commonly used method. The ratio will give the relatively most profitable solution, which means that a cheap solution that makes little profit might score better than a big investment with higher profits. This is because the benefits are divided by the costs which leads to a ratio of euro's gained by one euro costs.

In figure 2.17 a graph is shown with the indicators Expanded NPV (on the x-axis) and B/C-ratio (on the y-axis). The graph is made for solution #. In the legend on the right the different investment moments are shown as options for the solution. Each shape represents another investment moment. The fourth investment moment in this graph is an option that has a negative Expanded NPV and a B/C-ratio lower than 1. Therefore this investment moment is not financially beneficial to use for this solution. Investment moment (or option) 3 has a positive value for the Expanded NPV, which indicates a financially beneficial outcome. However the B/C-ratio is negative for this option. This can happen because the scenario combinations are build out of multiple scenario and an average NPV and B/C-ratio is given for an investment moment. Therefore also the third moment is not a good investment. The first and the second options are both positive and the best investment moment can not be decided right now. Therefore the outcomes of the other scenario combination are needed to see if there is a best outcome for all the scenario combinations. But for this example can be said that deferring the investment till the third or fourth decision moment is not a wise decision.

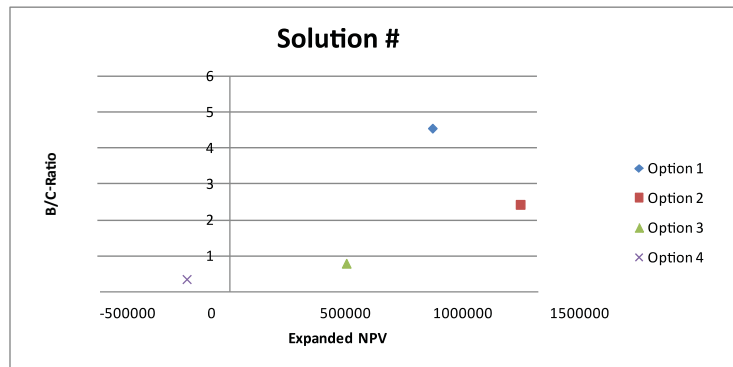


Figure 2.17: Expanded NPV and B/C-ratio Graph

A third way to show the results is in a MCA, where aspects can have a higher weight dependent on the actor involved. This however leads to a new research after all actors involved and their appreciation towards reduction of: emissions, delay hours, latecomers, maintenance costs, etc. One aspect that cannot be forgotten is the value of the investment costs. A solution can be very profitable but if the decision maker does not have the money to do the investment another solution must be found. Depending on the decision maker the results must be presented. This can vary per Hallmark Event. In the case study a justification will be made for the way the results are presented.

2.5.2 Interview with an expert

Because this type of uncertainty has not been captured in a ROA model along with the infrastructural options there are not a lot of experts in the field to interview. However this also leads to opportunities to interview experts regarding ROA in other fields to see their view on the matter with their own expertise and experience on using ROA for valuing options. For the interviews multiple questions were asked regarding the methodology that potentially can be applied for valuing (infrastructural) solutions for the travel demand problem at Hallmark Events. The following questions have been asked:

- What is your experience with ROA in your field of work?
- What kind of approaches do you use (see theory)
- How do you think the ROA can be used for Hallmark Events (again theory)

- How should uncertainty be captured for the number of repetitions?
- How should flexible options be inserted in the model?
- What can be the limitations of this approach?

Romijn wrote did multiple studies in the field of ROA in combination with infrastructure projects. In one of the studies that is also mentioned in the literature part of this chapter he already mentioned that the full ROA is probably not use full, but a valuation method with some of the features is interesting. Therefore Romijn is a perfect researcher to interview regarding this research, since this research shares the same thought on the way of using ROA in combination with infrastructural projects. In this interview the questions standing above were answered, but most interesting his opinion on the method and the research was given.

For the valuation of infrastructural investments at Hallmark Event the ROA might be an extreme measure, Romijn mentions. However the practical might be something that is really interesting for the decision maker at the event. The uncertainty in the amount of repetitions seems a significant uncertainty to take into account for this type of project. The flexibility in investment moments is the only real way to apply flexibility Romijn expects.

At the moment of the interview the method was not fully correct and Romijn helped with the final corrections to finish the method in the correct way. Overall Romijn thinks the method is an interesting application of his original approach and can be use full at Hallmark Events. He mentions that the valuation of the solutions throughout the year might be not that interesting, since they will not solve huge problems otherwise those investments would be made already. Therefore the focus should only lie on the event itself.

2.6 Conclusion

In this chapter the following question is answered:

To what extent can the ROA be an addition to the current valuation methods to develop a potential valuation method relevant for Hallmark Events?

In the first part the Hallmark Event has been discussed and it became clear that a Hallmark Event has a few characteristics before it is seen as a Hallmark Event. The Hallmark Events that will be considered are the events with the main uncertainty on the amount of repetitions. The traditional CBA is not capable on its own to handle this type of uncertainty. The real options approach (ROA) has some advantages in terms of handling uncertainties that can be implemented within the current CBA. In the field of ROA in combination with infrastructural investments there is not much common ground build from in terms of available literature. However the CPB (Renes, G. Romijn, 2013) did develop a method to implement flexibility to the traditional valuation method. They pointed out that the full ROA is not preferred, since this is a complex mathematical approach, not suitable for quick valuation calculation.

The method by the CPB was the main starting point for the development of the new method made for the valuation of investments at Hallmark Events. The method is adjusted specially for Hallmark Events by turning risks and scenarios into the amount of repetition of the event, since this is the major risk of such an event (Burgan & Mules, 1992). The problem at the event is the high travel demand by tourists and the capacity that is not sufficient at the event. The queuing theory could give a simple but effective solution for valuating solutions by looking at the bottleneck capacities. Uncertainties can handled with different options from the ROA theory, but those are not all applicable on infrastructural investments at Hallmark Events. The flexibility for Hallmark Events could be captured in two main forms of flexibility: 'Natural Flexibility' and 'Waiting for Certainty'. The last ROA feature that could be implemented was the decision tree. This decision tree is based on a scenario tree that could be made based on repetitions. In this case a number of repetitions can be seen as a scenario and multiple outcome scenarios could be used to develop a scenario tree. The decision moments and the type of information that is gathered at a decision moment makes the full decision tree.

The method has been shown to Gerbert Romijn that wrote in a few of the used paper from CPB (Bos

F. & Zwaneveld, 2016; Centraal_Planbureau, 2017; Renes, G. Romijn, 2013). He mentions that the method is probably useful, but might be a too complex approach for this type of projects where valuation is needed. After the interview a few corrections have been made that were pointed out in the interview.

Chapter 3

Case Study: Dutch Grand Prix at Zandvoort

In this chapter the case study will be performed for testing the new methodology for implementing flexibility on the valuation of infrastructural investments at Hallmark Events. The case study in this report will be based on the Dutch Grand Prix (DGP) in Zandvoort. At first the event will be explained and after that the steps of the methodology will be used. The methodology is turned into a calculation tool that can be found in Appendix E. The results in this chapter will be used for giving a solution for the DGP. In the next chapter general results for the methodology and for other Hallmark Events will be handled.

3.1 Hallmark Event: Dutch Grand Prix at Zandvoort

The Grand Prix in Zandvoort has a rich history that goes back to 1930 when the first plans were made for a racing circuit in Zandvoort. In 1939 the first race was held and was at that time driven on the streets of Zandvoort. During World War 2 the racing track was developed and in 1948 the first Grand Prix of Zandvoort was held. In 1952 the track became part of the official world championship of the Formula One. From that moment on the track would be part of championships for 30 times on a (almost) yearly basis with the last race in 1985.

After 35 years there are plans to bring back the Grand Prix in Zandvoort under the name Dutch Grand Prix (DGP), but the current infrastructure is not designed for the amount of visitors that it would attract these days. They estimate this amount on 100,000 visitors per day with a peak of 140,000 visitors on the day of the actual race. Also there is no information on the amount of repetitions that the event could have in the future. The amount of visitors and uncertainty on the repetitiveness makes this event a Hallmark Event when looking at the literature that has been handled in Chapter 2. This Hallmark Event will be picked to work out as a case study in this research. The steps shown in image 2.7 will be used to work out this case study to find the best solutions for this event in combination with the best investment moments.

3.2 Step 1: Hallmark Event Characteristics

The event will attract 140,000 at the busiest day of the Grand Prix and this is an amount of visitors that the current capacity cannot handle all at once. It is expected that 35,000 people will stay in Zandvoort for the weekend and that 105,000 visitors will use the available networks to visit the event. On summer days the beach of Zandvoort also has 100,000 visitors but the difference is the spread of visitors over the whole day (Organisation of DGP, 2019). An estimation of the amount of visitors per modality can be found in Appendix F. Zandvoort has one advantage and this is the fact that 26% of the

ticketholders lives within a 25 kilometer range from the circuit at Zandvoort. This causes for an expected percentage of 18% of visitors by (electric) bicycle and moped. In table 3.1 is an overview of those number simplified to the four modalities that will be used in this case study.

Table 3.1: Input data on visitors and modality

Total amount of visitors	105,000	#
Share of cars	40	%
	42,000	#
Share of bicycle	18	%
	18,900	#
Share of PT	40	%
	42,000	#
Share of pedestrians	2	%
	2,100	#

The DGP already did some research on the arrival pattern that will occur. In figure 3.1 the demand curves for car and train visitors are given. With these arrival percentages per hour the cumulative curve model in Appendix C.1 the arrival rate is given in 10 minutes to calculate the delay. For the pedestrians and cyclists the same curve as the car users will be used, since there is no data available on those demand curves.

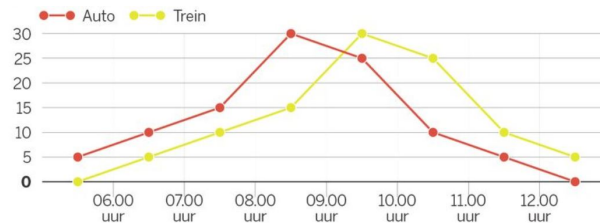


Figure 3.1: Expected demand curve for car and train at Zandvoort, (Organisation of DGP, 2019)

3.3 Step 2: Network Qualities

The city of Zandvoort is accessible with train, car, bike and by foot. For all the networks a capacity can be calculated with the number out of the previous chapter.

Car

The city of Zandvoort has two main arterial roads leading towards the centre. The N200 and the N201, both two lane roads with a speed limit of 80km/h. These are the only roads to enter the city with a car. The main bottlenecks for these routes are in the roundabouts that give access to the N200 and N201. Outflow capacities for roundabouts are mostly measured in vehicles per day for all four possible directions. If there is one main direction without any inflow from the other branches the outflow capacity can be between 1600 and 1800 vehicles per hour (Fortuijn, 2013). The 2 lane N200 has a theoretical capacity of 4200 vehicles per hour, which is lower than the maximum outflow of the roundabout. Another type of roundabout or intersection might increase this inflow.

The city has a lot of parking locations since this is also an attractive place in the summer time. In Appendix F a map can be found with the entrance routes and the parking facilities. In table 3.2 all the different parking facilities that are currently available in Zandvoort are represented. Even if all the parking places for cars would be filled with four persons per car there would still not be enough capacity for all the visitors that come by car. This is a major problem if all the visitors that come by car need to park in the city of Zandvoort. Parking locations:

Table 3.2: Car parking facilities in Zandvoort

Parking number	Name of parking	Distance walking (km)	Number of places
P1	De Zuid	3.5	1300
P2	Ir. G. Friedhoffplein	3.3	150 + 480
P3	Geerling	2.8	200
P4	Zandvoortselaan	3.9	150
P5	Tennispark de Glee	3.4	150
P6	Barnaart Zuid	0.7	130
P7	Barnaart Boulevard	1.5	1100
P8	Circuit Zandvoort	0.0	1250
P9	Parnassia	2.3	650
P10	Parnassia aan zee	5.0	1150
P11	Koevlak	7.0	400
P12	Kennemer Sportcentrum	8.5	720
Total	Average distance	4 kilometers	7850 places

In the area around the circuit there are multiple parking places, but the distance towards the event differs. In Appendix D the acceptable walking distances for pedestrians are given (3.2 kilometers), there is need for post-transport from some of the facilities if this maximum distance of 3.2 kilometer cannot be exceeded.

Bicycle

The bicycle network has a more densed grid than the car network and is better accessible from multiple directions. The downside is the willingness to travel long distances with this modality (see Appendix D). In Appendix F the routes that can be taken towards the circuit from multiple direction are shown. The width of the paths are given and the capacity that comes with it. Bicycle parking facilities are not available at the circuit of Zandvoort yet, but the costs for the solution and for the effects are not found in the literature. Also an aspect like illegal bicycle parking, what is common in the Netherlands, makes that a real shortage will probably not happen. Only hindrance is generated by the shortage of parking places.

Public transport

Zandvoort has a train station that can handle four trains per hour arriving at Zandvoort. The type of train is the SGM or SGM3. The capacity in this train is 40 first class seats and 184 second class seats. The amount of standing places is estimated on 270. This is roughly 500 persons per train multiplied by two trains per hour makes 1000 persons per hour by train, see Appendix D.

Pedestrian

The pedestrian flow can be seen as a form of post-transport when traveling with another modality like train or car. Since Zandvoort has only 16 thousand inhabitants the arriving visitors will outnumber this group of pedestrians. The flows of people from the parking places and the train station can be seen as the main flow that use the sidewalks. In Appendix F the sidewalk widths are used to give an indication of the capacity on the access roads towards the circuit. The capacity of the walking routes is not exceeded and therefore there is no need for pedestrian investments. This might be the case for the Grand Prix location itself, but that is out of the scope of this research.

Total of capacities

All the found information about the current networks is shown in table 3.3. With these figures and knowledge the zero option can be calculated and the total costs for making no investment.

Table 3.3: Capacities of different networks in Zandvoort

Modality	Description	Data	Capacity description
Car	Access road capacities	4400	3 * 4000 = 12,000 visitors per hour Parking Capacity = 23,550 visitors
	Intersection capacities	4000	
	Parking capacity	7850	
	Entry capacity	7200	
	Loading factor	75%	
Bicycle	Access road capacities	15,000	10,000 Cyclists per hour
	Intersection	10,000	Parking Shortage = 0 for illegal parking
	Parking capacity	4000	
Public Transport	Trains per hour	4	2,000 visitors per hour
	Capacity of vehicle	500	
Pedestrian	Sidewalk LOS	E	3600 pedestrians/hour/meter with multiple access roads

The main problems can be found for car traffic at the arterial roads N200 and N201 towards Zandvoort, which have a combined capacity of approximately 4000 vehicles/hour because of the roundabout that give access to those arterial roads. For the PT the capacity is based on the train which has only a capacity of 2000 vehicles per hour since there can only arrive four trains at a time. With the demand curves and the capacities of the different networks the delay hours and latecomers can be calculated. The demand curve for cyclists and walking are taken the same as the demand curve for public transport. In Appendix F the calculations are made for these first steps. With all the information of the previous section the following delay hours and amount of latecomers are calculated:

Table 3.4: Travel Time Calculations

Modality	Delay hours	Costs	Latecomers	Costs
Car	27,500	292,929	18,450	2,767,500
Bicycle	1,772	18,871	0	0
Public Transport	203,055	1,706,064	32,646	4,896,900
Pedestrian	0	0	0	0

For the delay hours a VOT (Value of Time) can be used to calculate the monetized value for delay hours. The values that can be found in literature vary between €8.00 and €24.00, but a common value for this travel time loss is €9.00 per hour with an additional multiplier for type of delay, see Appendix D. For the latecomers another approach should be used to calculate the financial loss. The ticket price is the price that a visitors losses immediately because he/she bought a ticket but is not using the value of that ticket. Another aspect mentioned by dr. van Wee, interview in discussion, is the consumer surplus. This is the value that the visitor is actually willing to pay. The tickets might costs €10, but the visitor is willing to pay €12, than the consumer surplus is €2.

For missing the event it would be nice the know the Value of Missing Out (VOMO). This is what the visitor is willing to pay extra for not missing the event. This value can than be multiplied by the amount of latecomers. Because there is nothing known about this VOMO the value is set to €150, this is the additional amount of money the delayed visitor is willing to pay extra for being able to arrive on time. This value is €150 based what the value for the cheapest tickets is roughly 3.2, however the value of VOMO is not described in literature and therefore highly uncertain.

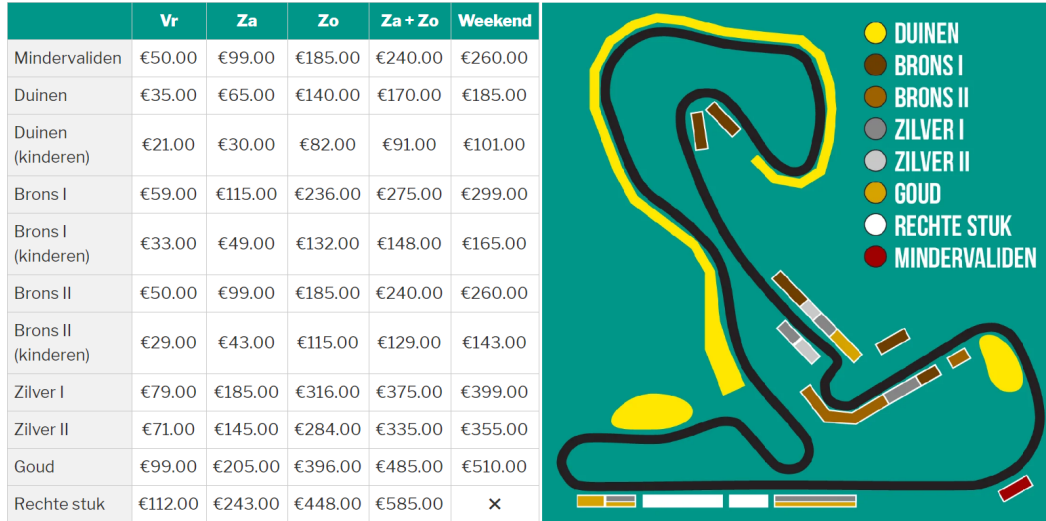


Figure 3.2: Ticket prices for DGP

3.4 Step 3: Determine Solutions

In the first two steps the effects of the DGP in combination with the current available networks were determined. All the different networks encounter some delay, except for the pedestrians which has a sufficient capacity towards the circuit in Zandvoort. Therefore in this third and fourth step solutions will be determined and flexibility will be implemented for the different solutions.

The capacity of the networks are too low and the peak of 30% of visitors in the busiest hour will cause a lot of delay (see table 3.4). For the different networks solutions are given in the table. In the first column the modality that the solution is for is given with the actual solution in the 2nd column. The descriptions follow in the third. The type of flexibility that is applicable to the solution is given in the fourth column based on the form of flexibility described in section 2.4. The 6th column gives solution specific costs for the investment, maintenance, operational costs and external costs. Investment costs are the costs that need to be paid at the start of the investment. Maintenance gives the fixed maintenance for a solution, maintenance by usage will be calculated at with the effects. Operational costs are the costs to keep the investment operational, for trains the costs for personal and electricity. External costs can be costs for reservations of land that is not used if the solution is deferred or other costs that will be described in the tool in Appendix E. The costs for the different solutions are more extensively explained in the Appendix D.

Table 3.5: List of possible investments at Zandvoort to facilitate the Hallmark Event

Solution Number	Name	Description	Type of flexibility	Cost type	Costs
1	Extra parking places for cars	In the current situation with the expected number of cars there are 15,000 parking places short, if parking would be facilitated in Zandvoort.	Waiting for Certainty	Investment Maintenance Operational External	€3,150,000 €9,450 €- €15,000
2	Parking restrictions for cars	Zandvoort expects an average of 2.7 persons per car. The restriction doesn't allow cars to pass when less than 3 persons are in.	Natural Flexibility	Investment Maintenance Operational External	€50,000 €- €25,920 €-
3	Car Infrastructure	The N200 is a 2x2 lane arterial road towards Zandvoort, but has a single lane roundabout connection in Overveen. This could be transformed into a turbo-roundabout for a higher capacity.	Waiting for Certainty	Investment Maintenance Operational External	€3,000,000 €20,000 €- €-
4	Extra parking places for bicycles	If every bicycle should have facilitated parking place there are 10,000 places short.	Natural Flexibility	Investment Maintenance Operational External	€- €- €280,000 €-
5	Route information guiding and rental bikes	Rental bikes at station Haarlem and regional P+R with route information.	Natural Flexibility	Investment Maintenance Operational External	€- €- €500,000 €-
6	More trains per hours (electric)	A change of overhead lines is needed to facilitate more than four trains per hour. With this change 12 trains per hour is possible.	Waiting for Certainty	Investment Maintenance Operational External	€5,000,000 €91,237 €43,200 €-
7	More trains per hours (diesel)	Diesel trains can increase the amount of trains per hour without a overhead line investment	Natural Flexibility	Investment Maintenance Operational External	€- €- €43,200 €-
8	Stations Lengthening	The station can only handle trains with 2 carriages (approx. 500 travellers) the lengthening makes this a 4 carriages train	Waiting for Certainty	Investment Maintenance Operational External	€2,000,000 €100,000 €- €-
9	Busses from Haarlem	Busses will transport the visitors from station Haarlem towards the event.	Natural Flexibility	Investment Maintenance Operational External	€- €- €150,000 €-
10	Traffic management	This marketing campaign will change the modality of the visitors. The impact is small, but can reduce delay time relatively cheap.	Natural Flexibility	Investment Maintenance Operational External	€50,000 €- €- €-
11	Busses from parkings	The walking distance from the parking places in Zandvoort are large and reducing the walking time reduces the total travel time.	Natural Flexibility	Investment Maintenance Operational External	€- €- €30,000 €-
12	Post and pre-activity	This investment spreads out the demand curve and therefore delay hours.	Natural Flexibility	Investment Maintenance Operational External	€- €- €100,000 €-
13	Busses from P+R (in region)	This solution bans the car from entering Zandvoort and park in the region where busses will transport the visitors towards the event	Natural Flexibility	Investment Maintenance Operational External	€- €- €250,000 €-

3.4.1 Adding flexibility to the options

In section 2.3.1 the different ways to apply flexibility have been discussed. In this case study the three ways of implementing flexibility will be used. In the figures 3.3 and 3.4 two of those flexibility implementations are shown. The option 'Waiting for Certainty' will be implemented by choosing multiple decision moments where the investment can be made and having decision moment where the future of the event becomes more certain. In figure 3.3 the choices are shown that can be made. Once an investment is done there is no going back, but if one would choose to post phone the decision maker still has the option to build or not at the next decision moment.

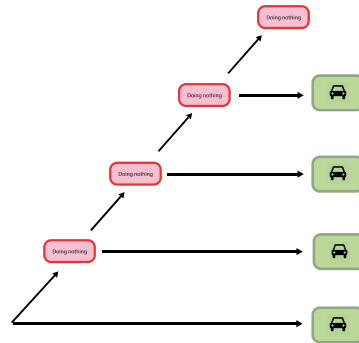


Figure 3.3: Simplified Decision Tree Waiting for Certainty

The 'Natural Flexibility' is applicable for temporary solutions or solutions with low investment costs compared with the operational costs. In this case no big investment costs will be wasted once the event stops. Temporary solutions have this form of flexibility by themselves because there is an option to abandon this solution at any time. In figure 3.4 it is shown that every time a decision had to be made both options (yes or no investment) can be chosen.

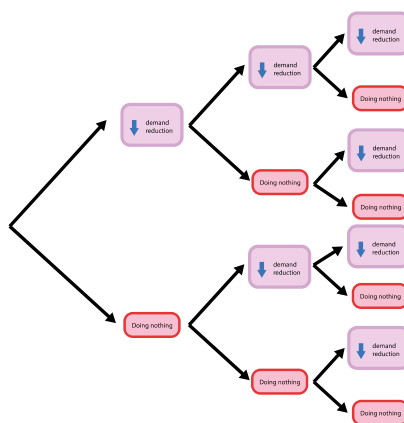


Figure 3.4: Simplified Decision Tree for 'Natural Flexibility'

The solutions in table 3.5 are assigned with a form of flexibility that can be implemented with that particular solution. In the model the forms of flexibility will be assigned to those solutions in the way the figures 3.3 and 3.4 have shown. The Extension Combination option is based on making additional investments every decision moment. Invest, for example, in the first year for the car and the second year for bicycle and train. The combination with 'Natural Flexibility' and 'Waiting for Certainty' can be made in this option to combine solutions. These combination will be made in step 7.

3.5 Step 4: Determine Effects

The solutions all have effect on the capacity for one or more networks, but also external effects are taken into account. The capacity enlargements are given in table 3.5, but there are effects on delay hours, latecomers, travel time, traffic safety, maintenance, emissions and parking shortage. All these effects are captures in the spreadsheet given in Appendix E. The effects can be found there and are based on key figures that are described in Appendix D.

3.6 Step 5: Determine Costs

In table 3.6 the effects are given that will be used for the valuation of the different solutions at the DGP. In the Appendix E the whole spreadsheet is given with descriptions on the calculations, where the values for all those different aspect per modality are given. In this table below are just the aspect with the calculation steps that are used to monetize the different effect.

Table 3.6: Effects of the Hallmark Event Zandvoort

Aspect	Explanation	Data	Source
Emissions	The costs for emissions that are cause by a modality. For CO ₂ , NO _x , PM _x and SO ₂ .	Total €/vehicle kilometer	(van Essen et al., 2008)
Traffic Safety	Costs for deaths and heavily injured people caused by a modality.	€/per death or injured, Deaths or injured per vehicle kilometer	(SWOV, 2011, 2017)
Noise	Noise hindrance caused by modality	€/per vehicle kilometer	(CE Delft, 2014)
Maintenance	Damage on infrastructure cause by modality	€/per vehicle kilometer	(CE Delft, 2014)
Delay hours	Value of Time used for total time that visitor spends to get to the event. Delay hours are calculated with cumulative curve method	VOT * Delay hours	(CE Delft, 2014)
Latecomers	Amount of persons that will not make it in time to the event due to delay	VOT * factor * Delay hours	(CE Delft, 2014)

3.7 Step 6: Risks and Scenarios

In section 2.4.3 the scenario development has been explained. For the scenarios the past Grand Prix racing tracks will be used with the amount repetitions that are average for a racing track. This is no scientific information, but more of an educated guess on what scenarios are most likely to occur. In Appendix F a more elaborate explanation is given for the reasoning behind the different scenarios. The first two columns in table 3.7 give a brief summation of Appendix F.

Table 3.7: Scenarios used for the Zandvoort Case Study

Scenario Description	Reasoning	Scenario Combination with Probability p.				
		- 1	p=20% 2	p=40% 3	p=60% 4	p=80% 5
1 repetition	This could be the case when the Grand Prix Organisation is not pleased by the quality of the track or surroundings of the event.	25%	80%	60%	40%	20%
4 repetitions	Looking at the tracks used the last year this was the minimum amount of repetitions that the track with the lowest amount of repetitions has (Wikipedia, 2020).	25%	16%	24%	24%	16%
14 repetitions	This is the average amount of repetitions if one would look at the all the races in the last 50 years and the tracks that were used(Wikipedia, 2020).	25%	3.2%	9.6%	14.4%	12.8%
29 repetitions	This is the average amount of repetitions if one would look at the average amount of repetitions of the tracks used the last season(Wikipedia, 2020).	25%	0.8%	6.4%	21.6%	51.2%

The amount of repetitions have no specific probability, but the scenario description gives the four most likely outcomes for the amount of repetitions based on historic information. Because no other information is available the ROA method is used to solve this problem. The probability p is set for a chance of having multiple repetitions, see figure 3.5. If a p is chosen it means that all four scenarios have a specific chance of happening. Which is a significantly difference from the traditional scenario planning, where just probabilities for one of the four outcomes would be chosen. Setting a p therefore gives a 'Scenario Combination' with a chance for all possible scenarios. The visualisation of the scenario combinations can be found in figure 3.5, which is based on the method presented in Chapter 2. At year 0 it is possible that the event has 1 or more repetitions (with chance p), after the first year the outcome will be known. Two possible outcomes appear: 1 repetition (chance $1-p$) or 4 or more repetitions (chance p). This continues until all possible amount or repetitions are known at year 14. Every outcome is a scenario which has a probability to occur, according to the probabilities given in table 3.7.

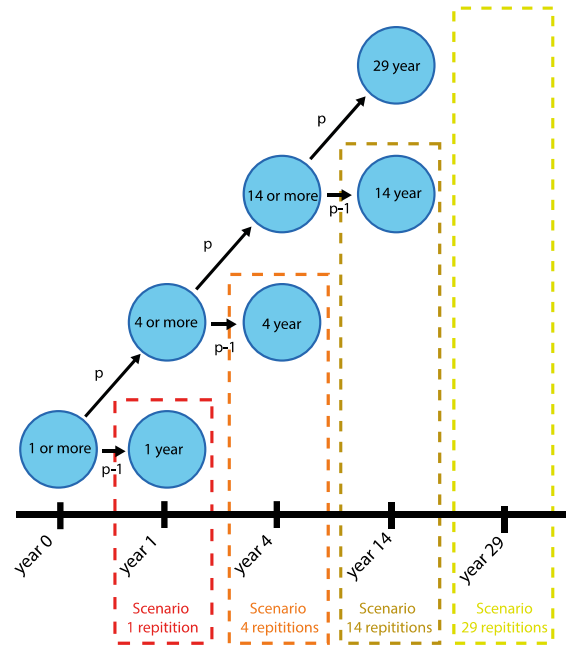


Figure 3.5: Scenario Tree for DGP Zandvoort

3.7.1 Strategic options and value of flexibility

With the previous steps of the solutions, effects, costs and scenarios the complete decision trees can be developed. Figure 3.6 gives the full decision tree for solutions that are supplemented with the 'Waiting for Certainty' option. An investment can be made in year 0 or the investor can wait a year until the next decision moment. For both choices the next decision moment can give the knowledge that the event will not have any more repetitions. For both the choices an outcome can be given for the scenario of only 1 repetition.

In case the event will continue for 4 or more years there is no choice if the investment is already made. However if the investor has waited, again the choice to wait or to invest in infrastructure is again available in year 1. This moment the invest has a little more knowledge about the repetitions in comparison with year zero, where only one repetition was certain. When the event stops after 4 repetitions there are three options to consider: Investment is made in year 0, Investment is made in year 1 or investment is not made. For all three of the routes the costs and benefits will be calculated. This will continue until all decision moments are handled. With the last scenario of 29 repetitions ending up with five outcomes, because of four possible investing moment and the option to don't make the investment at all.

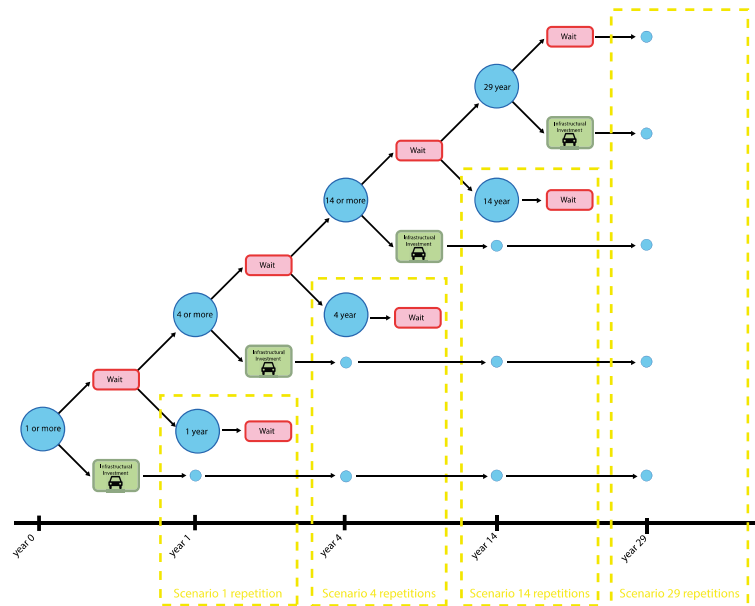


Figure 3.6: Simplified Decision Tree Waiting for Certainty

The solutions that are supplemented with 'Natural Flexibility' have another decision tree. The decision moments are on the same years, the choices are without regret, since the temporary solutions can be stopped at any time. In Chapter 2 this type is handled in the text box, see figure 2.10. Solutions with this type of flexibility can be found in table 3.5. If the solution is profitable it is unlikely that an investor would stop implementing this solution at a decision moment. However if the temporary solution is used only the first year and from the next decision moment an infrastructural investment is done (this is the Extensive Combination option), it is possible that this replaces the temporary solution. This is however an option of Extension Combinations, where multiple solutions can be combined and spread out over the decision moments, shown in figure 2.13.

For all the solutions there are four possible first investment moments. To compare the investment moments the solutions are altered over the decision moment and for that investment moment the Expanded NPV is calculated. These investment moments are shown in figure 3.8. For all the 13 possible solutions these investment moments will be tested even though it is probably the case that the first investment moment for 'Naturally Flexibility' is the most profitable investment moment. If solutions are

not profitable at all it will be the other way around. The 'Waiting for Certainty' options are the ones where other investment moment might be better of than the first year or not invest at all.

Table 3.8: Investment Moments

Solution	Decision Moment	Year 0	Year 1	Year 4	Year 14
Solution 0	-	-	-	-	-
Solution 1	1	Invest	-	-	-
	2	wait	Invest	-	-
	3	wait	wait	Invest	-
	4	wait	wait	wait	Invest
Solution 2	1	Invest	Invest	Invest	Invest
	2				
	3				
	4				
Solution ..	1	Invest	Invest	Invest	Invest
	2				
	3				
	4				
Solution n	1	Invest	Invest	Invest	Invest
	2				
	3				
	4				

3.8 Step 7: Determine Investment Moments

For this step a spreadsheet has been build to determine the best investment moments of the individual solutions. In Appendix E the spreadsheet or 'tool' is explained. The Appendix G contains all the outcomes of the spreadsheet, but explanations will be given throughout this section. In this part a few remarkable outcomes will be discussed together with the overall outcomes. How to read the figures can be found in the last step of the methodology in Chapter 2, but a brief explanation will be given here again:

Brief reading guide for the outcome graphs

Option 1.1 refers to the first solution combined with the first decision moment (year 0), Option 1.4 is solution 1 invested at decision moment 4. For every solution the different investment moments are given in the graphs. On the y-axis the B/C-ratio is given and on the x-axis the Expended NPV. These two values are commonly used in the representation of valuations in the traditional CBA. The Expanded NPV is expected value of the investment. The B/C-ratio is giving the overall value for money, which is simplified the amount of euro's an investor gets in return for investing one euro. For the B/C-ratio the common rule is; If the value is higher than 1 the solution is profitable and therefore the investment should be made. For the NPV the investment is profitable if the value is positive. The values for Expanded NPV and B/C-ratio are given in Appendix G. Both the NPV and B/C-ratio are taken into account, since big investment have a higher chance of getting a high NPV in return, but small investments not. On the other side the smaller investment have a higher chance of getting a high B/C-ratio. By taking both the B/C-ratio and the Expanded NPV as measurement the big investments and temporary investment both have a chance of high scores.

3.8.1 Most interesting individual outcomes

The first (very obvious) outcome of the tool is that the solutions with 'Natural Flexibility' have the best investment moment in the first year. When a temporary solution is financially beneficial it should therefore be implemented as soon as possible. This makes total sense, since these solutions are specifically designed to solve the problem on a temporary basis and can be stopped at any time. This means that waiting another year to invest directly leads to travel time loss or loss of other monetized effects, because no problem is solved. In figure 3.7 three randomly chosen solutions out of scenario combination 3 are shown, but the results for the 'Naturally Flexibility' options are all similar in best investment year outcomes.

Scenario Combination 3

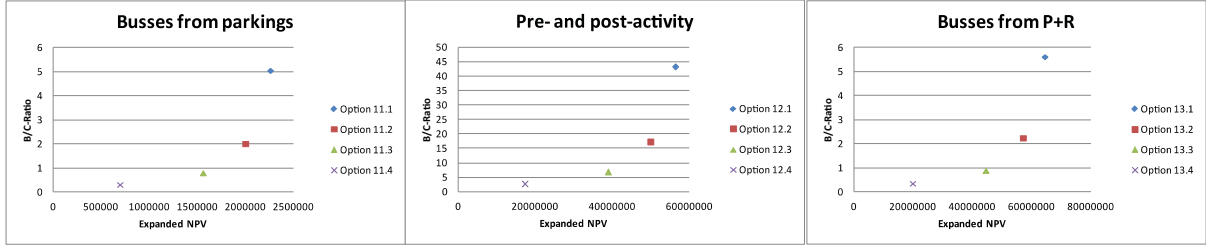


Figure 3.7: Best Investment moments for Natural Flexibility solutions

For the infrastructural investments that are supplemented with 'Waiting for Certainty' as form of flexibility the results differ per investment. For the investments in train infrastructure the different scenario combinations all give the first year as best investment moment. This is mainly because there so much to gain in this modality when looking at the travel time savings and latecomers (see table 3.4). One remarkable result is that the Diesel Trains (Natural Flexibility) are scoring better than the Electric Trains (Waiting for Certainty). The environmental savings and lower maintenance costs that the solution for electric trains generates, do not outweigh the costs for the overhead upgrade (approximately €5,000,000). But overall the individual solutions that increase the public transport network capacity are all financially beneficial. This holds for all the scenario combinations.

Scenario Combination 4

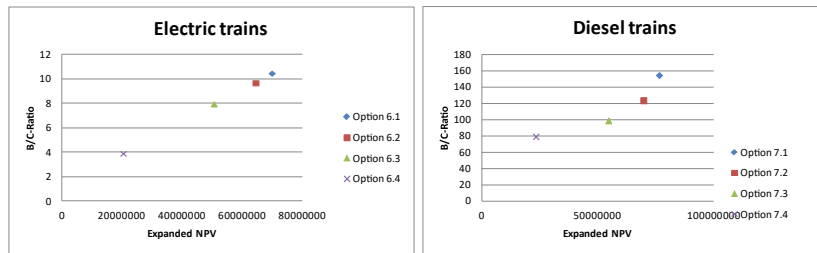


Figure 3.8: Best Investment moments for Train related solutions

The reconstruction of the roundabout at the N200 (solution 3 for the car network) is the most interesting solution of all the individual solutions that have been developed in table 3.5. In figure 3.9 the best options are shown for the solution. The investment has some scenarios where the NPV is positive, which implies a financial beneficial solution, but on B/C-ratio the investment has a hard time becoming valid. It is clear to see that when the probability p (chance for additional amount of repetitions) increases the Expanded NPV and B/C-ratios become higher. But only in the scenario combination with $p = 80\%$ the investment is financially beneficial and even at that moment the tool points out that the second investment moments is better than the first one. Therefore waiting a year to gain more certainty is a better option.

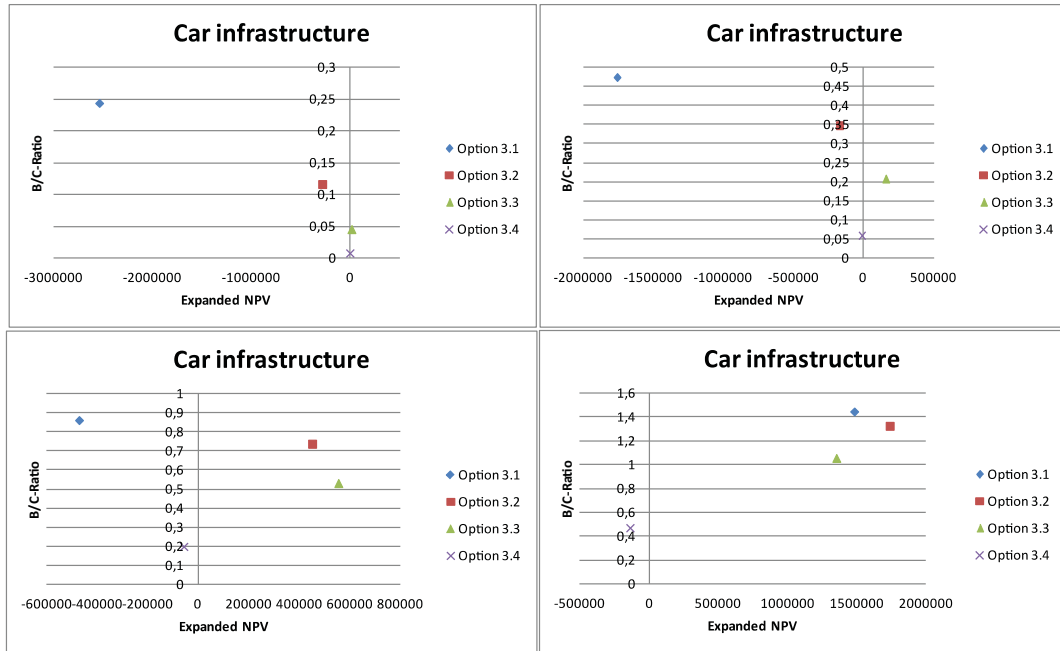


Figure 3.9: Best Investment moments for Car Infrastructure solution (up-left p=20%, up-right p=40%, down-left p=60%, down-right p=80%)

Two paragraphs before it was mentioned that all the solutions with 'Natural Flexibility' all had the same best investment moment. This was the first year, because all these solutions are financially beneficial. One exception must be mentioned, which is the solution of parking places for bicycles, figure 3.10. By looking at the figure it is clear to see that the Expanded NPV is below 0 and the B/C-ratio is under 1. The conclusion can be made that this solution is not financially beneficial under any circumstances. The reason for this outcomes has to do with the valuation of bicycle parking. Imagine there are not enough parking places for bicycles, than the visitors will not cycle back to Haarlem and take the train. They will probably park their bike somewhere else (illegally). The social costs for this behaviour are unclear and therefore no value can be given for the reduction of illegal bicycle parking. At this moment an extra hour delay is given to every visitor on a bike that does not have a parking place. However the monetized effect of this delay is not enough to make the investment in parking places for bicycles financially beneficial.

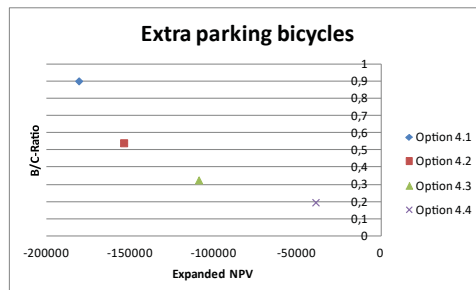


Figure 3.10: Best Investment moments for Extra Parking for Bicycles solutions

In addition to all the outstanding results the table 3.9 shows all the best investment moments in terms of Expanded NPV and B/C-ratios for all the solutions in all the scenario combinations. In Appendix G

all the graphs like the ones shown before in figures 3.7, 3.8, 3.9 and 3.10. The table below is a summary of the outcomes for just the best investment moment.

Table 3.9: Best investment moments for individual solutions

Solution	Score	Combination 1	p=20% 2	p=40% 3	p=60% 4	p=80% 5
1. Extra parking places for cars	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
2. Parking restrictions for cars	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
3. Car Infrastructure	Expanded NPV B/C-ratio	Dec. Moment 2 Dec. Moment 1	Dec. Moment - Dec. Moment -	Dec. Moment 2 Dec. Moment -	Dec. Moment 2 Dec. Moment -	Dec. Moment 2 Dec. Moment 1
4. Extra parking places for bikes	Expanded NPV B/C-ratio	Dec. Moment - Dec. Moment -	Dec. Moment - Dec. Moment -	Dec. Moment - Dec. Moment -	Dec. Moment - Dec. Moment -	Dec. Moment - Dec. Moment -
5. Rental bikes + route guiding	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
6. Extra Electric Trains	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
7. Extra Diesel Trains	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
8. Station Lengthening	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
9. Busses from Station Haarlem	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
10. Modal Shift Management	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
11. Busses from parking	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
12. Pre- and post activity	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1
13. Busses from P+R	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1	Dec. Moment 1 Dec. Moment 1

In Appendix G all the graphs are shown. In this section the outcomes of the individual solutions are given. When looking at the results for the first combination of scenarios it is clear to see that almost all the solutions will have the first year as the best investment moment. This is because of the probability of having more 75% and the benefits of the solutions are spread over 4, 14 or 29 years. The earlier mentioned bicycle investment (solution 4) is only one that has no best investment moment. For the solution 3. Car infrastructure the best investment year is the decision moment by looking at B/C-ratio and second decision moment when looking at Expanded NPV. For the scenario combination 2 (p=20%) the chance of getting more repetitions every decision moment is low. This 20% means a 20 percent chance of having more repetitions every decision moment. The same best investment moments can be seen, but the values for B/C-ratio and Expanded NPV are lower. The 3rd and 4th investing moments become irrelevant because the B/C-ratios are lower than one for some of the solutions. This is all because the chance for still having the event after 14 years is only 4%. The combinations with p=40% has a higher chance for more repetitions every decision moment. Car and Bike infrastructure is still not profitable. For the p=60% the same conclusions can be drawn. When looking at the p=80% the car infrastructure becomes profitable for multiple investment moments. All investments have higher NPV and B/C-ratio values for a higher p of the scenario combinations.

3.8.2 'Extension Combinations'

Now that the best scoring investment moments are known it is not directly the case that investments can be made. The main problem with the outcomes is that all the individual investments still cause a lot of delay hours and latecomers, as can be seen in figure 3.10. The capacities of the currently available networks are low in comparison with the demand that is generated by the event. Realistic solutions have been developed that cannot eliminate the delay hours and amount of latecomers completely. Therefore combinations will be needed to make sure the delay hours and latecomers are reduced to a minimum. Also the comparison of temporary solutions with infrastructural solutions will be made with these combinations. This section is dedicated to the option of 'Extension Combinations' to see if the individual solutions could given obvious combinations and to test proposed combinations by the DGP.

Table 3.10: Delay hours and Latecomers per network for solutions

Solution	Car Network		Bicycle network		Train network	
	Delay hours	Latecomers	Delay hours	Latecomers	Delay hours	Latecomers
No action performed	27500	18450	1772	13900	203055	18746
1. Extra parking places for the car	27500	9000	1772	13900	203055	18746
2. Parking restrictions for the car	25292	17508	1772	13900	203055	18746
3. Infrastructure for the car	6535	18450	1772	13900	203055	18746
4. Extra temporary parking places for the bike	27500	18450	1772	100	203055	32746
5. Route information guiding + available rental bikes	27500	18450	12908	29650	101394	12504
6. More trains per hour (Electric)	27500	18450	1772	13900	79390	2009
7. More trains per hour (Diesel)	27500	18450	1772	13900	79390	2009
8. Station Lengthening	27500	18450	1772	13900	135806	10161
9. Busses from Haarlem instead of trains	27500	18450	1772	13900	31557	13900
10. Modal Shift Management	21457	15300	2385	14950	216654	19768
11. Busses from the parkings for car users	27500	18450	1772	13900	203055	18746
12. Post and Pre activity	9295	14450	0	12100	174949	14167
13. Busses from car-pool locations for the car users	16087	0	1772	13900	203055	18746

In table 3.9 the best investment moments were given for the different solutions. The actual value for Expanded NPV and B/C-ratio can be found in Appendix G. With this information the best scoring solutions can be combined together with the best investment moments for these solutions. In table 3.11 the overall best solutions in terms of Expanded NPV and B/C-ratio are given. For the Expanded NPV it is financially beneficial to invest in the train network. For the highest relative revenue the Diesel train is the best option, but followed by non modality related solutions like Modal Shift Management and Post and pre activities.

For the combinations all the previous found information, about best investment moments, delay hours, latecomers and scores on Expanded NPV and B/C-ratio, is included. Train solutions are financially beneficial, but combining solution 6, 7 and 9 does not make sense, since they all solve the same problem. The non modality specific solutions 10 and 12 are financially beneficial and independent of any other solutions therefore these two will be implemented in all the combinations. Six Extension Combinations have been developed along with the original plan that the DGP has for the event. The following combinations have been made and are described below:

Table 3.11: Expanded NPV and B/C-ratio best scores

Expanded NPV			B/C-ratio		
Solution Number	Modality	Description	Solution Number	Modality	Description
Solution 9	Train	Busses from Haarlem	Solution 7	Train	Diesel trains
Solution 7	Train	Diesel trains	Solution 10	none	Modal Shift Management
Solution 6	Train	Electric trains	Solution 12	none	Post and pre activity
Solution 5	Bicycle	Rental bikes	Solution 9	Train	Busses from Haarlem
Solution 13	Car	Busses from P+R	Solution 5	Bicycle	Rental bikes

1. Cheap solutions + parking places for cars

For the parking capacity for car there are two solutions; Solution 1: Extra parking places for cars or Solution 13: Parking at P+R. Solution 13 scores better on NPV while Solution 1 scores better on the B/C-ratio. Solution 1 will be alternated over the decision moments and solution 13 will be used when no investment has been done for car parking. Some extra solutions are added to this 'Extension Combination' option.

2. Only car combination

The next combination is also based on car solutions. This is because it became clear that the most profitable investment moment for car infrastructure is dependent on the scenario. If the capacity is increased by other solutions this might lead to one most profitable investment moment for all scenarios. Here the parking invest is done in the first year and solution 3 is altered over the decision moments.

3. Train investments (Diesel)

The third combination is based on train investments. The station lengthening is tested for a more profitable investment moment if diesel trains already increase the capacity. Every train investment is profitable individually since the capacity is low and the demand high, shown in section 3.8. There is some overlap in what the solutions solve, so they might not be financially beneficial if they are all executed.

4. Train investments (Electric)

The fourth combination is based on train investments, but here the overhead upgrade is tested. If the overhead is not yet installed busses will be used. For example: If the investment for the overhead is made in year 4, the solution 9 will be used from year 0. At year 4 the solution 9 will be stopped and the overhead upgrade will be used.

5. Bicycle combination

The fifth solution is entirely based on bicycle investments. Solution 4 includes bicycle parking places and solution 5 generates rental bikes for train users from station Haarlem. Because all the solutions are having 'Natural Flexibility' there is no use in introducing multiple investment moments, but the increase in Expanded NPV and B/C-ratio will be an interesting outcome with this combination.

6. full Natural Flexibility combination

The sixth combination is again totally based on 'Natural Flexibility'. The four solutions in this combination are used in the other combination, which makes it interesting to see what the effect of only these combinations is.

7. Adjusted DGP plan

8. Original DGP plan from mobility plan, (Organisation of DGP, 2019)

The last (eighth) combination is the combination the DGP is implementing. The seventh combination is based on the combination the DGP is willing to implement, but with a few solutions that have 'Natural Flexibility'. The DGP will upgrade the overhead lines, lengthen the station of Zandvoort and build temporary bicycle parking places. The car users have to park in the region and busses will take them from the parking places towards the event (Organisation of DGP, 2019). For the spread of demand they have a pre activity (Formula 2 and 3 races) and a post activity (music festival). Instead of the overhead upgrade the diesel trains will be used in this combination and

also the bicycle parking is left out of the combination. Because those solutions turned out to be more beneficial.

In table 3.12 the descriptions of the combinations are given. In the columns the investments per decision moment (year 0, year 1, year 4 and year 14) are given. Only for the first combination the total investment table is filled in. For the four different investment moments all the solutions that are applied are given. In bold the first solution is altered over the decision moments. The solution 13 is given between brackets because is temporary solution is only used if the investment of solution 1 is not yet made. For the other combinations only the altering investment is shown for the decision moments. This way it is more easy to visualize which investment is made at which decision moment. The other investments are all performed every decision moment no matter if the altering investment is made. The solutions between brackets will be stopped once the altering solution is performed.

Table 3.12: Investment Moments

Extension Combinations	year 0	year 1	year 4	year 14
Combination 1 Cheap solutions with extra parking places for cars	1,2,9,10,12 2,9,10,12,(13) 2,9,10,12,(13) 2,9,10,12,(13)	2,9,10,12 1,2,9,10,12 2,9,10,12,(13) 2,9,10,12,(13)	2,9,10,12 2,9,10,12 1,2,9,10,12 2,9,10,12,(13)	2,9,10,12 2,9,10,12 2,9,10,12 1,2,9,10,12
Combination 2 Only car investments	1,2,3,10,12 1, 2, 10, 12, (13) 1, 2,10,12, (13) 1,2,10,12, (13)	- 3 - -	- - 3 -	- - - 3
Combination 3 Station Lengthening with Diesel trains	7,8,10 7,10 7,10 7,10	- 8 - -	- - 8 -	- - - 8
Combination 4 Train investments with Electric trains	6,8,10 8, (9),10 8, (9),10 8, (9),10	- 6 - -	- - 6 -	- - - 6
Combination 5 Flexible Bicycle Solutions	4, 5, 10	-	-	-
Combination 6 Total Flexible Combination	2, 9, 10, 12	-	-	-
7. Adjusted DGP plan	7, 8, 10, 12, 13	-	-	-
8. Original DGP plan	4, 6, 8, 10,	-	-	-

Extension Combination Results

Appendix G.2 gives all the outcomes for the different combinations that have been made, conclusions can be drawn from the outcomes in terms of investment moments. In the table below (table 3.13) the best investment moments in terms of Expanded NPV and B/C-ratio are given for the first four combinations. Further explanations for the results is given in the paragraphs.

Table 3.13: Best investment moments for individual solutions

Combination	Score	Combination 1	p=20% 2	p=40% 3	p=60% 4	p=80% 5
Cheap solutions with extra parking places for car	Expanded NPV B/C-ratio	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4
Only car solutions	Expanded NPV B/C-ratio	Dec. Moment 3 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 3 Dec. Moment 4	Dec. Moment 3 Dec. Moment 4	Dec. Moment 2 Dec. Moment 4
Train investments with Diesel trains	Expanded NPV B/C-ratio	Dec. Moment 1 Dec. Moment 4	Dec. Moment 1 Dec. Moment 4	Dec. Moment 1 Dec. Moment 4	Dec. Moment 1 Dec. Moment 4	Dec. Moment 1 Dec. Moment 4
Train investments with Electric trains	Expanded NPV B/C-ratio	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4	Dec. Moment 4 Dec. Moment 4

For the first combination of cheap solutions with car parking places altered over the decision moments the best investment moment is the fourth decision moment, see figure 3.11. This pattern for having the best investment moment for the additional parking places at the fourth decision moments means that the investment is best not made. Clearly the P+R in the region that is used before the investment is made is less expensive than the parking places investment. For the individual solutions the best investment moment was the first moment in every scenario for car parking places. Because the other temporary solutions are already solving the biggest part of the problem the parking becomes relatively more expensive and therefore the investment in parking places becomes less interesting. Parking places are therefore not a good investment, since the value of this solution is dropping once it is combined with other necessary solutions.

The second combination, based on only car investments, already has a parking places in the first year. The improvement of the small roundabout at the N200 is altered over the decision years. Depending on the scenario the investment scores better or worse. This is similar to what happens with the individual scores of the solution. In figure 3.11 in the right corner the 'Combination 2' can be found. This is a random pick of that solution out of the scenario combinations, all the graphs can be found in Appendix G.2. For almost all of the scenario combinations the improvement of the roundabout is an interesting solution, but not for the first year. Therefore this investment should not be made this year.

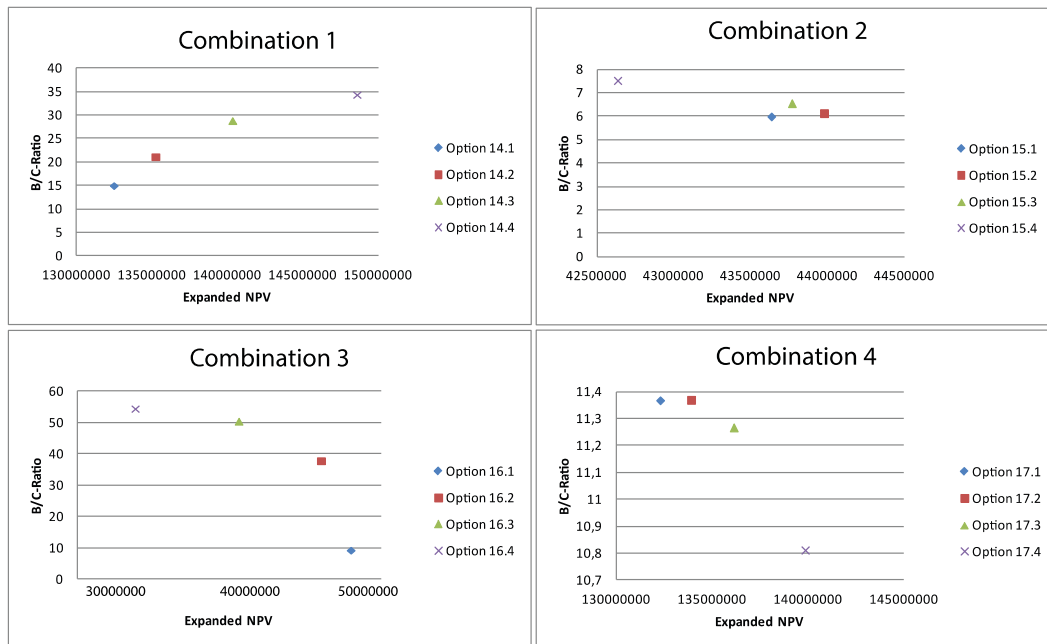


Figure 3.11: Outcome examples for the first four combinations

In combination three the station lengthening is altered over the decision years and it is clear to see the investment in the first year is better scoring on NPV but the fourth investing moment is better scoring on B/C-ratio. In this case the station lengthening is a good scoring solution, but the B/C-ratio of the combination without the station lengthening is more efficient. Because the diesel train solves more of the problem for less money the B/C-ratio is high. With the expensive station lengthening the average B/C-ratio goes down. Still the ratio is over 1 in all scenarios and the Expanded NPV is over €10 million even in the least scoring scenario combination. Therefore the station lengthening is an attractive investment.

For the overhead line upgrade the costs are high and the benefits not much more than the diesel trains, which are used when the overhead is not yet upgraded. This causes that the latest investment moment is the best, because the gains are not much higher than with the diesel trains. Only on safety

and emissions the overhead upgrade generate less social costs and therefore the B/C-ratio is higher in the first year. For the overhead lines there are multiple argument to do the investment or not and a clear advice cannot be given for this solution.

For the 5th, 6th, DGP and adjusted DGP combinations the outcomes where just compared on Expanded NPV and B/C-ratio, because no additional investment was altered over the decision moments. The solutions score all better when the amount of repetitions is increasing (p is higher), which is an expected outcome. The actual values for these aspects can be found at the end of Appendix G.2. For the first four combination the table 3.13 can be read for the best investment moments in terms of B/C-ratio and Expanded NPV for the four decision moments.

3.9 Step 8: Show results

In this section an attempt will be made on how the outcomes of the methodology should be presented to a decision maker. Therefore this section will have a conclusive character.

Individual Solutions

The individual solutions that have been presented in step 3 are all financially beneficial and could be used if the Expanded NPV and B/C-ratio are taken into account. An investment in one of the solutions for public transport is obviously the best choice for a decision maker. The amount of latecomers and delay hours can be reduced the most by an investment. The scores for Diesel trains, Electric Trains, Station Lengthening and Busses from Station Haarlem all have high scores on Expanded NPV and B/C-ratio. The costs for busses is not empirically found, therefore this might solution might be less accurate than the other three solutions mentioned. There are two exceptions which are not financially beneficial the bicycle parking solution and the car infrastructure solution for adjusting the northern roundabout at the N200. This last one can be profitable, but the best investment moment is not in the first year and therefore not the most financially beneficial investment for the first decision moment. For the solution Car Infrastructure the method is very useful, since it points out that the solution can be financially beneficial, but the best investment moment is not the first year.

Extension Combinations

For solving the demand problem at Zandvoort there is a need for multiple solutions. Combinations have been developed and were tested with the same methodology again. For the first four combinations a check was done if an infrastructural investment was still preferable when a combination of solutions was used. The infrastructural investments were altered over the investment moment to check if there was a moment when it would become more financially beneficial to make the infrastructural investment instead of performing the temporary solution. This comparison between a temporary and an infrastructural investment is one of the features from the ROA that was implemented in the CBA with the usage of the tool described in Appendix E.

The investment for Station Lengthening turned out to be a good investment, which doubles the amount of persons that can be transported to Zandvoort. This investment has less costs than the upgrade of the overhead line and therefore the risks for this solutions are lower. The overhead upgrade turned out to be less financially beneficial than the usage of the temporary solution Diesel Trains. The investment for car parkings is not more beneficial than using P+R in the region with busses to take visitors to the DGP. However once the parkings are already there the reconstruction of the northern roundabout can become financially beneficial. There should be mentioned that investing in this solution should not be done in the first year and that it is better to 'Wait for Certainty' and do the investment the next decision moment.

For the 5th and 6th combination only solutions with 'Natural Flexibility' were used and no altering infrastructural investment was needed. The combination for only bicycles was the least scoring combination of the eight combination that were developed. And therefore it can be said that investments for the bicycle network is way less beneficial. The combination 6 was a combination of the best scoring temporary solutions from the individual solutions. On B/C-ratio this combination is one the best scoring sets of solutions for all scenario's. On Expanded NPV the combination performs good, but it can be seen that other combinations like the original DGP plan and the Adjusted DGP plan score higher in some of the scenario combinations.

The last two combinations were the original DGP plan (DGP) and the adjusted DPG plan (combination 7). For the different combinations the Expanded NPV and B/C-ratio were calculated. In figure 3.12 an example for the scenario combination 4 is given with the outcomes for the combinations. It can be seen that for the DGP temporary solutions can be used, but that there are infrastructural investments that solve the problem more efficient than the temporary solutions. In Appendix G.2 the outcomes for the other scenario combination can also be found.

Scenario Combination 4					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	118900204	Combi 3	4	53,13
Combi 1	3	113055791,1	Combi 6	1	49,27
Combi 7	1	109249164,7	Combi 3	3	47,07
Combi 1	2	108843946,3	Combi 3	2	34,44
Combi 6	1	108609856,4	Combi 1	4	33,25
DGP	1	106011562	Combi 1	3	28,94
Combi 1	1	105588903,6	Combi 1	2	21,86
Combi 4	4	82273192,54	Combi 3	1	15,34

Figure 3.12: Example of Expanded NPV and B/C-ratio scores for Extension Combination Options

For the decision maker the following results can be given for him to make a decision:

- All the individual thirteen solutions can be seen as a financially beneficial solution, except for the bicycle parking.
- The individual solutions cannot remove the entire amount of latecomers and delay hours, combinations need to be made.
- The combination showed that the solutions 'Car parking places' and 'Electric trains' are not financially beneficial and could be replaced by the temporary solutions 'P+R in the region' and 'Diesel Trains'.
- The infrastructure for cars when parking places are build is financial beneficial, but it is best to wait another year for more knowledge.
- Station lengthening is financially beneficial investment that should be done right away.
- The original DGP plan can be adjusted which turns to a more financially beneficial outcome of the combination of solutions.
- The Adjusted DGP plan does include some infrastructural solutions and therefore it can be concluded that even though the amount of repetitions is unknown some infrastructural investments can still be executed.

Limitations

For the outcomes a few limitations of the spreadsheet should be taken into account that the decision maker should consider.

For the best investment moment, for the altering solutions in the combinations, the aspects B/C-ratio and Expanded NPV were taken into account. The solutions can also be compared on investment costs, delay hours and Latecomers or other aspects. In table 3.14 the right column includes the investment costs that need to be made. For the decision maker, with a limited budget this can be an important indicator the actual decision on the combination of investments. However the budget of the (local) government for the DGP is unknown.

The delay hours and latecomers are monetized in the tool, where delay hours are multiplied with the value of time (for purpose and modality) and the latecomers generate additional costs of €150 per latecomer. This value might be higher, but no value could be found on the value of missing out. In table 3.14 the total delay hours and latecomers can be found. All these most important aspects can be presented for decision makers. In the end its there choice which solution will be implemented. The budget, acceptable amount of latecomers and delay hours can even be implemented into a multi criteria analysis (MCA), but this is out of the scope of this research.

Table 3.14: Other potential decision criteria for decision makers

Combination	Description	Delay Hours			Latecomers	Investment costs (x €1000)
		Car	Bicycle	Train	Total	
1	Cheap investment and car parking	8885	121	22.097	4530	€3,250
2	Car investments	61	121	216.996	36767	€6,250
3	Station lengthening + Diesel	14583	31	10.457	18450	€2,050
4	Electric trains	14583	31	10.457	18450	€7,050
5	Bicycle solutions	7838	0	216.996	45437	€50
6	Natural Flexibility solutions	2423	2612	1.314	7008	€50
7	Adjusted DGP	3560	121	13.131	0	€2,050
8	Original DGP	5883	31	10.457	0	€7,050

3.10 Conclusions

In the chapter the case study has been performed to answer the following question:

How could the potential method be performed at a case study, taking into account the uncertainties of repetitiveness?

For the case study the methodology that was developed in Chapter 2 has been used. The steps described in that method are followed to test the methodology and to generate practical solutions for the DGP. The majority of the steps were performed without problems and are practically possible. The uncertainties could be captured with methodology by developing a decision tree with the possible scenario outcomes. For the practical outcomes for the event in Zandvoort the steps 7 and 8 can be read. The method is able to identify different best investment moments that just the first year. An extensive conclusion about the usage of the method, in combination with the CBA tool that has been developed in Appendix E, will be discussed in the next chapter. Some minor notes should be added to the way this method is executed and what might be specific for this case in comparison with other Hallmark Events that might be valued in with the same method.

The scenario development is probably the biggest uncertainty within the whole new developed methodology. Where the traditional valuation methods would just give a probability for a scenario, this new methodology includes another uncertainty for the chance of additional repetitions. This is actually a more realistic approach since this method includes the probability of having another repetitions after a previous one, but the determination of this probability cannot be found empirically. Therefore only extra uncertainties are introduced, but the method has the advantage of pointing out all probable future outcomes and the steps towards the outcome. Therefore the extra uncertainty can be justified, because it is more realistic although the determination of the probability p is hard to find. The way it is handled in the case study is by choosing multiple values for p and run the valuation spreadsheet multiple times. If the p value can be found with more certainty the method would be much more useful.

One problem that not specifically has to do with the methodology is the monetizing of some of the effects. The values for effects like: latecomers, illegal parking for bicycles and some of the costs for solutions are uncertainties within valuation method. However these uncertainties are not different from the traditional CBA.

Generic Hallmark results

From this specific case study there are also some conclusions to draw for the general Hallmark Events with uncertainties about the amount of repetitions. The main problems are caused by the demand for transport from the visitors. The current qualities of the different networks is of great importance since this generates the size of the problem. Some uncertainties that have been found can be seen as general uncertainties, since there is no information to be found on that specific matter. Investments for bicycle

infrastructure are difficult to monetize, could be seen for the DGP. The uncertainties for the monetizing of illegal parking, hindrance by the parking of delay because of the lack of facilities cannot be found in the literature. Therefore investments for the modality comes at higher risks, but it is likely that infrastructural costs are lower in comparison with car or train. Zandvoort has the advantage that 26% of the visitors live within 25 kilometers from the event and therefore the bicycle reduces also the amount of visitors by car or by train (Organisation of DGP, 2019). Other locations might not have this location advantage and are even less likely to make a bicycle investment.

In general it can be said that the location is very important, because Zandvoort did not have possibility to build an extra road or enough parking places for all visitors by car. A Hallmark Event in a more rural area with open fields to make temporary parking places might be better off with a few infrastructural investments to the car network. On the other hand does Zandvoort have a big advantage for the already available train infrastructure. This might not be available at other locations. Therefore in general there is no consensus found on what is applicable for all Hallmark Events.

Chapter 4

Validation of the results

The case study has been performed and conclusions for the DGP at Zandvoort were drawn in the previous chapter. Also some practical outcomes for Hallmark Events in general have been discussed. This chapter will cover the usage of the results for Hallmark Events by showing the methodology to experts in the field of valuation methods. The spreadsheet that has been made for the calculations will also be discussed by performing a sensitivity analysis. When this is done an overall conclusion can be made on the outcomes and for the methodology itself.

4.1 Generic results for the usage of the new methodology

Out of the practical results from the case study in Chapter 3 also some generic conclusions can be drawn, which are actually more interesting since there is a lot of uncertainty in the data that was used for the solutions in the previous chapter. The results will be discussed by looking at the individual solutions and the combinations of solutions.

4.1.1 Individual Solutions

For the individual solutions some generic conclusions can be drawn from the shapes that were formed in the graphs that are presented in section 3.8. The first most common shape is the shape of the solutions with 'Natural Flexibility'. The shape of these outcomes, see figure 3.7, is a shape where the most beneficial investment is the first investment moment. Because this temporary solution is more beneficial than doing nothing it makes no sense deferring this solution to another decision moment. This pattern is also found for solutions with the option 'Waiting for Certainty', see figure 3.8. With a more critical view on the information, this is not an interesting outcome. This is because a traditional CBA would also come to the same advice, since that valuation method would only consider the first moment and when this methodology would advice to invest at the first investment moment there is no difference. Therefore this outcome is interesting, but the traditional CBA would give the same advice.

Another similar shape is the shape of a solution that is not financially profitable in any way, like the Extra parking places for bicycles, see figure 3.10. In this case non of the investment moments become profitable. In this case there is no action preferred for an investment in this solution. This is again not a very interesting outcome if it would be compared with the traditional CBA, since that valuation method would also advice to reject the investment.

The most interesting shape that could be distinguished in the graphs of the individual solutions is the shape of the Car infrastructure Investment, figure 3.9. In this figure it became clear that the best investment moment was dependent on the scenario combination. This is an interesting outcome for a valuation method like this, that compares the different investment moments. An outcome like this shows that the method can be used to identify a best investment moment other than the first or last moment. In a normal valuation method the first investment moment might be profitable, but it does not show that

waiting a year is a better option.

4.1.2 Combinations of Solutions

For the individual solutions the results have been discussed and it is clear that the method can distinguish the best investment moment. The individual solutions did not solve the whole problem for Zandvoort, therefore combinations are needed. Also the comparisons of infrastructural investments with temporary solutions are desirable. Therefore the 'Extension Combination' option is used to alter infrastructural investments over the four decision moments to see if a better investment moment would show up if a combination of solutions is made. Until the infrastructural investment is made a temporary solution (or solution with 'Natural Flexibility') is used and the best moment to switch from a temporary solution to an infrastructural investment is tested.

The 7th and 8th combination where the combinations based on the plans by the DGP. The 8th plan is a one on one copy of the original plan and the 7th combination is an adjustment on that plan. It can be seen that adjusting the original plan by interchanging solutions with higher financial benefits will lead to a more financially beneficial combination. This is again an obvious outcome, but it should be mentioned that adjusting a plan with other solutions, that came out more profitable from the individual solutions, is possible. The first four combinations are much more interesting because in every one of those combinations one of the individual solutions was altered over the decision moment. By looking at the result graphs in Appendix G.2 four different patterns can be distinguished. Those four patterns of the graphs will be mentioned and explained below.

The first pattern that can be distinguished is the pattern where the best investment moment is the last investment moment. This pattern is shown in figure 4.1 by looking at the first combination that was made in step 7 of the case study. The additional parking places for car were altered over the decision moments with busses from the region when the investment was not yet made. It is clear to see that the best investment is at the last decision moment. This actually does not mean that the investment in year 14 is the best one, but that the additional investment that is tested in the combination should not be made at all. If there would be a fifth decision moment than that would be the better investment and therefore the investment should not be made at all. The temporary solution 'busses from the P+R in the region' is a more financially beneficial solution. The pattern where every later investment moment is better than the previous one is called 'Don't make the additional infrastructural investment'.

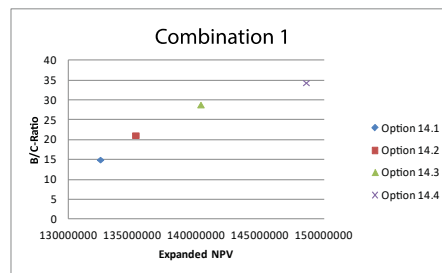


Figure 4.1: Shape: Don't make the additional infrastructural investment

The second pattern shows an opposite pattern where the investment is scoring better on Expanded NPV for every earlier investment moment. In this example for combination 3 the first investment moment scores best and the last investment moment scores the least on Expanded NPV. The Expanded NPV is the actual monetized revenue from the investment and therefore leading in the outcomes. The B/C-ratio just indicates the efficiency of the investment.

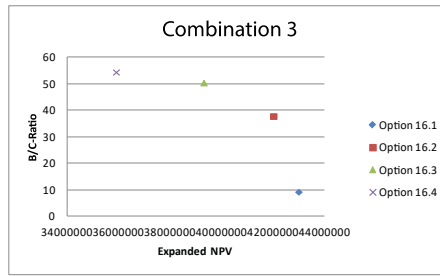


Figure 4.2: The additional solution solves problems for a higher price

The B/C-ratio in this example is higher for the fourth decision moment and lower for the first investment moment. This is typical for the comparison between temporary solutions and infrastructural investments, as been mentioned in section 2.5.1. The net benefits for a temporary solutions are expected to be lower, but because costs are also lower a high B/C-ratio can be seen for these type of solutions. With the infrastructural solutions this is the other way around. The benefits might be higher once the investment is done, but the investment comes at high costs. This reduces the B/C-ratio, but leads to a higher Expanded NPV. The conclusion that can be drawn from this pattern is that the additional solution is solving the last part of the problem for higher benefits, but also with higher costs. Adding this solution will lead to a higher NPV can be seen on the x-axis. It can be seen that the average B/C-ratio is dropping once the investment is done. Therefore the solution will lead to a more positive Expanded NPV, but the average benefits per euro invested are reduced. But overall it can be said that adding this investment is a wise decision.

The third pattern to show is one without consistency in the increase or decrease of the NPV or B/C-ratio per decision moment. In the first pattern is became clear that deferring the investment became more beneficial every decision moment and in the second pattern the first investment moment is the best one. In this third pattern the combination of the scenarios and the different values for the Option Premium result in a visualisation where there is no consistent pattern. There is only one interesting conclusion to draw which is: do not invest in this solution right now. The investment might be a financially beneficial solution, but deferring this investment till the next decision moment might be even more beneficial.

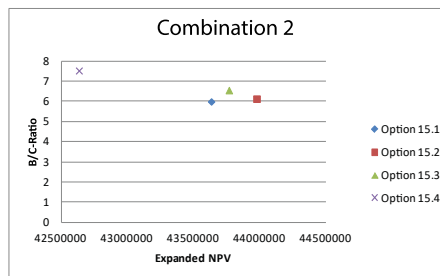


Figure 4.3: Shape: Do another check next decision moment

This last outcome is the major contribution to the traditional CBA, without flexibility. Because this outcome cannot be generated by a traditional CBA. The first two patterns are interesting, but a CBA would come to the same conclusion of investing or not. This third patterns can tell the decision maker: 'This investment might be beneficial, but waiting for certainty is a better option in this case'.

4.2 Sensitivity Analysis

One the most important steps to make, concerning the interpretation of the results of a model, is the execution of a sensitivity analysis. A sensitivity analysis is: *The study of how uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input* (Saltelli et al., 2004). The more practical meaning of this definition is that the uncertainty of the outcome can be tested by adjusting values in the model that are also uncertain.

Saltelli et al. (2008) mention the most common ways to perform a sensitivity analysis. Depending on the type of research and the setup of a model an approach can be picked. For most of the approaches it comes down to the calculation of the derivative. In other words how much does outcome Y increase by increasing variable X. In the spreadsheet there are multiple variables that can influence the outcome of the Expanded NPV or the B/C-ratio. The most interesting variables are the variables with the highest uncertainty, since those variables are most likely to have another value than the one that is used in the model. The variables can be changed individually or combined. The down side with changing variables all at once is that it becomes unclear with variables influence the outcome the most. Therefore variables will be changed one by one. The changes in the model will be changed by a percentage and the outcomes will be divided by the original outcomes to check what the relative change on the outcome is. If the outcomes do not change much, it can be said that the influence of that particular variable is not that big. In the case of big changes (a bigger relative change to the outcome than the relative change of the variable), the model can be called unstable and more research is needed to that particular variable. In this method the most interesting thing to know is the changing of the best investment moments, this is something that is not specifically mentioned in by Saltelli et al. (2008). Therefore the sensitivity analysis will only look at the relative changes of the Expanded NPV and B/C-ratio but also the changes of the outcome shapes. These shapes are mentioned in the previous section.

In the previous section some of the bigger uncertainties of the method, that are put into the spreadsheet, have been discussed. For the sensitivity analysis some of these values in the spreadsheet will be adjusted. These adjustments will generate different outcomes for the solutions that are valued in the spreadsheet. The relative changes to the Expanded NPV and B/C-ratio will be used as indicator the sensitivity. Another aspect to look at are the outcomes of the best investment moments for the different solutions of combination of solutions (Saltelli et al., 2008). In table 4.1 the changes that are used to test the sensitivity are given.

Table 4.1: Verifying of the spreadsheet

Description	Sheet	Values Changed
Increase value of time	0. Data input	VOT Person 200% VOT Person (PT) 200%
Increase value of missing out	0. Data input	Value of missing out €150 to €300
Increase social costs for emissions	0. Data input	NOx = 400%
Value for illegal bicycle parking	0. Data input	€9 to €18
Set scenario combination probabilities dependent on years	Scenario Combination	p = 90%
Increase duration of the event	Discounted Cash Flows	Event duration in days = 6

In Appendix H all the variables that are used for the sensitivity analysis are presented with the relative changes to the outcomes for Expanded NPV and B/C-ratio. The appendix also contains a list of scatter plots that are used to visualize the changes on the Expanded NPV and B/C-ratio. Scatter plots are one of the more basic ways to perform a sensitivity analysis on a model or outcomes (Saltelli & Annoni, 2010). In this report it is performed in a one at a time (OAT) approach. The six uncertain variables have been tested OAT and their individual effect on the outcomes is shown. This is simple, but effective approach to visualize the sensitivity of the variable. Three of those scatter plots are shown in this section. The scatter plots are made out of the relative changes on the Expanded NPV (x-axis) and the B/C-ratio (Y-axis). The outcomes of the results are divided by the initial outcomes of the spreadsheet, shown in Appendix G. All those outcomes are subtracted by one. By doing this the outcomes that are nearest to the origin represent the least influenced points by the changing of a variable. A scatter plot with all the outcome points on the origin means that the outcomes of the spreadsheet are independent of the variable.

If the points are far apart of the origin the spreadsheet is very dependent on the variable changed.

The VOT for the travel time and also for the delay hours is an important factor. The delay hours and the latecomers are the main social costs in the spreadsheet. In Appendix H the relative changes are shown of the increased VOT by 200%. For the individual solutions the outcomes have an effect really dependent on the solution. The parking solutions do not change at all, since the modal includes this shortage in the amount of latecomers. The VOT has a big influence on the car infrastructure solution. This solution mainly has social costs for delay hours and delay hours are directly influenced by the VOT. For solutions like the diesel train, there are also costs for latecomers, maintenance, safety and emissions. Therefore these solutions are less influenced. In the scatter plot for Value of Time, figure 4.4, it is clear to see that most of the outcomes are changed just minor. The outliers in the graph are the relative changes to the outcome for the car infrastructure solution. A positive thing to notice is that the combined solutions do not change much. An average change of 17% for the NPV and 9% for the B/C-ratio.

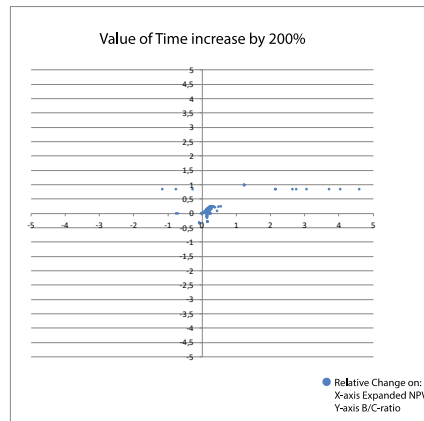


Figure 4.4: Scatter Plot changes to VOT

The relative changes to the Expanded NPV and the B/C-ratio are actually not that interesting for the usage of the new methodology. For the case study outcomes it might be very interesting to see what the changes are to Expanded NPV and B/C-ratio, but for the methodology the outcome patterns are of much more interest. With the spreadsheet also the outcome patterns are generated and it can be said that for all the changes the three different outcome patterns are visible, see figure 4.5. In the figure below the outcomes patterns are given for the changing of the value for VOT, but these patterns are visible for all the changes of the variables.

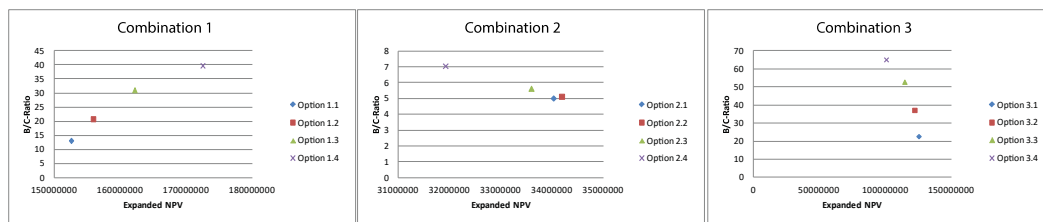


Figure 4.5: All three outcome patterns visible for changing VOT

For the value of missing out the changes generate less outliers in the scatter plot, see Appendix H. The average change on the outcomes is much higher, 65% for the individual solutions and 88% for the combined solutions. Especially for the combined solutions, because the VOMO is relatively high (€300 per person) and the combined solutions solve a large part of the problem. This is positive thing because this value for missing out is picked low, see section 3.3.

Another variables that might not be so interesting, but should be mentioned are the costs for emissions.

A very trending topic in the Netherlands are the nitrogen emissions. Therefore the costs for emissions are set to 400% of their original value. This is the largest relative change to a variable, but the influence on the outcomes is low. In figure 4.6 the scatter plot for the costs for emissions is shown. It can be seen that the outcomes lie closest to the origin of all the scatter plots.

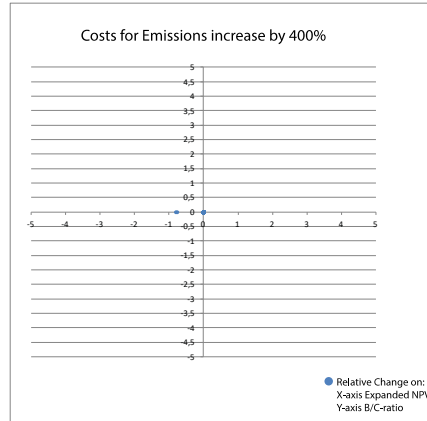


Figure 4.6: Scatter Plot changes to cost of Emissions

The social costs for not having enough bicycle parking places is set €9 per cyclist without a parking place. There was no actual value for this and the value was set to €9 for one hour extra for finding a parking place. Changing this value has no impact on any of the individual solutions but the extra parking places for bicycles. For the combined solutions there is a change depending on the combination and scenario between 1% and 5%.

The increase of the event duration is causing the largest changes in the outcomes for Expanded NPV and B/C-ratio. By tripling the amount of event days the outcomes for the Expanded NPV and B/C-ratio are going up. The investment costs are only counted one time, but all the other monetized effects are generating costs and benefits for the amount of days that the event lasts. The changes to the outcomes vary from 2 times the original Expanded NPV towards 3 times. The B/C-ratio varies from almost no change up to twice the original value. Some outliers can be found which are the non financially beneficial individual solutions. The relative change to outcomes is often lower than the relative change to the original value of the event duration.

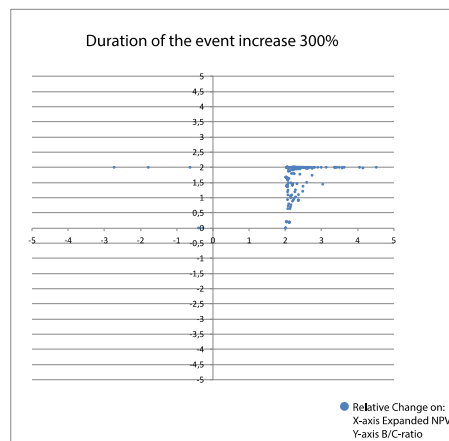


Figure 4.7: Scatter Plot changes to duration of the event

The last variable that was checked was the p value for the scenario combinations. In this test the p became dependent on the years and not on the amount of decision moments. This means that the chance

for every year was calculated by the formula:

$$\text{Probability for } n \text{ years} = p^{n-1} \times (1 - p) \quad (4.1)$$

Then the probabilities for the years between the decision moments were added up. For the first scenario the outcome for the probability is 1-p. For the scenario 4 years the probabilities for $n = 2$, $n = 3$ and $n = 4$ were added up and so on for the scenario with 14 repetitions and the scenario with 29 repetitions. Multiple values for p were tested and the main purpose here was to check if the same patterns could be found that were identified in the generic results.

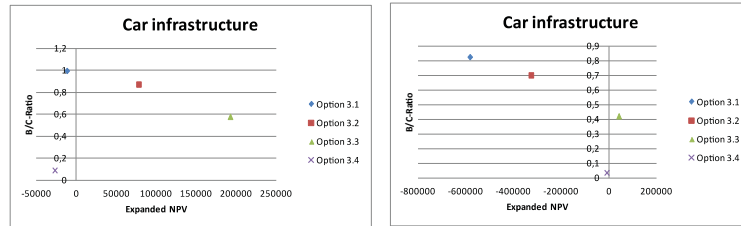


Figure 4.8: Changes to scenario probability p , (left $p = 85\%$, right $p = 80\%$)

In Appendix H the outcome of the graphs for $p = 95\%$ and $p = 90\%$ are given. In both the outcomes there are examples of the different patterns that were identified. This goes on until $p = 75\%$. In figure 4.8 the p for 85% and 80% are shown. Although the B/C-ratio is no longer higher than one the outcome pattern is still visible. From the moment on the p becomes lower the chance of have more than 4 repetitions become relatively low, which results in a pattern where doing no investment is always the best.

4.3 Interview with Experts

The difficulty with the topic is the lack of comparable projects, because there are none that used the same approach for the valuation of investments. Therefore two in dept interviews with experts in the field of CBA are executed. Their view on the topic and the usability of the new method will be used to complete the validation. The interview is done by giving a presentation about the research with in-between-questions that the experts had to answer. The presentation can be found in Appendix I. The following questions were asked:

- How should there be dealt with uncertainties at Hallmark Events concerning the amount or repetitions?
- What do you think a priori about the usability of the method with the possibility to defer the investment? And what is the difference with current valuation methods?
- What is the added value of the outcomes for the individual solutions compared with the traditional valuation methods? Or what are the disadvantages?
- What is the added value of the outcomes for the combinations of solutions compared with the traditional valuation methods? Or what are the disadvantages?
- Do you have additional remarks on the method?

4.3.1 Dr. Mr. N. (Niek) Mouter

Mouter did a PhD on the subject of cost benefit analysis. Infrastructure project appraisal is at the moment the topic that Mouter is handling, which includes valuation of infrastructure projects using a CBA. He also did a lot of research after the usability of the outcomes of a CBA for the decision makers.

How should there be dealt with uncertainties at Hallmark Events concerning the amount or repetitions?

A best case and a worst case is the approach that Mouter would suggest with the uncertainty at Hallmark Events. He mentions that he has a lot of experience with how politicians read the outcomes of such projects. 'They often have a few minutes to read through the rapport and make a decision'. By making more options and making the outcomes more complex to understand the decision maker will lose important time to read other reports. Therefore two possible outcomes, best or worse case, is the most easy way for the politician to understand what the potential benefits and potential risks are.

The main problem with the valuation researches is the lack of knowledge about what the decision makers need. This causes a big gap between what the researcher is investigating and what (little) information the decision maker needs. Mouter advises that transport researchers should do more research to what the decision makers need instead of making more complex calculations about future outcomes. This way the researchers can really give an answer to what the decision maker really needs. It is also very important to explain in a better way what the main results are. The scientists think that they make the best calculations and that their reports are of high quality. Although this might be the case, it is even more important to show the results in a way that the decision maker understands what the outcomes are. The main problem is also not that the politicians don't understand the CBA, but they just don't have the time to read the report and the methodology used.

What do you think a priory about the usability of the method with the possibility to defer the investment? And what is the difference with current valuation methods?

About the value of flexibility that is added to the solutions with the method can be said that it is not complete. Next to the Option Premium that is handled in the report there is also a value for flexibility because of the uncertainty for local inhabitants. Imagine a road that might be build, than local people have stress about if the road is being build or not. This is another negative aspect that should be included according to Mouter.

The main concern Mouter points out is that if the ROA had been useful for these kind of investments, why have they not been used more often already? However it is interesting to add knowledge to scientific field about this topic, because it might be possible that a decision maker chooses such an approach.

What is the added value of the outcomes for the individual solutions compared with the traditional valuation methods? Or what are the disadvantages?

Mouter repeats his previous answer to answer this question. But he points out that the main difference, which is the usage of flexibility, could be made more explicitly. This can be done by really explaining if the flexibility is positive or negative and what the advantages are of this information.

What is the added value of the outcomes for the combinations of solutions compared with the traditional valuation methods? Or what are the disadvantages?

For the decision maker it is very interesting to make the distinction between the three outcomes:

- This investment should be done
- This investment should not be done
- This invest can be done, but definitely not this year.

The main argument for this distinction is the difficulty the pictures, that have been made, give. The explanation of the results is the most difficult challenge.

Do you have additional remarks on the method?

No additional remarks were left.

4.3.2 Prof. dr. G.P. (Bert) van Wee

Van Wee is an expert in transport in the field of strategic long term planning, which includes road, rail, airports, ect. He also has a lot of experience with the CBA and the effects on emissions, traffic safety and accessibility.

How should there be dealt with uncertainties at Hallmark Events concerning the amount or repetitions?

Van Wee mentions that in the case of a Hallmark Event there is a distinction between the business case and the social costs benefit analysis. In the business case the only monetary values are taken into account. In this case the infrastructure is seen as an investment that really makes money. In the S-CBA all the effects are monetized and this case includes all types of other aspects. With the SCBA all aspects can be implemented, but a main risk is still the amount of repetitions and are there factors that influence the chance for having multiple repetitions. Van Wee mentions that the chance for having an additional repetition is way smaller for the 2nd time, than for the, for example, 11th time. Because there is much more known about effects. For dealing with uncertainties van Wee would calculate the break even point in time for an investment.

What do you think a priori about the usability of the method with the possibility to defer the investment? And what is the difference with current valuation methods?

The method seems reasonable, but van Wee mentions that there should be side mark that there are investments that need to be made to even host the event. So the method is usable, but for the investments that can be deferred. The simplification of the method is that all the options are on-or-off-solutions, but there are also options that are gradual. For example giving people a discount by using the train, might only be used for the busiest moments. Which will lead to a spread of demand, but is not an option that is executed the whole duration of the event. Therefore more detail in the different solutions could be implemented.

Another mark should be made for the amount or repetitions. There is a change that the event might stop, but it could also be transformed into another event. Those future uncertainties could also be implemented in the calculations.

What is the added value of the outcomes for the individual solutions compared with the traditional valuation methods?

The outcomes are very useful does van Wee think, but the main disadvantages is the explanation of the research. Because the images and the calculations need to be understandable by the layman or non-expert. The uncertainties in the calculations can cause a lot of variation in the outcomes and therefore a sensitivity analysis seems in place. And the main goal of that sensitivity analysis would be how much change in a variable is needed before another outcome pattern becomes visible. Another imperfection is the independence of a solution on the amount of repetitions, because van Wee mentions that a good infrastructure can influence the amount of repetitions.

What is the added value of the outcomes for the combination of solutions compared with the traditional valuation methods?

The story line for the development of the combinations needs to be very clear and it would be nice if a decision maker could combine his own solutions. This way the decision maker can see the results of his own strategy of making investments. Another important aspect in the calculations are the effects of the solutions on the network for the rest of the year. And there might be solutions that only influence the outcomes for the event and other ones that influence the network for the whole year. This distinction should be made for a full SCBA. Those long term effects are interesting to include for the solutions. This also holds for individual solutions, but is extra interesting for combinations.

Do you have additional remarks on the method?

Van Wee mentions that the real options approach aspects in the CBA are really interesting, but even more for the next year. At that moment the real effects of the event are known and a decision can be made with much more certainty. Also price differentiation in the different solutions can be an interesting addition to spread the demand of visitors over time.

4.4 Conclusion

In this chapter the generic results were presented and validation steps have been executed by performing a sensitivity analysis and have experts share their view on the scientific work that have been performed in this thesis. All this is done to answer the last sub question from the methodology:

What is the experts point of view on the new methodology for dealing with uncertainty at Hallmark Events?

For the generic answer on the usage of the methodology it is clear to say that the methodology can be performed and that the outcomes can actually differ from the traditional CBA. The different patterns that can be distinguished with the usage of this methodology can be seen as the added value of this new methodology. The way the uncertainty is captured by adding flexibility within the solutions can be seen as a main difference with the traditional CBA.

To validate the outcomes a sensitivity analysis has been performed to see the effect on the outcomes by changing individual variables. The effects on the outcomes differ per variable, but most interesting is that the changing of variables do not change the possibility to have all three different outcome patterns. However the scenario probability p does have influence on those outcomes patterns and it was represented that with a low value for p not all the outcomes patterns could be distinguished. This was already visible in the case study, but with a p dependent on the years and not on the decision moments this effect becomes even more visible.

The experts were interviewed on their view on the developed methodology. The shortcomings that they identified, but also their positive aspects of the new methodology are listed below. From the interviews a few shortcomings on the spreadsheet have been given. These shortcomings are:

- If this method is a method that is needed, why is it not already developed?
- Flexibility can have a negative value for local people, because of the stress they experience for not knowing what will happen.
- Outcomes need to be clear for decision makers, don't present too much different options.
- Is the information really what the decision maker needs?
- The figures are difficult to understand for an expert so definitely for a decision maker.
- Explanation is an overall difficulty of the method because more information means also more complex story telling.

Next to the shortcomings of the spreadsheet and the model there are also a (potential) positive aspects. The experts pointed out the following positive aspects:

- The three outcome forms with the information on doing an investment or not and the best investment moment is real contribution to the traditional valuation methods.
- The estimation of the decision moments are now providing more information on the future every next decision moment, but also other effect that will be known after the first year will provide more certainty on the outcomes.
- The spreadsheet could be an interesting cause for developing a tool that can be used by decision makers to try their own set of combinations to test the best investment moments.

With this last overview from the experts this validation chapter is complete. The next chapter will include the discussion to reflect on the findings, but also on the opinions that the experts gave in this chapter.

Chapter 5

Discussion

The purpose of this research was to use the ROA as an addition to the traditional validation methods. The difference in the outcomes for the new methodology indirectly gives input for a decision maker. The results of this thesis will be discussed to indicate the usability of these outcomes for a decision maker. This chapter will be used to discuss all the findings that have been presented throughout the previous chapters. The thesis can be seen as a research with answers at three levels:

- Case study
- Usage of the methodology
- Outcomes for Hallmark Events in general

For all the three aspects some limitations can be found that will be discussed. Some limitations are general for all the three levels since the model is tested on one case study specifically. The usability of the method on the case study will be discussed at first. The outcomes for the case study and the validity of those outcomes will follow. At the end a critical view will be given on the innovativeness of this new method. Future research that might bring the new methodology to a higher level will be given in the conclusion chapter.

5.1 Method Usability from the Case Study

The methodology is developed to be usable for decision makers with a step-wise approach to guide the decision maker through the method. Therefore the method needs to be understandable and practically useful. The steps of the method have been developed in an iterative way. Therefore when the research faced difficulties it was easier to adapt and change the approach. However there are some disadvantages for the method. In this section all the steps of the method will be discussed individually for comprehensibility and practical usefulness.

Step 1 and 2 are easy to perform once all the information is available, but also with key figures that were used in the case. In these steps the 'Problem Definition' is made (see figure 5.1). For the DGP the information on amount of visitors and the demand curves was available by looking at the 'Mobiliteitsplan' (Organisation of DGP, 2019). With the key figures that have been found in Appendix D the main bottlenecks could be identified and the effects of the solutions could be monetized. More detail could be added if information was available by the municipality of Zandvoort, but that was not the main goal of this research. The method is therefore a valid way to identify the capacity shortage and determine the problem definition.

In the third step the solutions were developed and flexibility was added to the solutions. For the temporary solutions the way to add flexibility became 'Natural Flexibility' and for the infrastructural investments this became 'Waiting for Certainty'. Thirteen solutions were made and these options were applied to those solutions. It should be mentioned that there might be more applicable solutions, but

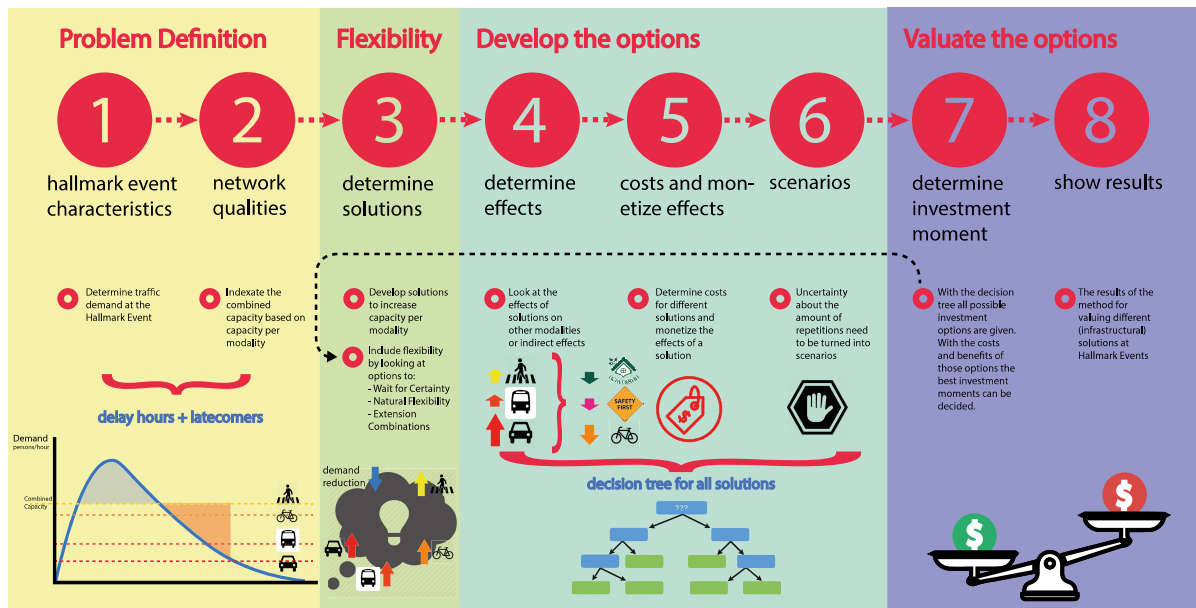


Figure 5.1: Methodology to deal with uncertainty of repetitions at Hallmark Events

the thirteen shown in table 3.5 were used. Professor van Wee mentioned there were also possibilities to include solutions with price differentiation and more complex alternatives. The solutions in this case study were based on solutions developed by the DGP themselves and other obvious solutions for the DGP at Zandvoort for testing the methodology. The implementation of flexibility is a relatively easy step to make because there is no difficult choice to make in terms of choosing the right type of flexibility. This is the case with table 2.1 where seven different types of options were presented. A decision maker can get confused by this amount of options, but the new methodology makes this choice more understandable.

The fourth step is about the effects that the solutions had on aspects such as: emission, traffic safety, delay hours, etc. With the spreadsheet presented in Appendix E these effects are defined. Step five was also included in the spreadsheet to immediately monetize the effects. The level of detail could again be increased by adding more aspects into the valuation method, but also by having more information about specific effects like value of missing out (VOMO), bicycle parking and other aspects mentioned by the experts. The specific effects that need to be researched will be given in the recommendations. The outcomes for the case study might be not as detailed as desired by a decision maker, but for the testing of the methodology this level of detail was not necessary. Overall these two steps do not make the method less understandable or useful, since these steps are also common in the traditional CBA (Renes, G. Romijn, 2013).

Step 6 is one of the more difficult steps, since the concept of developing scenarios with the probability p is a difficult one to explain. Additionally is the estimation of probability p difficult to comprehend. This chance for having more repetitions has a big influence on some of the outcomes. The car investment for the intersection at the N200 had multiple different best investment moment depending on the scenario combination. If a decision maker chooses the wrong probability value it is possible that the wrong decision is made. A last remark that should be made is that the Waiting for Certainty is very dependent on the estimation of the decision moments. In the case study every decision moment more knowledge was gained, in terms of more repetitions till the next decision moment. This caused a situation where waiting gives more knowledge every time, but it is not sure if this is a realistic approach.

The determination of the best investment moment in step 7 can also be difficult to understand for a decision maker. The individual solutions are understandable since they only have one solution that is influencing all the different effects. In the case of the 'Extension Combinations' this becomes more difficult. In section 3.8, the different combinations were compared and multiple outcomes were generated with the different combination and the different scenario combinations. The interpretation of the results

is a time consuming process and need some knowledge on how the spreadsheet is working and what combinations of solutions are used at which decision moment. Dr. mr. Mouter also mentioned that the decision makers do have little time to consider a report and therefore the practical usage of the method might be diminished. This step might therefore not be specifically useful for a decision maker, however the municipality of Zandvoort did not want to participate in the research. With their input on their envisioned outcomes this step might be much more usable.

Step 8 is a step that can be designed by the decision maker themselves. The priorities of the decision maker can be used to compare the different solutions. A MCA could be an example of how to show the best outcomes for different actors if they are involved. This is however not a difference from what Renes, G. Romijn (2013) showed in their step wise approach for a CBA.

Most of the steps that are used were based on the traditional CBA and therefore generate no problems regarding comprehensibility and practical usefulness. The scenario development and representation of the result are the steps with more difficulties. Further recommendations on this will be given in the recommendation part in the conclusion chapter.

5.2 Case study results and Hallmark Events in general

For the case study and the Hallmark Events in general the same question about the meaning of the results can be asked. The outcomes for the case study were presented for the individual solutions and the different combinations of these solutions. The individual solutions were almost all profitable from the first moment on. For all the networks, except for the pedestrians, there were solutions found that could be seen as financially beneficial according to the CBA with ROA in the spreadsheet. The bicycle parking solution was not beneficial, but mainly because the effects could not be monetized. A solution can solve a part of the problem and will have a very positive NPV and B/C-ratio compared with doing nothing. If combinations are made the total investment might be less efficient, due to overlap in the part of the capacity that is increased. This inefficiency will lead to a higher chance of having a solution that is not financially beneficial, although the individual solutions are extremely beneficial. These outcomes seem reasonable although the CBA could have been build with more detail. Also flexibility values for uncertainty among inhabitants on an investment could have been included like dr. mr. Mouter mentioned, but finding these values could have been a research on its own.

For the option 'Extension Combinations' different solutions were combined to reduce the amount of delay hours and latecomers even more. At first combinations were made out of individual solutions that had high values for Expanded NPV and B/C-ratio. With these combinations infrastructural investments were again tested for the best investment moment, since temporary solutions could solve the problem until the investment was made. Also an attempt was made on improving the original DGP plan for the Hallmark Event. This one was a bit obvious, because all the least scoring solutions were either removed or replaced by a better scoring solution. For the combinations that altered a infrastructural investment over the decision moments it turned out to be that the parking places for cars were not beneficial even as the overhead line for the electric trains. The station lengthening however turned out to be still beneficial. The investments for car infrastructure was beneficial if parking places were available, but interesting it was to see that the best investment moment was not the first moment. The outcomes for these combinations might be different from reality and this is mainly because of lack of detail in the calculations. Therefore actual usage of the results might not be the case, but the knowledge that some of the investments might be interesting to value again in a few years is an interesting outcome. Therefore it can be justified to defer an investment because this research showed that it might be profitable to not directly make the investment.

The next part to discuss is the usability of outcomes for other Hallmark Event. From the practical usage and the review on the methodology itself in the last two sections a few recommendations can be made. In terms of general outcomes for Hallmark Events it is a lot harder to draw an overall conclusion.

Zandvoort had a few very specific problems that came into play when developing solutions. Extra road infrastructure is hard to build, since the whole area is a protected environmental area. The city has a train station, but with a very low capacity at the moment with a maximum of four trains per hour

and a short platform. With the low capacity of the public transport network and the expectation of 40.000 visitors by train all the investments in the train network became profitable. This cannot be seen as something that is general for all events. For the investments for car or train infrastructure no generic conclusions has been made. However the bicycle is probably not beneficial in any case if no value for illegal parking can be found. The DGP does have 26% of the ticket holders within a 25 kilometer range from the event. For a rural area Hallmark Event this is an unlikely amount. Otherwise the event would become more of a community event by looking at table 2.1 (Hall, 1989). Overall there are not much generic results for all Hallmark Events based on the finding in the case study. The outcomes are very location and event specific.

It might actually be save to say that the location of Zandvoort is not appropriate for such a Hallmark Event. This would also mean that the whole methodology developed for the Hallmark Events is unnecessary and only needed when a location for an event is poorly chosen. Then the question might not be; What kind of valuation method is needed?, but; What location is more appropriate for the event? However the methodology points out that there are better or worse investment moments and for poorly chosen location with low probabilities for more repetitions it would suggest to defer an investment or give the advice to reject the investment. With that knowledge the methodology might be useful, but an addition might be made on requirements for the location choice.

To conclude the part of the Hallmark Events in general it can be said that there is no general conclusion to make. More Hallmark Events with an unknown amount of repetitions shall need to be tested with this method to make a solid argument on that.

5.3 Interpreting the results

In the first section the practical usage of the method is discussed. The seventh step on the determination of the best investment moment and how to show those results turned out to be difficult. In section 2.2.1 the interpretation of results by decision makers was already mentioned for the usage of the traditional CBA. However for the methodology itself it is interesting to see if the way the results are presented can be improved. For the case study the results are based on the Expanded NPV and the B/C-ratio. The approach was chosen in Chapter 2, because for the infrastructural investments it was expected that these would have a higher Expanded NPV and for the temporary solutions a higher B/C-ratio. In the outcome tables in Appendix G can be found that this is partly true. The B/C-ratio is higher for the temporary solutions, but the temporary solutions are also good performers on the Expanded NPV. Therefore the B/C-ratio might be unnecessary and another comparing aspect might be placed on the y-axis of the graphs. It was also mentioned in the end of Chapter 3 that a decision maker should be involved in the process of showing the results. In possible future cases this could be done to experience what kind of outcome visualisation is preferred by the decision maker. This was also mentioned by Mouter. On the other hand the DGP is the first case used for the methodology and the methodology might need some repetitions on its own to improve the way the results are shown. Since the results were also a bit difficult to understand by the experts, but also for the author. Therefore a few more case studies might give a better insight into the aspects that need to be shown to the decision maker. The Expanded NPV stil remains a crucial indicator for the solutions, since this indicates the monetized revenue of the investments. Other aspects might be tested for a better understanding by decision makers.

5.4 Is the method innovative and useful?

The reason for developing a new method was because of the lack of the traditional valuation method to deal with uncertainty that comes with a Hallmark Event. The ROA seemed an appropriate method to base the new methodology on, because of its possibility to point out all future outcomes with multiple moments were a decision could be made. Two main differences with the traditional valuation methods are:

- Ability to identify investment moments other than the first year.

- Adding a decision tree with decision moments, future outcomes and scenario probabilities all in one.

Renes, G. Romijn (2013) developed a road-map for performing a CBA, that was presented in Chapter 2, figure 2.1. In this 'recipe' for making a CBA no identification of best investment moment was included. This leads to a black box between the choices to do the investment and to reject the investment without any nuance. The influence of extra knowledge that can be gained over time is not included in this valuation method and this is something that the new method is able to include. This is also a conclusion that the interviewed experts point out in section 4.3. Knowing that with more information that can be gathered over time a better decision can be made is one of the key differences and additions to the traditional CBA.

The decision tree is the main part of the ROA that makes the different investment moments possible. This visualisation of the future outcomes and moments to invest gives a more detailed choice set for a decision maker. Dr. mr. Mouter pointed out that he does not see the added value of the way scenarios are developed within this ROA feature. The way scenarios are developed nowadays is also based on educated guesses and probabilities. However a clear distinction should be made with how scenarios are developed within the traditional CBA and in this new methodology. The traditional way is to make scenarios and give them a priory a probability for occurring. This gives for three scenarios three different probabilities adding up to a 100%. The reasoning behind this development can be very unclear for a decision maker, whereas the new methodology can have a probability for more repetitions at every decision moment. This means that there are more probabilities, but the reasoning behind this can be explained more clear. One could argue that the probability for more repetitions becomes more or less every decision moment based on information that is gathered. This is also something that professor van Wee mentions and the experts have no consensus about. The view of dr. mr. Mouter is something that can be justified because there is a lot of uncertainty at the beginning of a Hallmark Event. However the new methodology forces a decision maker to think about the probability for more repetitions. This can be seen as an improvement of the traditional CBA, since it obliges the decision maker to gather more information about the possible future outcomes.

To conclude this last part of the discussion, the new methodology has some innovative parts in comparison with the traditional CBA. The ROA features can be seen as an advantage for pointing out all future outcomes, decision moments and best investment moments. The scenario development however should be tested more to really justify the advantages of this part. This will also be adopted in the recommendations.

Chapter 6

Conclusion

The research that was proposed in the first chapter has been executed and conclusions have been drawn for the sub-questions in the different chapters. The research has been developed around the following main question:

To what extent results applying ROA for valuing infrastructure projects at Hallmark Events into useful decision-making information?

The first sub-question regarded the usability of the implementation of ROA into the traditional CBA. The currently used valuation method for large scale projects is the cost benefit analysis. This analysis tries to capture and monetize all the effects that come with a project. The major problem that occurs with this valuation method is that it cannot handle future uncertainty (Renes, G. Romijn, 2013). This future uncertainty might be tackled by introducing flexible solutions that are adjustable once the future turns out differently. The real options approach has some different options to deal with uncertainty. Eight different options could be identified, but only a few features were usable for infrastructural investments at Hallmark Events. The option to defer an investment and the usage of the decision tree, to point out all future outcomes and decision moments, are the ROA features used in the new valuation method.

The next phase regarded the application of the new method on a case study. This part can be seen as the overall conclusion of the practical outcomes for the thesis. The method was tested on the Dutch Grand Prix, which is a coming Hallmark Event for the formula 1 racing, hosted in Zandvoort. The location has a clear problem with the amount of visitors that will be attracted by the event and the lack of capacity that the current networks in Zandvoort have. For the different networks multiple solutions were developed both infrastructural and temporary. The results for the case study at Zandvoort did not show a best investment for making more car parking places in Zandvoort. For the reconstruction of the northern roundabout, that gives access to the N200, the best investment moment is not in the first year. It does not give a negative advice on making the investment, but the second or third moment came more financially beneficial out of the valuation method. Therefore it is wise to defer this investment and do the investment next decision moment based on the outcome of the future and amount of repetitions. For the train investments the station lengthening came out positive and the overhead investment is not more beneficial than the temporary diesel trains. Overall the most gains can be found in the train network and for pedestrian and bicycles almost no monetized benefits can be found. For the car it is most beneficial to wait at least till the next decision moment and than make the decision for the investment again with more knowledge about the future of the event.

For the validation of the answers a sensitivity analysis was performed followed up by interviews with experts. Although this is also a validation for the outcomes for Zandvoort it is even more important for the new methodology itself. The sensitivity analysis pointed out that the scenario development, that was adopted from the ROA, had significant influence on the outcomes. A few limitations were mentioned by the experts, but they acknowledged that the method could be useful. The most important remark was the comprehensibility by decision makers. The outcomes should be easy to interpret for a decision maker to actually be able to use it. Although this was already found in the literature study in Chapter 2, the outcomes are still difficult to interpret. Again the scenario development was mentioned, but currently

the scenario development is also a big uncertainty and therefore not that different from the scenario uncertainty in this method.

With all the findings during the process of the research it can be concluded that it is possible to develop a valuation methodology for dealing with the uncertainties at Hallmark Events. As an answer to the main question of this thesis it can be said that the ROA as an addition to the CBA can result in more detailed information for a decision maker. Compared with the traditional CBA the method is able to identify a third outcome: Invest at another decision moment. This outcome does not give the advise to invest or not, but at another moment or to check again at a next decision moment with more information about the future. With the knowledge that the new methodology is able to identify a best investment moment, that is not the first moment, by checking multiple investment moments it can be said that this methodology could give a broader insight in the possible options for investing.

6.1 Recommendations

Throughout the report multiple limitations and focus areas were pointed out. This section will mention those aspects with possible following up research to tackle the occurring problems.

The most important limitation of the method is the usability of the results mentioned in section 2.2.1. In the main question it is clear that ROA is used to generate more detailed information that can be used by the decision maker. It became clear that the method is able to identify other investment moments which is an addition to the traditional CBA. However it was discovered in the interviews that the experts already had some difficulties understanding the outcomes at first sight. The new methodology introduces flexibility by applying ROA-features, but it probably becomes even harder to understand the actual outcomes of the method. The way the results were shown was chosen in Chapter 2, because for the infrastructural investments it was expected that these would have a higher Expanded NPV and for the temporary solutions a higher B/C-ratio. The municipality of Zandvoort did not want to participate in the development of the method and therefore the information needed might be different from what is presented in the report. An extended research is needed after what type of information the decision maker is hoping to get from a report using this new methodology or how the information should be presented to the decision maker. If this could have been possible the outcome graphs might have looked very different from what they do now. Because the ideal way of presenting the results is not known an additional research for the result representation is advised.

Another major point of attention is the scenario development. The usage of the methodology did not bring many problems, since the method was developed in an iterative way while performing the case study. However the development of scenarios that was inspired on the ROA did come with a new uncertainty. To make a good estimation about the future the method sets multiple values for the probability p that indicates the chance of having an additional repetition. With this p value it is easy to make multiple scenario combinations, but information on the future is needed to develop these scenarios. In the case study four values for p were chosen, together with a scenario combination of all scenarios with the same chance for happening. From the experts point of view it did not differ much from the traditional way of developing scenarios. However the decision tree with probabilities is the main difference from the traditional CBA. Therefore the addition of this ROA feature becomes questionable once the development of the decision tree is uncertain. A research to what can influence these probabilities is needed.

In addition to the scenario development also information that is gathered over time for the option 'Waiting for Certainty' is something that can be justified with an additional research. For the case study extra knowledge that was gained every decision moment was based on certainty for extra repetitions. Van Wee mentioned that knowledge might also be found in other aspects. Knowledge of actual gains might be available after the first year and therefore even more value could be added to the option 'Waiting for Certainty'. To what extent this information is influencing the outcomes and how this information should be included in the method might be found in an additional research.

In the previous section a conclusion is given for Zandvoort as a practical outcome of the methodology and for the methodology itself. One missing aspect is the conclusion on Hallmark Events in general. Unfortunately this cannot be seen covered with this research. The methodology should be tested on multiple

case studies to see if an overall conclusion could be made on the best investment type. For Zandvoort public transport was obviously a good network to invest in, but that cannot be said for Hallmark Events in general. More information might give more insight into the most beneficial investments at Hallmark Events.

To a lesser extend also unidentified effects play a role in the outcomes of the methodology. For the case study some effects could be included that are not included at this moment. Out of the interviews with dr. mr. Mouter and van Wee multiple effects were mentioned to add to the spreadsheet that was built for the calculations. The Expanded NPV was based on the NPV and the additional value for flexibility, but this value is more complex than just a loss or gain for deferring an investment. For example, local inhabitants can actually experience stress because of the uncertainty for them if an investment will be made or not for their infrastructure. A more inclusive research to all the effects of introducing uncertainty for actors might be possible.

At last, at detail level, it is important to have the proper monetization for the effects. Some effects that were monetized at the case study could not be found in literature and assumptions were made. The first effect that could not be monetized was the value for bicycle parking. The hindrance for local people and how much a parking place is worth for a visitor is a big uncertainty. For the sensitivity analysis it didn't come out as a big influence on the outcome, but it might influence the image of the event. In a country like the Netherlands it is likely that this value is really important for decision makers and therefore a research is recommended. A survey based research with a discrete choice model could be an example for finding the value for this effect.

The next effect is the value of missing out (VOMO). The costs for a ticket have now been used for the value of missing out, but this value is probably higher and in the sensitivity analysis it became clear that this value does influence the outcomes. Therefore a research to this real value is needed. A similar approach as for the value for bicycle parking could be used.

To conclude at last, the method can generate information for decision makers with more detail than just the information: invest or not. However more empirical research is needed to the ROA scenario development within the method. Also the presentation of findings for decision makers can be seen as a research itself.

Bibliography

- Adner, R., & Levinthal, D. A. (2004). What is not a real option: Considering boundaries for the application of real options to business strategy. *Academy of management review*, 29(1), 74–85.
- Anciaes, P. R., & Jones, P. (2015). The influence of motorised traffic on pedestrian flows—new insights using bus stop data. Association for European Transport Papers Repository.
- Annema, J. A., Frenken, K., Koopmans, C., & Kroesen, M. (2017). Relating cost-benefit analysis results with transport project decisions in the Netherlands. *Letters in Spatial and Resource Sciences*, 10(1), 109–127. <https://doi.org/10.1007/s12076-016-0175-5>
- Arnegger, J., & Herz, M. (2016). Economic and destination image impacts of mega-events in emerging tourist destinations. *Journal of Destination Marketing & Management*, 5(2), 76–85.
- Bos F., V. d. P. T., & Zwaneveld, P. (2016). Reële opties en het waarderen van flexibiliteit bij infrastructuurprojecten. *Centraal Planbureau*.
- Bos, F., & Zwaneveld, P. (2014). Reële opties en de waarde van flexibiliteit bij investeringen in natte infrastructuur. *Centraal Planbureau*, 100.
- Bots, P. (2014). Plus: Gebeurtenis-beslisboom. TU Delft. <https://mod-est.tbm.tudelft.nl/wiki/index.php/Plus:Gebeurtenis-beslisboom>
- Brent Ritchie, J. R. (1984). Assessing the impact of hallmark events: Conceptual and research issues. *Journal of travel research*, 23(1), 2–11.
- Burgan, B., & Mules, T. (1992). Economic impact of sporting events. *Annals of tourism research*, 19(4), 700–710.
- Burke, M. I. (2011). Are cycle centers effective transport interventions? Evaluating king george square cycle center in Brisbane, Australia. *Transportation research record*, 2247(1), 118–125.
- Byrne, D., & Ragin, C. C. (2009). *The Sage handbook of case-based methods*. Sage Publications.
- Cashman, R., & Darcy, S. (2008). *Benchmark games*. Benchmark Games.
- CE Delft. (2014). Externe en infrastructuur-kosten van verkeer - Een overzicht voor Nederland in 2010, 332.
- Ceballos, G., & Curtis, O. (2004). Queue analysis at toll and parking exit plazas: a comparison between multi-server queuing models and traffic simulation, In *Ite annual meeting and exhibit*.
- Centraal Bureau voor de Statistiek. (2018). No Title. <https://opendata.cbs.nl/statline/%7B%5C#%7D/CBS/nl/dataset/83495ned/table?fromstatweb>
- Centraal Planbureau. (2017). Hoe omgaan met flexibiliteit in infrastructuurbeleid en MKBA's. <https://doi.org/10.1017/CBO9781107415324.004>
- Chalip, L. (2006). Towards social leverage of sport events. *Journal of sport & tourism*, 11(2), 109–127.
- Chin, H.-C. (1996). Reexamination of the analysis of freeway bottlenecks. *ITE Journal (Institute of Transportation Engineers)*, 66(1).
- Coffeng, G. (2016). Verkeerskundige analyse Leidse Ring Noord. *Gemeente Leiden*.
- Council, N. R. (1994). TRB, Manual, Highway Capacity, Washington, DC, 1994. *Google Scholar*.
- CROW. (2015). Kostenkengetallen regionaal openbaar vervoer 2015.
- CROW. (2019). Ontwerpwijzer Fietsverkeer. *CROW Online Kennisbank*.
- Daamen, W., Knoop, V. L., & Hoogendoorn, S. P. (2015). Generalized macroscopic fundamental diagram for pedestrian flows, In *Traffic and granular flow'13*. Springer.
- Dhondt, J.-L., Farriaux, J.-P., Saily, J.-C., & Lebrun, T. (1991). Economic evaluation of cost-benefit ratio of neonatal screening procedure for phenylketonuria and hypothyroidism. *Journal of inherited metabolic disease*, 14(4), 633–639.
- Dunn, K. M., & McGuirk, P. M. (1999). Hallmark events.

- Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, 5(1), 1–4.
- Faulkner, B. (2003). Evaluating the tourism impacts of hallmark events. *Progressing tourism research*, 93e113.
- Fawcett, W., Urquijo, I. R., Krieg, H., Hughes, M., Mikalsen, L., & Gutiérrez, Ó. R. R. (2015). Cost and environmental evaluation of flexible strategies for a highway construction project under traffic growth uncertainty. *Journal of Infrastructure Systems*, 21(3), 5014006.
- Federal Highway Administration. (2017). Simplified Highway Capacity Calculation Method for the Highway Performance Monitoring System. *U.S. Department of Transportation*, (October). <https://www.fhwa.org/media/reports/201233.pdf>
- Flyvbjerg, B., Priemus, H., & Wee, B. (2008). *Decision-Making on Mega-Projects: Cost-Benefit Analysis, Planning and Innovation* (Vol. 40). <https://doi.org/10.4337/9781848440173>
- Fortuijn, L. (2013). *Turborotonde en turboplein : ontwerp, capaciteit en veiligheid* (Doctoral dissertation). TU Delft.
- Gijzen, F. (2016). Added Value Of Different Approaches Of Real Options In Transportation Infrastructure Projects Decision-making. *TU Delft*, 1–10.
- Godefrooij, H., Hulshof, R., & Welten, H. (2016). De capaciteit van fietsinfrastructuur bij verkeerslichten. *Nationaal verkeerskundecongres 2016*.
- Goemans, J. W., Daamen, W., & Heikoop, H. (2011). Handboek Capaciteitswaarden Infrastructuur Autosnelwegen (CIA) Volledig Vernieuwd. *Nationaal verkeerskunde congres*, (november).
- Goldsmith, C. (2018). The true cost of large infrastructure projects. <https://www.worldfinance.com/infrastructure-investment/the-true-cost-of-mammoth-infrastructure-projects>
- GWWkompas. (2011). *Kengetallenkompas* (tech. rep.). <http://www.bouwkostenkompas.nl/dwnl/voorbeeldkkg2011.pdf>
- Hall, C. M. (1989). The definition and analysis of hallmark tourist events. *GeoJournal*, 19(3), 263–268. <https://doi.org/10.1007/BF00454570>
- Harrison, M. (2010). *Valuing the Future: The social discount rate in cost-benefit analysis*.
- Heinen, E., & Buehler, R. (2019). Bicycle parking: a systematic review of scientific literature on parking behaviour, parking preferences, and their influence on cycling and travel behaviour. *Transport Reviews*, 1–27.
- Itami, R. M. (2002). Estimating Capacities for Pedestrian Walkways and Viewing Platforms. *A report to Parks Victoria 20*, (June).
- ITF (International Transport Forum). (2019). What is the Value of Saving Travel Time? *ITF Roundtable Reports*, No. 176.
- Kennisplatform_CROW. (2018). Handboek Wegontwerp. *CROW online Kennisbank*.
- Knoop, V. (2018). *Introduction to Traffic Flow Theory: Theory and exercises*. TU Delft.
- Laing, J., & Frost, W. (2010). How green was my festival: Exploring challenges and opportunities associated with staging green events. *International Journal of Hospitality Management*, 29(2), 261–267.
- Los, P. (2006). Current HCM Methodology. *Pedestrian Level of Service Study, Phase I*, (April), 9–22. https://www1.nyc.gov/assets/planning/download/pdf/plans/transportation/td%7B_%7Dpedloschaptertwo.pdf
- Mackie, P. J., Jara-Díaz, S., & Fowkes, A. S. (2001). The value of travel time savings in evaluation. *Transportation Research Part E: Logistics and Transportation Review*, 37(2-3), 91–106.
- Mackie, P., Batley, R., & Worsley, T. (2018). Valuing transport investments based on travel time savings—a response to David Metz. *Case Studies on Transport Policy*, 6(4), 638–641.
- Madden, J. R. (2006). Economic and Fiscal Impacts of Mega Sporting Events: A General Equilibrium Assessment. *Public Finance & Management*, 6(3).
- Maršanić, R., Zenzerović, Z., & Mrnjavac, E. (2011). Application of the queuing theory in the planning of optimal number of servers (ramps) in closed parking systems. *Economic research-Ekonomska istraživanja*, 24(2), 26–43.
- Martens, K., & Di Ciommo, F. (2017). Travel time savings, accessibility gains and equity effects in cost-benefit analysis. *Transport reviews*, 37(2), 152–169.
- Martins, J., Marques, R. C., & Cruz, C. O. (2013). Real options in infrastructure: Revisiting the literature. *Journal of Infrastructure Systems*, 21(1), 4014026.
- Matheson, V. (2004). Economic multipliers and mega-event analysis.

- Morales, J. M. (1987). Analytical procedures for estimating freeway traffic congestion. *ITE J*, 57(1), 45–49.
- Mouter, N. (2012). Voordelen en nadelen van de MAatschappelijke Kosten-en Baten analyse nader uitgewerkt. *Colloquium Vervoersplanologisch Speurwerk 2012*, 1–18.
- Mun, J. (2002). *Real options analysis: Tools and techniques for valuing strategic investments and decisions* (Vol. 137). John Wiley & Sons.
- Nam, D. H., & Drew, D. R. (1998). Analyzing freeway traffic under congestion: Traffic dynamics approach. *Journal of Transportation Engineering*, 124(3), 208–212.
- NHnieuws. (2019). Al vroeg druk op de weg naar Zandvoort en Castricum. <https://www.nhnieuws.nl/nieuws/246880/al-vroeg-druk-op-de-weg-naar-zandvoort>
- Organisation of DGP. (2019). *Mobiliteitsplan Dutch Grand Prix 2020 at Zandvoort* (tech. rep.).
- Pereira, A. M., Andraz, J. M. Et al. (2013). On the economic effects of public infrastructure investment: A survey of the international evidence. *Journal of Economic Development*, 38(4), 1–37.
- Prorail. (2012). Kostentoerekening. https://www.prorail.nl/sites/default/files/3879648%7B_%7Dkostentoerekeningstelsel%7B_%7D2016%7B_%7Ddd%7B_%7D08mrt2016.pdf
- Quinn, B. (2009). Festivals, events and tourism.
- Renes, G. Romijn, G. (2013). *Algemene leidraad voor maatschappelijke kosten-batenanalyse*.
- Roche, M. (1994). Mega-events and urban policy. *Annals of Tourism Research*, 21(1), 1–19. [https://doi.org/10.1016/0160-7383\(94\)90002-7](https://doi.org/10.1016/0160-7383(94)90002-7)
- Rouphail, N. M., & Allen, D. P. (1998). Recommended Procedures Chapter 13, "Pedestrians," of the Highway Capacity Manual. *Highway capacity Manual*, (February), 1–56.
- Saltelli, A., & Annoni, P. (2010). How to avoid a perfunctory sensitivity analysis. *Environmental Modelling & Software*, 25(12), 1508–1517.
- Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., & Tarantola, S. (2008). *Global sensitivity analysis: the primer*. John Wiley & Sons.
- Saltelli, A., Tarantola, S., Campolongo, F., & Ratto, M. (2004). *Sensitivity analysis in practice: a guide to assessing scientific models* (Vol. 1). Wiley Online Library.
- Scandizzo, P. L., & Pierleoni, M. R. (2018). Assessing the olympic games: The economic impact and beyond. *Journal of Economic Surveys*, 32(3), 649–682.
- Sun, Y.-Y., Rodriguez, A., Wu, J.-H., & Chuang, S.-T. (2013). Why hotel rooms were not full during a hallmark sporting event: The 2009 World Games experience. *Tourism Management*, 36, 469–479.
- SWOV. (2011). Factsheet Verkeersonveiligheid van openbaar vervoer, 1–6.
- SWOV. (2017). Factsheet-Verkeersdoden in Nederland. *Swov*, 1–6.
- Treiber, M., & Kesting, A. (2013). *Traffic Flow Dynamics*. <https://doi.org/10.1007/978-3-642-32460-4>
- Triantis, A. J. (2003). *Real Options, Handbook of Modern Finance* (Doctoral dissertation). ed. D. Logue and J. Seward, Research Institute of America, New York.
- van Oort N, v. d. B. R. V. F. (2017). The wider benefits of high quality public transport for cities. *European Transport Conference in Barcelona*.
- van Aarle, R. (2013). *A Real-Options approach to company valuation* (Doctoral dissertation). University of Twente.
- van Essen, H., Davidson, M., & Brouwer, F. (2008). Berekening van externe kosten van emissies voor verschillende voertuigen | Op basis van nieuwe emissiecijfers en met analyse van toekomstige waarden. *CE Delft door Plan van de Leefomgeving*, (november), 87.
- van Spijk, J. (2016). *Brief weth. JuS 10 nov inz ondergronds parkeren Poort van Boerhaave*. Gemeente Haarlem.
- WATTERS, B. (1992). Values of travel time savings used in road project evaluation: a cross-country/jurisdiction comparison, In *Papers of the australasian transport research forum october 1992, canberra, volume 17, part 1*.
- Wikipedia. (2020). List of Formula One circuits. Wikimedia Foundation. https://en.wikipedia.org/wiki/List%7B_%7Dof%7B_%7DFormula%7B_%7DOne%7B_%7Dcircuits
- Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation practice*, 15(3), 283–290.
- Zegeer, J. D., Blogg, M., Nguyen, K., & Vandehey, M. (2008). Default values for highway capacity and level-of-service analyses. *Transportation Research Record*, 2071(1), 35–43.
- Zhao, T., & Tseng, C.-L. (2003). Valuing flexibility in infrastructure expansion. *Journal of infrastructure systems*, 9(3), 89–97.

Zhou, D., Xu, C., Wang, D.-H., & Sheng, J. (2015). Estimating Capacity of Bicycle Path on Urban Roads in Hangzhou, China. *94th Annual Meeting of the Transportation Research Board*, 856, 18–p. https://nacto.org/wp-content/uploads/2016/04/5%7B_%7DZhou-Xu-Wang-and-Sheng-Estimating-Capacity-of-Bicycle-Path-on-Urban-Roads-in-Hangzhou-China%7B_%7D2014.pdf%7B%5C%%7D0Ahttp://docs.trb.org/prp/15-1693.pdf

Appendices

Appendix A

Scientific Paper of the Thesis

Developing a valuation method for (infrastructural) investments at Hallmark Events

Richard Cornelis Smits

Technical University Delft, Februari 2020

Abstract

One-time occurring or limited occurring events with a regional or international function, such as Olympic Games or music festivals are called Hallmark Events. Transport infrastructure is often needed to facilitate the visitors. Other than the Olympic games, that have a specified duration, there are events with an unknown amount of repetitions or duration. For the Hallmark Events with an unknown number of repetitions the investment comes with high risks. The CBA is nowadays used for the valuation of investment projects, but future uncertainties are difficult to capture within the method. ROA features have been implemented in the traditional CBA to develop a new method for valuating transport investments at Hallmark Events. This new method has been used for a case study for the Dutch Grand Prix at Zandvoort in the Netherlands. With the outcomes for the case study conclusions could be drawn for the practical outcomes for Zandvoort, but also for the new methodology itself. Compared with the traditional CBA the method is able to identify a best investment moment. With the knowledge that the new methodology is able to identify a best investment moment, by checking multiple investment moments, it can be said that this methodology could give a broader insight in the possible options for investing.

Keywords: Cost-benefit Analysis, Real options approach, valuation method, Hallmark event, queuing theory

1. Introduction

The term Hallmark event is one that was already used in the 1980s. An event like this is often carried out in the form of a large exhibition, cultural or sports event (Hall, 1989). The main function of a Hallmark Event is to create a place where a high-quality way of tourism can be achieved. One of the downside of the event is that both nationally and internationally high costs can be incurred socially and for nature. The standard definition of a Hallmark Event can best be given by Brent Ritchie (1984):

"Major one-time or recurring events of limited duration, developed primarily to enhance the awareness, appeal and profitability of a tourism destination in the short and/or long term. Such events rely for their success on uniqueness, status, or timely significance to create interest and attract attention".

A few years later Burgan and Mules (1992) did a research to the characteristics of a "Special Event" and identified some main characteristics for an event to be called a "Special Event".

1. The first characteristic of the event is that there is not one single attractor, but the event can also provide other services such as accommodation, food, transport and entertainment.
2. The demand for the event is condensed into a very short period of time. This can vary from a single day to a few weeks, but not much longer than that. The main problem is that it is not possible to spread out the demand based on the activities that come with the event.
3. The demand leads to a peak in travel movements and this influences the benefits of the event.
4. The benefits or net impacts for local funds are relatively small, not that they don't profit from the situation, but most of the profit is made by national operating funds from outside of the region.

Hallmark Events are attractors of tourists on a local, regional, national or even international level. This might lead to big changes in the demand for road, train or public transport capacities, but depending of the period of time in which the demand and the amount of repetitions the need for infrastructural change different. The Hallmark Event is serving a group of tourists on a national/regional level with a limited amount of repetitions. The traffic problems or logistic problems that this might cause can therefore influence the decision making process of building new infrastructure or other solution that prevent these problems.

Eventhough the Hallmark Event is a concepts already mentioned in literature from the 80's there seems no specif valuation method for this type of projects. A commonly used method for valuing projects is the cost benefit analysis (CBA). In the Netherlands this CBA is even mandatory for projects of a significant size (Annema et al., 2017). The Centraal Planbureau (2017) made a general approach for

executing a social cost benefit analysis (SCBA) in the Netherlands that can be used for the mandatory CBA at large projects. This road map to execute a full CBA can be used by decision makers to value different problems. However the Centraal Planbureau (2017) also identifies some problems that occur with the CBA. The traditional CBA has some difficulties to cope with uncertainties:

- knowledge uncertainty
- policy uncertainty
- future uncertainty

Future uncertainty is especially important for long-term effects which is a major uncertainty within the Hallmark Events. Therefore the traditional CBA is not the appropriate valuation method for dealing with uncertainties at Hallmark Events. In the Netherlands the CBA is a mandatory valuation method for large scale projects to measure the effects of different solutions, but the outcomes of the CBA are often ignored by decision-makers (Annema et al., 2017; Mouter, 2012). Another downside of the methodology is the way the CBA deals with future uncertainty which cannot be captured in a systematic way.

It is possible to build durable infrastructure that can still accommodate uncertain future modifications. Infrastructure strategies based on this observation can be called flexible or responsive strategies. Numerous historic examples show that strategies of this kind have been used for a long time (Fawcett et al., 2015). The main theoretical approach in the mentioned studies are based on the ROA (Real Option Approach). This method comes from the economic field of research that was mainly focused on the uncertainty in the stock trading business. An actual project that used the full real options approach to value the possible solutions at a project have not been found (Bos & Zwaneveld, 2014). Within big companies the method has been used, but for governmental investments this is not the case.

All the shortcomings of the currently used CBA, regarding the uncertainties at Hallmark Events, makes is questionable if this is the right valuation method. The ROA is a potential method that could be used for value infrastructural investments needed at Hallmark Event. Although the ROA has not been executed fully for this type of investment. This raises the following question: To what extent results applying ROA for valuing infrastructure projects at Hallmark Events into useful decision-making information?

2. Methods

The type of research performed can be seen as an exploratory research. Exploratory research is a qualitative research to clarify the nature of a problem (Yin, 1994). Such researches can be executed in different ways and one is the use of a case study, which will be used in the second sub question. However, firstly this research looks into existing researches and knowledge in the field of dealing with uncertainties in the valuation methods. At the end a reflection will be given on the results and the usage of the new developed method to answer the main question.

A literature study will give extra insight on the usability of the ROA. All the findings on the valuation methods and their way of dealing with uncertainty will be taken into account to develop a potential valuation method for the infrastructural investments at Hallmark Events. The potential new method will be discussed with dr. Gerbert Romijn who is an expert in CBA. He also developed a method for adding flexibility in the traditional CBA for water constructions in the Netherlands. His expertise on developing a method with feature of ROA will be used to give more insight in the way the method should be developed.

Zandvoort is currently making plans for the Gran Prix that will be held in May 2020. The current infrastructure is not able to handle the amount of visitors for this Hallmark Event (Organisation of DGP, 2019). It is likely that the municipality has a budget and with this budget limited possibilities are available to develop infrastructure to deal with the capacity problems at Zandvoort. Because of the uncertainty of repetitions for the DGP at Zandvoort and the limited budget it is a good example for an event that can benefit from a method that deals with these factors. For different modalities multiple potential infrastructural solutions are developed within the new methodology. The different options for implementing flexibility were used to calculate the added value of the investments proposed. Flexibility was implemented with the different investment options to see what the difference is with the traditional CBA.

After the case study a reflection will be given on the methodology and generic outcomes are presented to draw generic solutions for the main question. A sensitivity analysis will be performed by using the visualisation method scatter plot to interpret the changes to the outcomes by changing variables. Eventually the results will be discussed with experts in the field of valuating infrastructural investments. Prof. dr. Bert van Wee and Dr. mr. Niek Mouter were interviewed on the topic and results were presented to these experts.

3. Results

Developing a valuation method

Even though the Real Options Approach (ROA) has not been used fully within infrastructural projects it is a methodology that takes care of uncertainties by developing flexible options for possible scenario outcomes. Options are investment approaches to reduce risk by adding flexibility to an investment (Mun, 2002). Examples are deferring an investment, possibility to abandon a project, a step wise investment and more options can be found (Gijzen, 2016; Triantis, 2003). The ROA is not applicable for every project and not every option is applicable for every investment. This can make it hard to figure out the added value of a ROA within the CBA. In 2004 Adner and Levinthal (2004) made a general approach for deciding if a project is suitable for applying the ROA. In figure 1 the two indicators are given on the axes, which are Uncertainty and Irreversibility. For the infrastructural solutions that we are looking for in this project the value for irreversibility becomes high, for the fact that infrastructure is often realized for a longer period of time. And the uncertainty is high for the number of repetitions of the Hallmark Event itself.

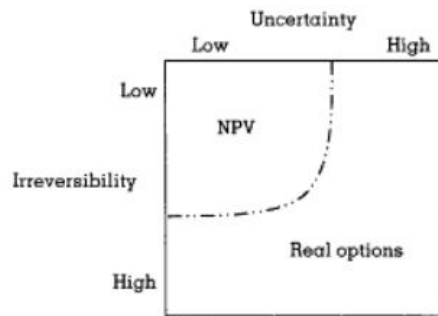


Figure 1: Boundaries of Applicability for Net Present Value or Real Options, (Adner & Levinthal, 2004)

The real options approach (ROA) has some advantages in terms of handling uncertainties that can be implemented within the current CBA (Gijzen, 2016; Triantis, 2003; van Aarle, 2013). In the field of ROA in combination with infrastructural investments there is not much common ground build from. But the CPB (Centraal Planbureau, 2017) did develop a method to implement flexibility to the traditional valuation method, the CBA. They pointed out that the full ROA is not preferred, since this is a complex mathematical approach, not suitable for quick valuation calculation. For the Hallmark Event specific investments no valuation methodology has been designed, although the amount of uncertainty is very high. Therefore the method designed by Centraal Planbureau (2017) is used as a starting point for developing a valuation method with flexibility for Hallmark Events. In figure 2 the new methodology is shown with the steps that need to be taken to apply flexibility in the valuation method for (infrastructural) investments at Hallmark Events. The method is strongly based on the methodology made by Centraal Planbureau (2017), but the parts are specially furnished for dealing with capacity problems at Hallmark Events. The main differences in the methods are:

- Problem definition is specified for 'Delay hours and Latecomers' as indicator for the problem based on the queuing theory by Knoop (2018).
- Only flexibility options applicable at Hallmark Events are included for implementing flexibility, not all the options shown by Gijzen (2016) are used. The flexibility could be captured in two main forms of flexibility: 'Natural Flexibility' and 'Waiting for Certainty'.

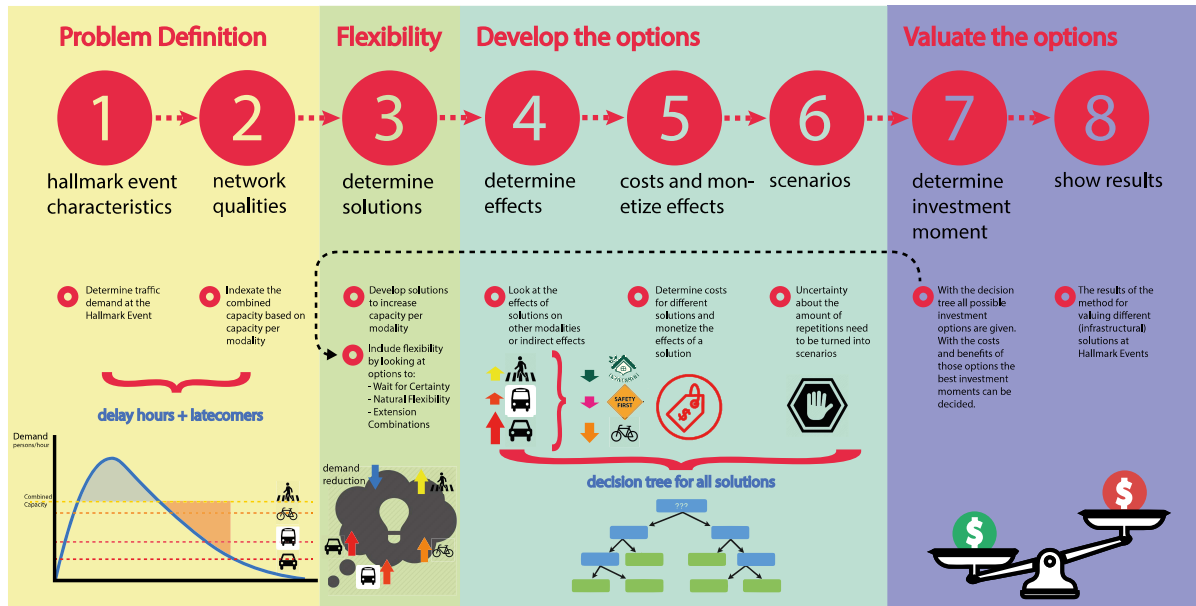


Figure 2: Methodology to deal with uncertainty of repetitions at Hallmark Events

- A feedback loop is introduced, after the determination of the best investment moment of an individual solution, to optimize the combination of different solutions.

In the figure a visualisation is given of the approach because the usability for a decision maker is a main difficulty for the currently used validation methods (Annema et al., 2017; Mouter, 2012; Mouter et al., 2015). All the steps are used within the case study and the most important findings from the usage of the method and the practical outcomes will be explained.

Case Study

After 35 years there are plans to bring back the Grand Prix in Zandvoort under the name Dutch Grand Prix (DGP), but the current infrastructure is not designed for the amount of visitors that it would attract these days. They estimate this amount on 100,000 visitors per day with a peak of 140,000 visitors on the day of the actual race. Also there is no information on the amount of repetitions that the event could have in the future. The amount of visitors and uncertainty on the repetitiveness makes this event a Hallmark Event to test the new methodology on.

For the execution of the methodology a spreadsheet is build to perform a cost benefit analysis that includes the different forms of flexibility that were introduced with the methodology. The problems at Zandvoort were already known at forehand, but the method is used to quantify the problem definition according to the method. The total delay hours were estimated on 230 thousand with also 50 thousand visitors that cannot even make it on time. In step 3 thirteen solutions were developed that might solve the problem at Zandvoort. Temporary solutions were supplemented with 'Natural Flexibility' and infrastructural investment with the 'Waiting for Certainty' option. The effects and monetization of those effects were covered in step 4 and 5, but are not different from the traditional valuation methods.

In step 6 of the method the scenario development is introduced which is also the basis for the decision tree. The ROA method for developing scenarios is used, which is based not only on the future outcomes, but also the steps that can be taken to get to a future outcome (Centraal_Planbureau, 2017; Gijzen, 2016; Triantis, 2003). For the Hallmark Events the outcomes are based on potential amounts of repetitions, see table 1. The outcome of a scenario does not exclude the outcome of more repetitions and therefore scenario combination can be made with a scenario tree (figure 3). The p value is the probability for more repetitions and this is different from the traditional way of scenario development were the scenarios do not influence each other.

Table 1: Scenarios used for the Zandvoort Case Study

Scenario Description	Reasoning	Scenario Combination with Probability p.				
		- 1	p=20% 2	p=40% 3	p=60% 4	p=80% 5
1 repetition	This could be the case when the Grand Prix Organisation is not pleased by the quality of the track or surroundings of the event.	25%	80%	60%	40%	20%
4 repetitions	Looking at the tracks used the last year this was the minimum amount of repetitions that the track with the lowest amount of repetitions has (Wikipedia, 2020).	25%	16%	24%	24%	16%
14 repetitions	This is the average amount of repetitions if one would look at the all the races in the last 50 years and the tracks that were used (Wikipedia, 2020).	25%	3.2%	9.6%	14.4%	12.8%
29 repetitions	This is the average amount of repetitions if one would look at the average amount of repetitions of the tracks used the last season (Wikipedia, 2020).	25%	0.8%	6.4%	21.6%	51.2%

Setting a p therefore gives a scenario combination with a chance for all possible scenarios, other than the traditional CBA with a probability for just every outcome. The visualisation of the scenario combinations can be found in figure 3. At year 0 it is possible that the event has 1 or more repetitions (with chance p), after the first year the outcome will be known. Two possible outcomes appear: 1 repetition (chance $1-p$) or 4 or more repetitions (chance p). This continues until all possible amount or repetitions are known at year 14. Every outcome is a scenario which has a probability to occur, according to the probabilities given in table 1.

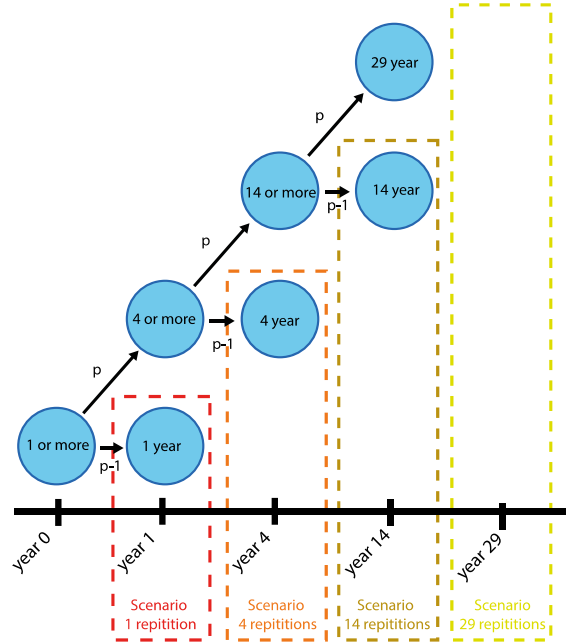


Figure 3: Scenario Tree for DGP Zandvoort

With the different solutions for Zandvoort it is now possible to develop the full decision tree. In figure 4 a full decision tree with all possible aspects is represented. This decision tree shown is for the option 'Waiting for Certainty'. The decision maker has a choice to make at every decision moment, but depending on the outcome of the future some choices become irrelevant. For example if an infrastructural investment has been made some decision moments will appear over time, but there is no choice anymore,

since an infrastructural investment is irreversible. Another example is the choice to stop, which is not really a choice since there are no revenues to be gained anymore. Every time a decision maker does decide to wait the flexibility is maintained, which means that the decision maker has still two options at the next decision moment.

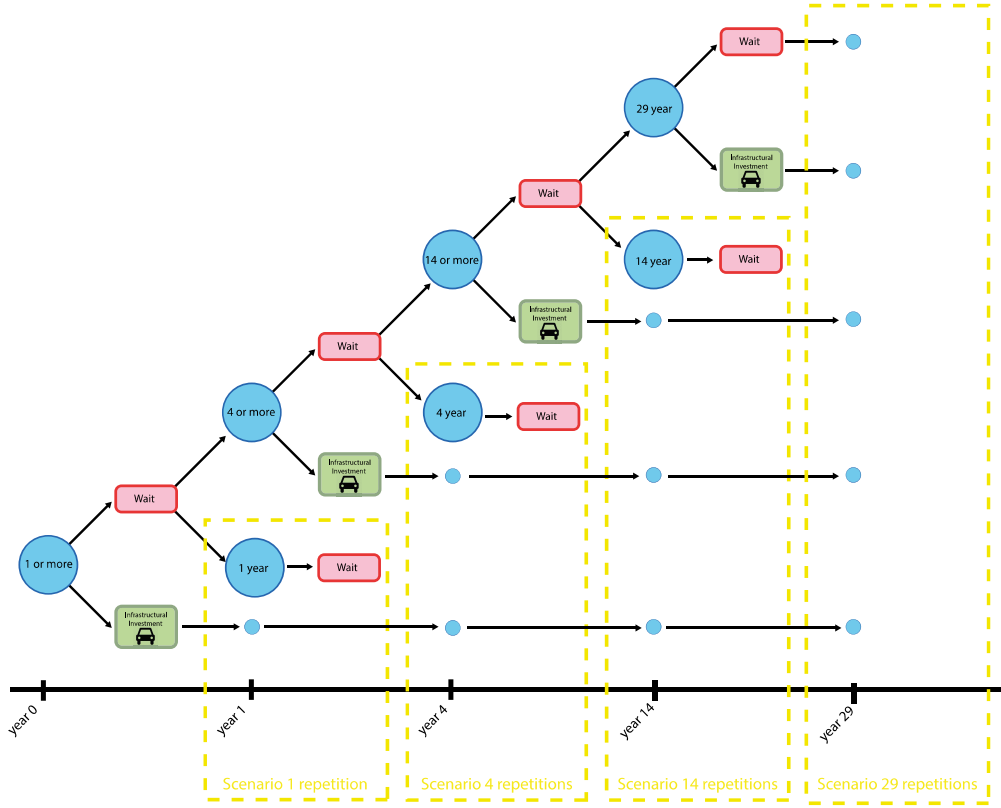


Figure 4: Decision tree example

The option to wait for certainty can have financial benefits, because money might be saved if an expensive investment is prevented and the event turns out to have very limited repetitions. This potential saving is called the value of flexibility. Centraal_Planbureau (2017) made a methodology for including ROA-features into a regular CBA. A more theoretical approach has been made by van Aarle (2013) who did a research in which he mentioned all the possible ways to use ROA as an add-on component for other valuing methods like CBA. Multiple options were discussed in his report and how the value of flexibility can be calculated for the different options. The most convenient method for Hallmark Events is the Expanded NPV method. This Expanded NPV can include time to build and growth which are options of the ROA (Gijssen, 2016; Triantis, 2003). The formula for this Expanded NPV is shown below:

$$\text{Expanded NPV} = \text{Passive NPV} + \text{Option premium} + \text{Strategic Value}$$

The passive NPV is the NPV without flexibility included. This is the value that the earlier discussed NPV would be in a specific year. The Option Premium can be seen as the true value for flexibility in the calculation for the Expanded NPV. The Option Premium can have many forms, but in case of the Hallmark Events it can be the value for deferring an investment to the next decision moment, to be explained later on. The Strategic Value can be seen as a competitive aspect in terms of investments for companies. If company A invests earlier than company B it might have positive effects for having a head start with respect to company B (van Aarle, 2013). The strategic value is left out of the calculations and this is because of the lack of information on this value. In case of Hallmark Events this value can be seen as very low, by looking at events like the World Championship of Football or Olympic Games. This is

because there is a chance of getting an event because a country already has a perfect infrastructure for hosting an event. However there are multiple examples of countries that got the concession for hosting an event, like the Olympic Games, that did not have a proper infrastructure at all (Hall, 1989).

Outcomes of the case study

For every solution the different investment moments are given in graphs that were developed. On the y-axis the B/C-ratio is given and on the x-axis the Expanded NPV. These two values are commonly used in the representation of valuations in the traditional CBA. The Expanded NPV is expected value of the investment. The B/C-ratio is giving the overall value for money, which is simplified the amount of euro's an investor gets in return for investing one euro (Dhondt et al., 1991). For the B/C-ratio the common rule is; If the value is higher than 1 the solution is profitable and therefore the investment should be made. For the NPV the investment is profitable if the value is positive. The values for Expanded NPV and B/C-ratio are given in Appendix G. Both the NPV and B/C-ratio are taken into account, since big investment have a higher chance of getting a high NPV in return, but small investments not. On the other side the smaller investment have a higher chance of getting a high B/C-ratio. By taking both the B/C-ratio and the Expanded NPV as measurement the big investments and temporary investment both have a chance of high scores.

An investment in public transport is the best choice for a decision maker. The amount of latecomers and delay hours can be reduced the most by an investment in the train network. The scores for Diesel trains, Electric Trains, Station Lengthening and Busses from Station Haarlem all have high scores on Expanded NPV and B/C-ratio. The costs for busses is not empirically found, therefore this might solution might be less accurate than the other three solutions mentioned. There are two exceptions which are not financially beneficial the bicycle parking solution and the car infrastructure solution for adjusting the northern roundabout at the N200. This last one can be profitable, but the best investment moment is not in the first year and therefore not the most financially beneficial investment for the first decision moment. In figure 5 the different outcomes for the car infrastructure investment are shown. Four different scenario combination are shown with different probability values for p. It can be seen that dependent on the scenario the investment moments are scoring different for Expanded NPV. Also it is visible that the second or third investment moment can be more beneficial than the first one.

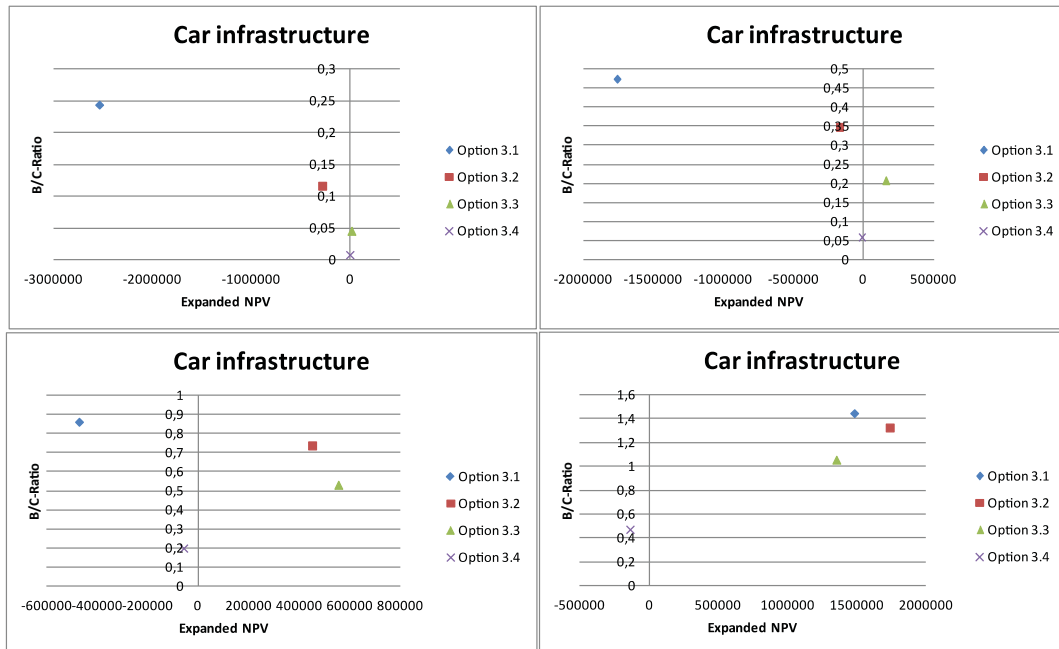
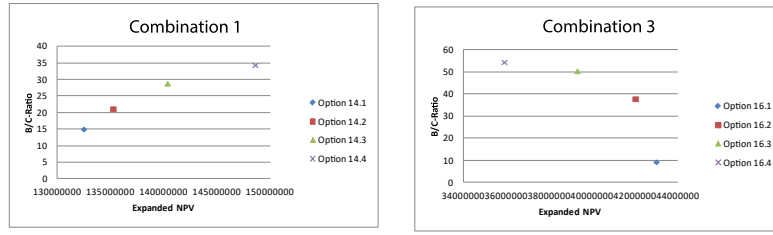


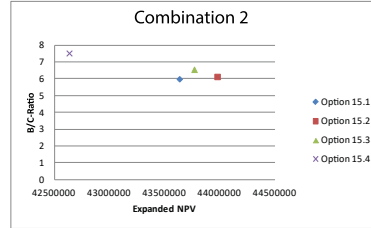
Figure 5: Best Investment moments for Car Infrastructure solution (up-left p=20%, up-right p=40%, down-left p=60%, down-right p=80%)

For solving the demand problem at Zandvoort there is a need for multiple solutions, because the individual solutions could not solve the problem because delay is encountered on multiple networks. Combinations have been developed and were tested with the same methodology again. For the first four combinations a check was done if an infrastructural investment was still preferable when a combination of solutions was used. The infrastructural investments were altered over the investment moment to check if there was a moment when it would become more financially beneficial to make the infrastructural investment instead of performing the temporary solution. This comparison between a temporary and an infrastructural investment is one of the features from the ROA that was implemented in the CBA with the usage of the spreadsheet. The investment for Station Lengthening turned out to be a good investment, which doubles the amount of persons that can be transported to Zandvoort. This investment has less costs than the upgrade of the overhead line and therefore the risks for this solutions are lower. The overhead upgrade turned out to be less financially beneficial than the usage of the temporary solution Diesel Trains. The investment for car parkings is not more beneficial than using P+R in the region with busses to take visitors to the DGP. However once the parkings are already there the reconstruction of the northern roundabout can become financially beneficial. There should be mentioned that investing in this solution should not be done in the first year and that it is better to 'Wait for Certainty' and do the investment the next decision moment. For the 5th and 6th combination only solutions with 'Natural Flexibility' were used and no altering infrastructural investment was needed. The combination for only bicycles was the least scoring combination of the eight combination that were developed. And therefore it can be said that investments for the bicycle network is way less beneficial. The combination 6 was a combination of the best scoring temporary solutions from the individual solutions. On B/C-ratio this combination is one the best scoring sets of solutions for all scenario's. On Expanded NPV the combination performs good, but it can be seen that other combinations like the original DGP plan and the Adjusted DGP plan score higher in some of the scenario combinations. The last two combinations were the original DGP plan (DGP) and the adjusted DPG plan (combination 7). For the DGP temporary solutions can be used that are more beneficial than the investments they have planned right now. Therefore the methodology is able to compare temporary and infrastructural investment to improve a developed investment plan.

The practical outcomes are described, but the visual outcomes of the methodology are more important and input for the usage of the methodology itself. Three different patterns can be distinguished with the usage of this methodology. In figure 6 the three different outcome patterns are presented. The first pattern that can be distinguished is the pattern where the best investment moment is the last investment moment. This pattern is shown in figure 6.a. It is clear to see that the best investment is at the last decision moment. This actually does not mean that the investment in year 14 is the best one, but that the additional investment that is tested in the combination should not be made at all. If there would be a fifth decision moment than that would be the better investment and therefore the investment should not be made at all. The second pattern shows an opposite pattern where the investment is scoring better on Expanded NPV for every earlier investment moment. In the case of this outcome pattern an investment should be made as soon as possible. The third pattern to show is one without consistency in the increase or decrease of the NPV or B/C-ratio per decision moment. In the first pattern it became clear that deferring the investment became more beneficial every decision moment and in the second pattern the first investment moment is the best one. In this third pattern the combination of the scenarios and the different values for the Option Premium result in a visualisation where there is no consistent pattern. There is only one interesting conclusion to draw which is: do not invest in this solution right now. The investment might be a financially beneficial solution, but deferring this investment till the next decision moment might be even more beneficial.



(a) Shape: Don't make the additional (b) The additional solution solves
infrastructural investment problems for a higher price



(c) Shape: Do another check next de-
cision moment

Figure 6: Three outcome patterns

This last outcome is the major contribution to the traditional CBA, without flexibility. Because this outcome cannot be generated by a traditional CBA. The first two patterns are interesting, but a CBA would come to the same conclusion of investing or not. This third pattern can tell the decision maker: 'This investment might be beneficial, but waiting for certainty is a better option in this case'.

The sensitivity analysis has been performed to see if individual variables could be changed to influence the outcomes. Most interesting outcome is that by changing variables the possibility to have all three different outcome patterns is still available. However the scenario probability p does have influence on those outcomes patterns and it was represented that with a low value for p not all the outcomes patterns could be distinguished. This was already visible in the case study, but with a p dependent on the years and not on the decision moments this effect becomes even more visible.

The experts were interviewed on their view on the developed methodology. The three outcome forms with the information on doing an investment or not and the best investment moment is real contribution to the traditional valuation methods according to the experts. The experts mentioned that the value of flexibility is now purely based on knowledge on more repetitions, but also other effect that will be known after the first year will provide more certainty on the outcomes. Also the negative effects of flexibility should be included, like the uncertainty about the future infrastructure for inhabitants. A last important notation is the difficulty to understand the outcomes. This is a crucial point of attention in the method.

4. Discussion

The purpose of this research was to see what difference information could be given to decision makers at Hallmark Events by using the ROA. A new methodology for implementing ROA into a valuation method has been developed and tested on a case study. The case study generated outcomes for the event itself, but also on the methodology. Some limitations of the method and of the approach will be discussed in this section.

One of the main problems with the CBA already is the usability of the results by decision makers (Annema et al., 2017; Mouter, 2012; Renes, G. Romijn, 2013). With the implementation of the ROA the results become even more difficult to understand and even the interviewed experts had some difficulties with understanding the outcome tables. The generated graphs might be to complex for a decision maker. The municipality of Zandvoort did not wanted to participate in the development of the method and therefore the information needed might be different from what is presented in the report. If this could

have been possible the outcome graphs might have looked very different from what they do now. Because the ideal way of presenting the results is not known an additional research for the result representation is advised.

The reason for developing a new method was because of the lack of the traditional valuation method to deal with uncertainty that comes with a Hallmark Event. The ROA seemed an appropriate method to base the new methodology on because of its possibility to point out all future outcomes with multiple moments where a decision could be made. Two main differences with the traditional valuation methods are:

- Ability to identify investment moments other than the first year.
- Adding a decision tree with decision moments, future outcomes and scenario probabilities all in one.

Mouter pointed out that he does not see the added value of the way scenarios are developed within this ROA feature. The way scenarios are developed nowadays is also based on educated guesses and probabilities. However a clear distinction should be made with how scenarios are developed within the traditional CBA and in this new methodology. The traditional way is to make scenarios and give them a probability for occurring. This gives for three scenarios three different probabilities adding up to a 100%. The reasoning behind this development can be very unclear for a decision maker, whereas the new methodology can have a probability for more repetitions at every decision moment. This means that there are more probabilities, but the reasoning behind this can be explained way more clear. One could argue that the probability for more repetitions becomes more or less every decision moment based on information that is gathered. This is also something that van Wee mentions and the experts have no consensus about. The view of Mouter is something that can be justified because there is a lot of uncertainty at the beginning of a Hallmark Event. However the new methodology forces a decision maker to think about the probability for more repetitions. This can be seen as an improvement of the traditional CBA, since it obliges the decision maker to gather more information about the possible future outcomes.

For the practical usage of the method the steps can be discussed to see what the main problems might be for a future project executed with this new method. Step 1 and 2 are easy to perform once all the information is available. In these steps the 'Problem Definition' is made (see figure 2). The queuing theory introduced with theories of Chin (1996), Daamen et al. (2015), Knoop (2018), Morales (1987), Nam and Drew (1998) is a main aspect in the problem definition, but can be performed in a relatively simplistic form. In the third step the solutions were developed and flexibility was added to the solutions. By looking at the Hallmark Event the temporary solutions and the infrastructural solutions were identified. With the development of the solutions a different kind of flexibility was applicable. For the temporary solutions the way to add flexibility became 'Natural Flexibility' and for the infrastructural investments this became 'Waiting for Certainty'. From the original ROA seven different types of options were presented (Gijssen, 2016; van Aarle, 2013). A decision maker can get confused by this amount of options, but in the new method the type of flexibility that should be added to a solution is very clear. The fourth step is about the effects that the solutions had on aspects such as: emission, traffic safety, delay hours, etc. Step five was also included in the spreadsheet to immediately monetize the effects. The level of detail could be increased by adding more aspects into the valuation method, but this is not the main purpose of the research. Overall these two steps will not be the problem, since these steps are also common in the traditional CBA (Renes, G. Romijn, 2013). Step 6 is one of the more difficult steps, which is discussed in the section above for usability. Step 7 and 8 concern the presentation of results, which can be improved once decision makers are included in the development of the method.

To a lesser extend also unidentified effects play a role in the outcomes of the methodology. For the case study some effects could be included that are not included at this moment. Out of the interviews with Mouter and van Wee multiple effects were mentioned to add to the spreadsheet that was built for the calculations. The Expanded NPV was based on the NPV and the additional value for flexibility, but this value is more complex than just a loss or gain for deferring an investment. Local inhabitants can actually experience stress because of the uncertainty for them if an investment will be made or not for their infrastructure. A more inclusive research to all the effects of introducing uncertainty for actors might be possible.

At last, at detail level, it is important to have the proper monetization for the effects. Some effects that were monetized at the case study could not be found in literature and assumptions were made. The first effect that could not be monetized was the value for bicycle parking. The hindrance for local people and how much a parking place is worth for a visitor is a big uncertainty. For the sensitivity analysis it didn't come out as a big influence on the outcome, but it might influence the image of the event. In a country like the Netherlands it is likely that this value is really important for decision makers and therefore a research is recommended. A survey based research with a discrete choice model could be an example for finding the value for this effect.

Overall can be concluded that there are some points of attention, but the main question is answered in a positive way. Outcomes for the case study might not be fully usable by the municipality of Zandvoort, since there is a bit of detail missing in the CBA. On the other hand the results made it clear to give a conclusion for the methodology itself. And the method is able to give extra information to the decision maker that is able to change the decision into a more beneficial investment strategy. The last part to discuss is the usability of outcomes for other Hallmark Event. Because the case study is a specific case more information might be needed on different Hallmark Event to give an overall conclusion for Hallmark Events with an unknown amount of repetitions.

5. Conclusion

With all the findings during the process of the research it can be concluded that it is possible to develop a valuation methodology for dealing with the uncertainties at Hallmark Events. As an answer to the main question of this thesis it can be said that the ROA as an addition to the CBA can result in more detailed information for a decision maker. Compared with the traditional CBA the method is able to identify a third outcome: Invest at another decision moment other than the advise to invest or not. This outcome does not give the advise to invest or not, but at another moment or to check again at a next decision moment with more information about the future. With the knowledge that the new methodology is able to identify a best investment moment, that is not the first moment, by checking multiple investment moments it can be said that this methodology could give a broader insight in the possible options for investing.

6. Acknowledgements

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7. Bibliography

- Adner, R., & Levinthal, D. A. (2004). What is not a real option: Considering boundaries for the application of real options to business strategy. *Academy of management review*, 29(1), 74–85.
- Annema, J. A., Frenken, K., Koopmans, C., & Kroesen, M. (2017). Relating cost-benefit analysis results with transport project decisions in the Netherlands. *Letters in Spatial and Resource Sciences*, 10(1), 109–127. <https://doi.org/10.1007/s12076-016-0175-5>
- Bos, F., & Zwaneveld, P. (2014). Reële opties en de waarde van flexibiliteit bij investeringen in natte infrastructuur. *Centraal Planbureau*, 100.
- Brent Ritchie, J. R. (1984). Assessing the impact of hallmark events: Conceptual and research issues. *Journal of travel research*, 23(1), 2–11.
- Burgan, B., & Mules, T. (1992). Economic impact of sporting events. *Annals of tourism research*, 19(4), 700–710.
- Centraal Planbureau. (2017). Hoe omgaan met flexibiliteit in infrastructuurbeleid en MKBA's. <https://doi.org/10.1017/CBO9781107415324.004>
- Chin, H.-C. (1996). Reexamination of the analysis of freeway bottlenecks. *ITE Journal (Institute of Transportation Engineers)*, 66(1).
- Daamen, W., Knoop, V. L., & Hoogendoorn, S. P. (2015). Generalized macroscopic fundamental diagram for pedestrian flows, In *Traffic and granular flow'13*. Springer.
- Dhondt, J.-L., Farriaux, J.-P., Saily, J.-C., & Lebrun, T. (1991). Economic evaluation of cost-benefit ratio of neonatal screening procedure for phenylketonuria and hypothyroidism. *Journal of inherited metabolic disease*, 14(4), 633–639.

- Fawcett, W., Urquijo, I. R., Krieg, H., Hughes, M., Mikalsen, L., & Gutiérrez, Ó. R. R. (2015). Cost and environmental evaluation of flexible strategies for a highway construction project under traffic growth uncertainty. *Journal of Infrastructure Systems*, 21(3), 5014006.
- Gijssen, F. (2016). Added Value Of Different Approaches Of Real Options In Transportation Infrastructure Projects Decision-making. *TU Delft*, 1–10.
- Hall, C. M. (1989). The definition and analysis of hallmark tourist events. *GeoJournal*, 19(3), 263–268. <https://doi.org/10.1007/BF00454570>
- Knoop, V. (2018). *Introduction to Traffic Flow Theory: Theory and exercises*. TU Delft.
- Morales, J. M. (1987). Analytical procedures for estimating freeway traffic congestion. *ITE J*, 57(1), 45–49.
- Mouter, N. (2012). Voordelen en nadelen van de MAatschappelijke Kosten-en Baten analyse nader uitgewerkt. *Colloquium Vervoersplanologisch Speurwerk 2012*, 1–18.
- Mouter, N., Holleman, M., Calvert, S., & Annema, J. A. (2015). Towards improved handling of uncertainty in cost-benefit analysis: Addressing the ‘price-quality’ and ‘communication’ dilemmas. *European Journal of Transport and Infrastructure Research*, 15(3), 341–361.
- Mun, J. (2002). *Real options analysis: Tools and techniques for valuing strategic investments and decisions* (Vol. 137). John Wiley & Sons.
- Nam, D. H., & Drew, D. R. (1998). Analyzing freeway traffic under congestion: Traffic dynamics approach. *Journal of Transportation Engineering*, 124(3), 208–212.
- Organisation of DGP. (2019). *Mobiliteitsplan Dutch Gran Prix 2020 at Zandvoort* (tech. rep.).
- Renes, G. Romijn, G. (2013). *Algemene leidraad voor maatschappelijke kosten-batenanalyse*.
- Triantis, A. J. (2003). *Real Options, Handbook of Modern Finance* (Doctoral dissertation). ed. D. Logue and J. Seward, Research Institute of America, New York.
- van Aarle, R. (2013). *A Real-Options approach to company valuation* (Doctoral dissertation). University of Twente.
- Wikipedia. (2020). List of formula one circuits. Wikimedia Foundation. https://en.wikipedia.org/wiki/List_of_Formula_One_circuits
- Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation practice*, 15(3), 283–290.

Appendix B

Real Option Approach types

In this appendix the different theories behind the real options approach will be described. Within ROA five main theories are often used. These five theories will be described below and form a basis of knowledge behind the ROA in Chapter 2.

BSOPM

The BSOPM (Black-Scholues Option Pricing Model) is one of the most famous formulas in the economic world. Fischer Black and Myron Scholes led the foundation to what led to the BSOPM. But Bob Merton took it to a new level and developed it into the modern interpretation that is still used today. In 1997 Scholes and Merton were awarded with the Nobel price for their work on the theory. The formula is praised for its simplicity since only six variables are needed to make a calculation on how to value an option. These are: initial value of the underlying asset, time until maturity, exercise price, difference between capitalization rate and the percentage of expected change in the value of the underlying asset, continuous compound risk-free rate of return, and the volatility in the underlying asset (Martins et al., 2013). For infrastructural valuation this theory has some limitations, because it is a theory for the European call and put options. The whole ecomic point of view from which it is arguing is difficult to use with infrastructural valuation on top of that are the limitations that the theory itself has in the economic fields for example that is limited to a fixed decision date for trading options.

BOPM

The BOPM (Binomial Option Pricing Model) is based on the evolution of the asset price. In figure B.1 an example of the BOPM is shown. The asset has an initial value X that is given to the asset at the start (left in the figure). The next moment the value can go down (X_d) or up (X_u). The probability for going up is given by p and the chance of down is given by $1-p$. In the following period the same steps are taken. There is a chance p of going up and a chance $1-p$ of going down which results in the outcomes: X_d^2 , X_{ud} and X_u^2 .

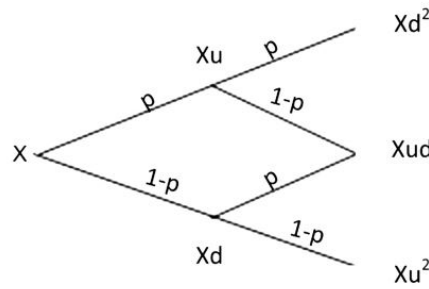


Figure B.1: Visual framework for the Binomial Option Pricing Model (Martins et al., 2013)

This model is popular because it is a very clear way of showing the added value over time with the probability that an outcome has. But also a very practical aspect is the uncertainty because there is only one uncertainty which is the chance of going up or down. This is also the main limitation of the model, because it is a very hard method to use once there are multiple uncertainties. In the valuation of growth options the BSOPM and BOPM are used widely across the economic field (Triantis, 2003). Also the theory for building a BOPM makes the assumption of risk free

RADT

The RADT (Risk-Adjusted Decision Tree) is easy visualized method which includes the probabilities of scenarios or events. The RADT includes the possibility to make a decision over time once or multiple times. It is however needed to include at least two decision moments to be able to analyze the flexibility of the options that are included in the model (Bos F. & Zwaneveld, 2016). The approach is able to visualise complex problems better, but is it also able to deal with multiple uncertainties which makes it a bit more realistic than the binomial decision tree.

This method is also the first of the five mentioned that can be used with a limited knowledge on economics and therefore it is useful in other fields of interest as well.

A decision tree contains three types of nodes:

- Decide buttons - usually represented as squares. Branches that start from a decision node display alternative choice options.
- Probability nodes - usually represented as circles. Branches that start from a chance node represent alternative events. For each of these branches, a chance (so a number between 0 and 1) must be given such that the sum of these chances is 1.
- End nodes - usually represented as triangles. At each end node a numerical value must be given for the decision criterion.

A decision tree has an implicit time dimension. The root of the tree must be a decision node that reflects the choice to be made now. Every path from the root to an end node describes a possible future. The criterion value at the end node then indicates how the decision maker values the end situation.

To determine which choice (s) are rational, the expected criterion value is calculated for each branch. A branch that ends in an end node has the value of the end node itself as the expected value. The expected value of a branch that ends in a chance node is the weighted sum of the value of the branches that depart from that chance node, that is (probability $\times$ outcome). A branch that ends in a decision node has as expected value the value of the branch with the most favorable value from that node, therefore the highest value if the decision criterion is, for example, revenues, and the lowest value if the decision criterion is, for example, costs or the number of victims. These calculation rules follow from the rational decision-making model that assumes that a decision-maker always chooses the best alternative. Although probability values are specified for chance nodes, the model is nevertheless a deterministic model. The

chances are not modeled as stochastic but as input variables of the model. The model calculation always gives the same result for the same input values (Bots, 2014).

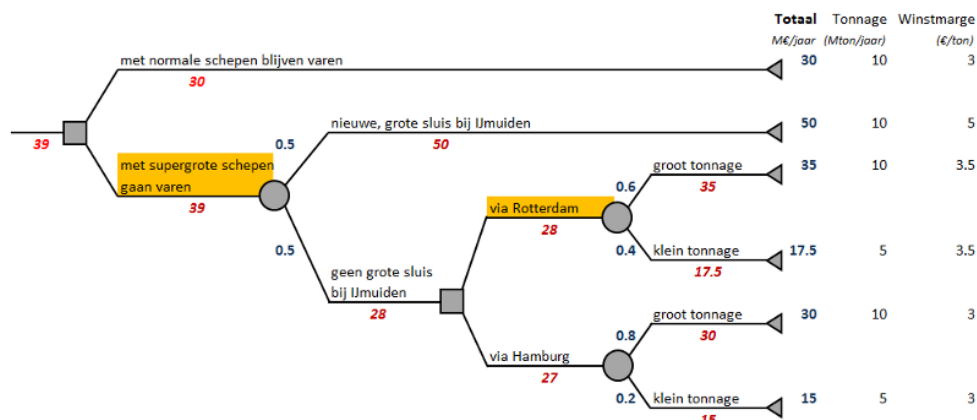


Figure B.2: Decision Tree Example (Bots, 2014)

In figure B.2 is an example of a decision tree shown with the case for a shipping company for buying bigger ships. There is a chance that a sluice is built and this enlargement allows the company to use bigger ships. They have a marge of €3 per tonnage, but expect a marge of €5 per tonnage once they use bigger ships. They expected income in million euro per year is given along with the amount of tons that can be sold with at a specific harbor with the type of ship. The model is not very sensitive: continuing to sail with normal ships only becomes more favorable if the chance that the new lock will arrive is virtually zero. Even if it were certain (probability = 1) that their market share in Rotterdam would halve (and the probability that that would happen in Hamburg therefore 50%), then sailing with super-large ships was expected to yield more.

Monte Carlo Simulation

For the experts in the field of ROA this fourth variant of valuing an option seems a logic one to add to the list of main valuation techniques. However this one is excluded from the main types because it is recognized as another type of valuation technique for its need for distributions in uncertainty for dealing with risks in the simulation (Renes, G. Romijn, 2013). The model is theoretically a perfect solution, but it requires some simulation skills and the methodology therefore lacks transparency (Gijssen, 2016). This transparency is important since the method is designed for decision-makers regarding Hallmark Events. Therefore this technique will not be included in the research.

Appendix C

Queuing Theory

This appendix will be dedicated to the queuing theory that is used for the 'Problem Definition' for the new developed method in section 2.4. At the end of this appendix the practical usage of the queuing theory is presented.

Since the late 80's a theory has been developed on queuing at that moment only for highway capacities for cars (Morales, 1987) (Council, 1994) (Chin, 1996) (Nam & Drew, 1998). The theory for queuing is mainly based on the macroscopic behaviour for traffic flows and the delays that occur at specific parts of the road. Two main analysis tools were introduced that are still used at the moment. In figure C.1 the two different analysis tools are shown given by Nam and Drew (1998). In figure C.1.a there are two curves in the figure: the capacity curve and the demand curve. The x-axis represents time and the y-axis represents the cumulative number of the vehicles, so the steepness of the lines means the amount of vehicles/time. The demand line is steeper and therefore a queue will occur since the capacity is not sufficient. The individual delay and vehicles in the queue can be read in the figure. For the total delay the surface between the lines needs to be calculated with the difference of the integrals of the demand and capacity curves.

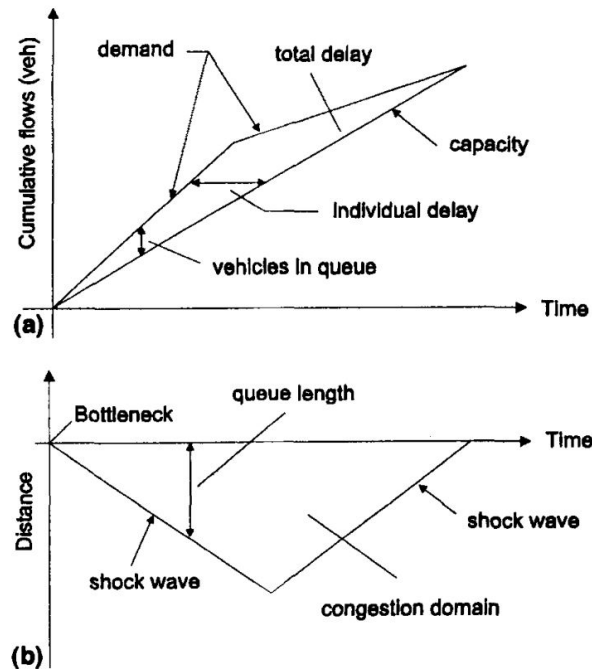


Figure C.1: Two macroscopic congestion Analysis Tools: Queuing Diagram of Deterministic (a) Queuing Analysis and (b) Time-Space Diagram of Shock-Wave Analysis (Nam & Drew, 1998)

In the b part of figure C.1 the time-space diagram is shown. This analysis is using the actual measures of vehicles to calculate the queue length and the growing speed of the queue in the negative direction of the traffic flow. The two tools should not be seen as separate but more as another way of looking at queues. The figure that now has been discussed can be seen as the major foundation for the queuing theory as we know it. At this point these theories are also applied for other modalities such as bicycles and pedestrians (Daamen et al., 2015).

Vertical Queuing Theory

Treiber and Kesting (2013) wrote a book about Traffic Flow Dynamics which includes not only the cumulative curves but also the vertical queuing theory which is the foundation of the cumulative curves shown in the figure above. In figure C.2 the theoretical principle is shown. In the figure the bottleneck is represented by the reduction of a lane, but instead of using the shock wave theory the amount of vehicles that cannot enter due to lack of capacity are stacked vertically. In the section below the vertical queuing theory of Knoop (2018) is described.

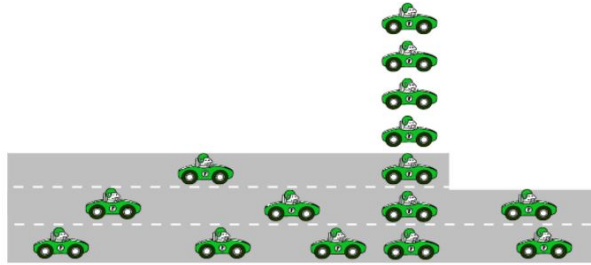


Figure C.2: Illustration of a vertical queue (Knoop, 2018)

The stacked vehicles 'theoretically' don't occupy any space and are therefore stacked vertically. Now every time step Δt a new amount of vehicles is in the stack based on the inflow and outflow of the stack at time step t (amount of vehicles in stack = S). The vehicles in the stack at a time point are dependent on the inflow and outflow at that moment. For the inflow the stack is updated, on an intermediate step $t+1/2$. In formula for the inflow the current stack is used with the incoming flow (equation C.1). S = number of stacked vehicles q_{in} = flow into the stack

$$S_{t+1/2} = S_{t+q_{in}\Delta t} \quad (C.1)$$

The outflow is the same except for one constraint. The outflow cannot be more than the capacity of the outflow. The minimum of vehicle that flow out is the amount of vehicles in the queue with the constraint of a maximum equal to the capacity (equation C.2).

q_{out} = flow out of the stack

C = capacity of bottleneck

$$q_{out} = \min\{C\Delta t, S_{i+1/2}\} \quad (C.2)$$

The last step is adding the two formula's which results in the equation C.3.

$$S_{i+1} = S_{i+1/2} - q_{out}\Delta t = S_{i+(q_{in,i}-q_{out,i})\Delta t} \quad (C.3)$$

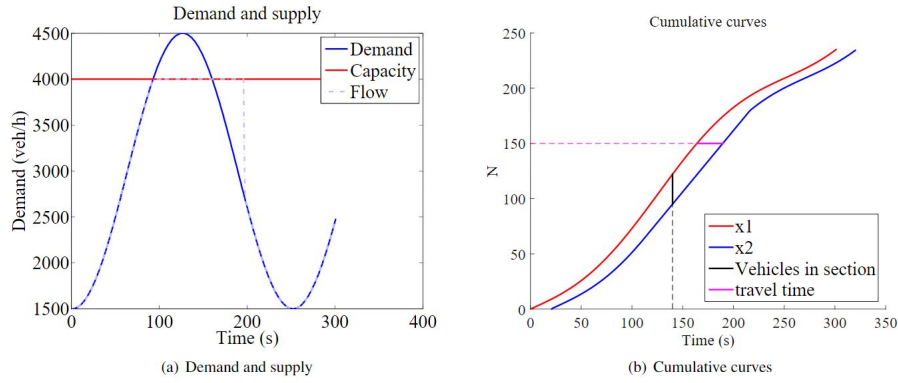


Figure C.3: Demand and cumulative curves (Knoop, 2018)

In figure C.3 the cumulative curves can be found on the right that can be seen as similar to the ones introduced by Nam and Drew Nam and Drew (1998). On the left part of the figure the origin for the particular cumulative curves is given with the capacity and demand curves. In the figure it is clear to see that the demand is higher at a specific time than the capacity. The traffic that is stacked will flow out with delay according to the (dotted) flow line. This line indicates the spread of the flow over time due to the lack of capacity. This is all translated in the right part towards two cumulative curves that represent the flow over that point. Once the curves start to walk apart the delay becomes larger for the individual vehicles. This way the vertical queuing is translated into a time related figure that indicated the delay.

Back of Napkin Approach

The problem that the Hallmark Event encounters can be found in the high demand that is occurring at a moment in time. And where there was only one modality in the previous example in figure C.3 there are actually more modalities that have a combined capacity for the outflow or inflow towards the Hallmark Event. The car network, bicycle network, pedestrian network, train network and other forms of public transport could be included for a combined capacity of the outflow or inflow of a location. In figure C.4 a theoretical example is given of the demand that is generated by the Hallmark Event and the capacities in persons/hour for all the different modalities. All those different capacities for the modalities add up to the combined capacity of the networks around the Hallmark Event. Just like in figure C.3 made by Knoop (2018) the overload of the network will experience a delay. The overload will be spread under the total capacity line in the demand and capacity figure (figure C.4). This example is however not realistic since the capacity for the bicycle network might be higher than the actual usage. Therefore the delay for the modalities need to be calculated separately.

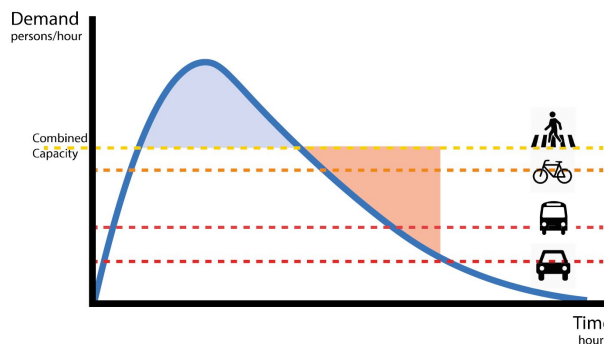


Figure C.4: Combined Capacity based on the queuing theory

The most obvious way to determine the capacities of the different networks is by looking at the main bottleneck in the specific network that reduces the capacity. This might be found in the parking

facilities, intersections, getting on or off a train and other parts in the network that might cause a major bottleneck for a specific network. By identifying those bottlenecks the capacity per network can be found, but the identification of those bottlenecks leads to possible solutions that can increase the capacity of that network for a modality. The solutions will come at a cost but will increase the capacity by tackling a bottleneck and this way a clear view on the cost and the gains in terms of money and capacity is given. In figure C.5 the increase of capacities is given with the demand and total capacity separately for all the networks.

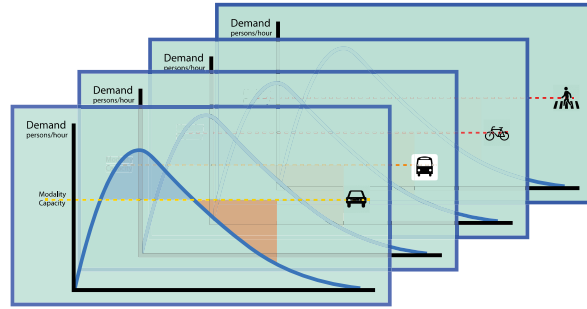


Figure C.5: Capacities of different networks based on the queuing theory

An obvious remark need to made, that when the main bottleneck is tackled another one will appear. Therefore multiple investments in one modality might be needed to be able to handle the total demand for a modality. This theoretical approach to determining the delay hours and latecomers need to be transformed into a calculation model or tool. This will be done in the next section.

C.1 Cumulative Curves Model

To include the delay calculations into the new valuation methodology, that will be developed in chapter 4, a calculation sheet is developed within the spreadsheet for the new method, see Appendix E. In this part the calculation sheet will be presented to explain the steps that are taken by the tool, based on the queuing theory that is described earlier.

The functions in the code will compute delays for the four different networks (car, bicycle, train and pedestrian) that are available at the Hallmark Event. The functions are based on two variables that are specific for every modality. The first one is the demand curve that simulates the inflow of visitors over a time step, in figure C.6 is an expected demand curve of the visitors by car and train for the DGP in Zandvoort.

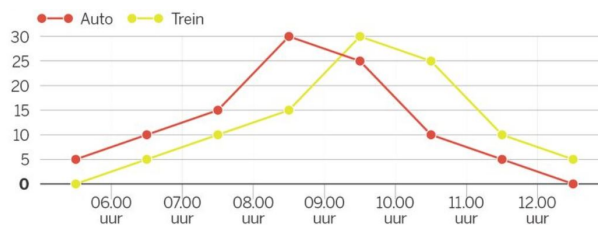


Figure C.6: Expected demand curve for car and train at Zandvoort, (Organisation of DGP, 2019)

The second variable is the capacity of the main bottleneck in the network which is also a different one for every modality. To estimate this value of this capacity the next few sections will describe methods to estimate the capacities of bottlenecks in the different networks.

The spreadsheet for the calculations is build in excel. At first the delay hour model was build in Matlab, but because of the inefficient combination between the two programs the final model was also build in excel. In the following pages images of the model are presented and in this section the explanation of the model will be given.

In the spreadsheet pages the Cumulative Curves' are presented. In the columns the different solutions are presented called 'options' in the sheet. For the different modalities the demand is given in the amount of visitors and for the different networks the capacities are given. These capacities are per 10 minutes. For the example the car capacity is not 2000 cars per 10 minutes, but 2000 visitors by car per 10 minutes. This is different from the amount of cars, since there are more people in a car than just the driver.

In the lower part of the first sheet the demand curves are given per modality. The demand curves are based on the expected demand curves by Organisation of DGP (2019), shown in figure C.6. For every modality there is also a +TM demand curve. This is the demand curve where traffic management is applied by hosting a pre or post event to spread the curves. This will lead to a lesser amount of delay hours since the peaks become lower. In figure C.7 an example is given for the 'Option zero' where the demand curve for the train users is presented together with the capacity per 10 minutes. This figure is based on figure C.3.

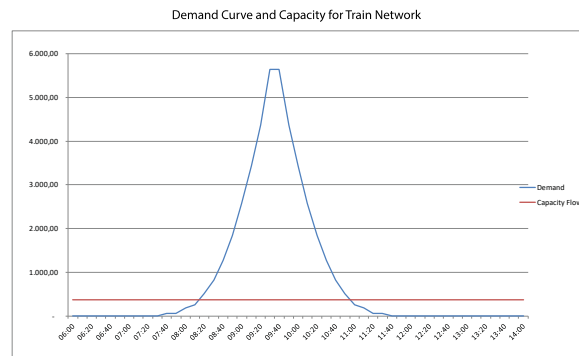


Figure C.7: Demand curve per 10 minutes and capacity from spreadsheet

In figure C.8 the amount of visitors by train in the network are presented. This curve is made out of the cumulative sum columns on the sheet in the following pages. From the moment the demand transcends the capacity curve the amount of visitors in the network will be stacked in the figure. At 11:00 the inflow is lower than the outflow of visitors in the network and amount of visitors stacked in the network will reduce. In this example the event starts at 12:00 o clock and end at 16:00, therefore the graph end at 16:00. After this moment there is no use for the visitors to still try to go the event. All the people stacked in the network in figure C.8 are contributing to the delay hours in the spreadsheet. Every visitor still in the network after 12:00 will be counted as a latecomer, which is another additional penalty for the Expanded NPV in the calculations.

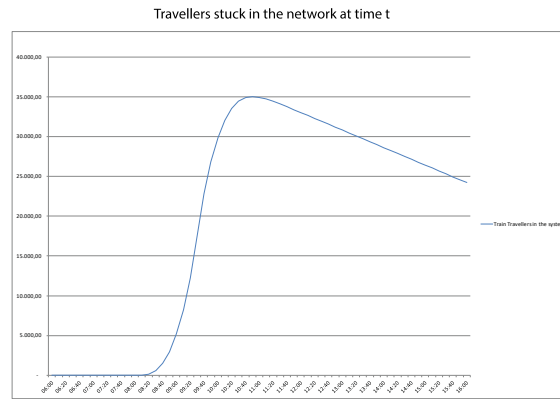


Figure C.8: Visitors still in the network for train for every 10 minutes

These calculations are made for all the individual solutions and also for the combinations of solutions. No actual figures are used to estimate the delay hours or latecomers, but these figures were made out of the result to show what is happening in the model. For reasons of 'environmental friendly thesis writing' not all the sheets for the Cumulative Curves are printed!

Cummulative curves

Capacity per solution and Demand based on the arrival curve per modality

Demand	Option zero	Option 1	Option 2	Option 3	Option 4	Option 5
Car	42.000,00	42.000,00	42.000,00	42.000,00	42.000,00	42.000,00
Bike	18.900,00	18.900,00	18.900,00	18.900,00	18.900,00	34.650,00
Train	42.000,00	42.000,00	42.000,00	42.000,00	42.000,00	26.250,00
Pedestrian	2.100,00	2.100,00	2.100,00	2.100,00	2.100,00	2.100,00
Traffic managemen	0	0	0	0	0	0

Capacity	Option zero	Option 1	Option 2	Option 3	Option 4	Option 5
Car	2.000,00	2.000,00	2.080,00	3.300,00	2.000,00	2.000,00
Bike	1.666,67	1.666,67	1.666,67	1.666,67	1.666,67	2.083,33
Train	366,67	366,67	366,67	366,67	366,67	366,67
Pedestrian	12.000,00	12.000,00	12.000,00	12.000,00	12.000,00	12.000,00

Demand curves	Car	Car + TM	Bicycle	Bicycle + TM	Train	Train + TM
06:00	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
06:10	0,000%	0,079%	0,000%	0,079%	0,000%	0,079%
06:20	0,000%	0,052%	0,000%	0,052%	0,000%	0,052%
06:30	0,000%	0,161%	0,000%	0,161%	0,000%	0,161%
06:40	0,000%	0,179%	0,000%	0,179%	0,000%	0,179%
06:50	0,000%	0,340%	0,000%	0,340%	0,000%	0,340%
07:00	0,000%	0,443%	0,000%	0,443%	0,000%	0,443%
07:10	0,133%	0,704%	0,000%	0,704%	0,000%	0,704%
07:20	0,143%	0,937%	0,000%	0,937%	0,000%	0,937%
07:30	0,429%	1,356%	0,000%	1,356%	0,000%	1,356%
07:40	0,615%	1,778%	0,000%	1,778%	0,133%	1,778%
07:50	1,234%	2,400%	0,000%	2,400%	0,143%	2,400%
08:00	1,949%	3,049%	0,000%	3,049%	0,429%	3,049%
08:10	3,020%	3,900%	0,133%	3,900%	0,615%	3,900%
08:20	4,364%	4,766%	0,143%	4,766%	1,234%	4,766%
08:30	6,117%	5,826%	0,429%	5,826%	1,949%	5,826%
08:40	8,175%	6,863%	0,615%	6,863%	3,020%	6,863%
08:50	10,405%	8,017%	1,234%	8,017%	4,364%	8,017%
09:00	13,416%	9,150%	1,949%	9,150%	6,117%	9,150%
09:10	13,416%	9,150%	3,020%	9,150%	8,175%	9,150%
09:20	10,405%	8,017%	4,364%	8,017%	10,405%	8,017%
09:30	8,175%	6,863%	6,117%	6,863%	13,416%	6,863%
09:40	6,117%	5,826%	8,175%	5,826%	13,416%	5,826%
09:50	4,364%	4,766%	10,405%	4,766%	10,405%	4,766%
10:00	3,020%	3,900%	13,416%	3,900%	8,175%	3,900%
10:10	1,949%	3,049%	13,416%	3,049%	6,117%	3,049%
10:20	1,234%	2,400%	10,405%	2,400%	4,364%	2,400%
10:30	0,615%	1,778%	8,175%	1,778%	3,020%	1,778%
10:40	0,429%	1,356%	6,117%	1,356%	1,949%	1,356%
10:50	0,143%	0,937%	4,364%	0,937%	1,234%	0,937%
11:00	0,133%	0,704%	3,020%	0,704%	0,615%	0,704%
11:10	0,000%	0,443%	1,949%	0,443%	0,429%	0,443%
11:20	0,000%	0,340%	1,234%	0,340%	0,143%	0,340%
11:30	0,000%	0,179%	0,615%	0,179%	0,133%	0,179%
11:40	0,000%	0,161%	0,429%	0,161%	0,000%	0,161%
11:50	0,000%	0,052%	0,143%	0,052%	0,000%	0,052%
12:00	0,000%	0,079%	0,133%	0,079%	0,000%	0,079%
12:10	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
12:20	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
12:30	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
12:40	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
12:50	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:00	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:10	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:20	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:30	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:40	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
13:50	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
14:00	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
	100%	100%	100%	100%	100%	100%

Car

Demand

06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	56,03	56,03	56,03	56,03	56,03	56,03
07:20	60,03	60,03	60,03	60,03	60,03	60,03
07:30	180,09	180,09	180,09	180,09	180,09	180,09
07:40	258,12	258,12	258,12	258,12	258,12	258,12
07:50	518,25	518,25	518,25	518,25	518,25	518,25
08:00	818,39	818,39	818,39	818,39	818,39	818,39
08:10	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60
08:20	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87
08:30	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22
08:40	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64
08:50	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08
09:00	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68
09:10	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68
09:20	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08
09:30	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64
09:40	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22
09:50	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87
10:00	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60
10:10	818,39	818,39	818,39	818,39	818,39	818,39
10:20	518,25	518,25	518,25	518,25	518,25	518,25
10:30	258,12	258,12	258,12	258,12	258,12	258,12
10:40	180,09	180,09	180,09	180,09	180,09	180,09
10:50	60,03	60,03	60,03	60,03	60,03	60,03
11:00	56,03	56,03	56,03	56,03	56,03	56,03
11:10	-	-	-	-	-	-
11:20	-	-	-	-	-	-
11:30	-	-	-	-	-	-
11:40	-	-	-	-	-	-
11:50	-	-	-	-	-	-
12:00	-	-	-	-	-	-
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-

Cummulative sum

06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	-	-	-	-	-	-
08:20	-	-	-	-	-	-
08:30	569,22	569,22	489,22	-	569,22	569,22
08:40	2.002,86	2.002,86	1.842,86	133,64	2.002,86	2.002,86
08:50	4.372,94	4.372,94	4.132,94	1.203,72	4.372,94	4.372,94
09:00	8.007,62	8.007,62	7.687,62	3.538,40	8.007,62	8.007,62

09:10	11.642,31	11.642,31	11.242,31	5.873,08	11.642,31	11.642,31
09:20	14.012,39	14.012,39	13.532,39	6.943,16	14.012,39	14.012,39
09:30	15.446,02	15.446,02	14.886,02	7.076,80	15.446,02	15.446,02
09:40	16.015,25	16.015,25	15.375,25	6.346,02	16.015,25	16.015,25
09:50	15.848,12	15.848,12	15.128,12	4.878,89	15.848,12	15.848,12
10:00	15.116,72	15.116,72	14.316,72	2.847,50	15.116,72	15.116,72
10:10	13.935,11	13.935,11	13.055,11	365,89	13.935,11	13.935,11
10:20	12.453,36	12.453,36	11.493,36	-	12.453,36	12.453,36
10:30	10.711,48	10.711,48	9.671,48	-	10.711,48	10.711,48
10:40	8.891,57	8.891,57	7.771,57	-	8.891,57	8.891,57
10:50	6.951,60	6.951,60	5.751,60	-	6.951,60	6.951,60
11:00	5.007,62	5.007,62	3.727,62	-	5.007,62	5.007,62
11:10	3.007,62	3.007,62	1.647,62	-	3.007,62	3.007,62
11:20	1.007,62	1.007,62	-	-	1.007,62	1.007,62
11:30	-	-	-	-	-	-
11:40	-	-	-	-	-	-
11:50	-	-	-	-	-	-
12:00	-	-	-	-	-	-
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Delay hours	27.499,90	27.499,90	25.291,97	6.534,52	27.499,90	27.499,90
Late arrivers	-	-	-	-	-	-

Bicycle

Demand

06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	25,21	25,21	25,21	25,21	25,21	46,22
08:20	27,01	27,01	27,01	27,01	27,01	49,52
08:30	81,04	81,04	81,04	81,04	81,04	148,57
08:40	116,16	116,16	116,16	116,16	116,16	212,95
08:50	233,21	233,21	233,21	233,21	233,21	427,55
09:00	368,28	368,28	368,28	368,28	368,28	675,17
09:10	570,87	570,87	570,87	570,87	570,87	1.046,60
09:20	824,79	824,79	824,79	824,79	824,79	1.512,12
09:30	1.156,15	1.156,15	1.156,15	1.156,15	1.156,15	2.119,61
09:40	1.545,14	1.545,14	1.545,14	1.545,14	1.545,14	2.832,75
09:50	1.966,54	1.966,54	1.966,54	1.966,54	1.966,54	3.605,32
10:00	2.535,61	2.535,61	2.535,61	2.535,61	2.535,61	4.648,61
10:10	2.535,61	2.535,61	2.535,61	2.535,61	2.535,61	4.648,61
10:20	1.966,54	1.966,54	1.966,54	1.966,54	1.966,54	3.605,32
10:30	1.545,14	1.545,14	1.545,14	1.545,14	1.545,14	2.832,75
10:40	1.156,15	1.156,15	1.156,15	1.156,15	1.156,15	2.119,61
10:50	824,79	824,79	824,79	824,79	824,79	1.512,12
11:00	570,87	570,87	570,87	570,87	570,87	1.046,60
11:10	368,28	368,28	368,28	368,28	368,28	675,17
11:20	233,21	233,21	233,21	233,21	233,21	427,55
11:30	116,16	116,16	116,16	116,16	116,16	212,95
11:40	81,04	81,04	81,04	81,04	81,04	148,57
11:50	27,01	27,01	27,01	27,01	27,01	49,52
12:00	25,21	25,21	25,21	25,21	25,21	46,22

12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Cummulative sum						
06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	-	-	-	-	-	-
08:20	-	-	-	-	-	-
08:30	-	-	-	-	-	-
08:40	-	-	-	-	-	-
08:50	-	-	-	-	-	-
09:00	-	-	-	-	-	-
09:10	-	-	-	-	-	-
09:20	-	-	-	-	-	-
09:30	-	-	-	-	-	36,28
09:40	-	-	-	-	-	785,69
09:50	299,87	299,87	299,87	299,87	299,87	2.307,68
10:00	1.168,81	1.168,81	1.168,81	1.168,81	1.168,81	4.872,96
10:10	2.037,75	2.037,75	2.037,75	2.037,75	2.037,75	7.438,24
10:20	2.337,62	2.337,62	2.337,62	2.337,62	2.337,62	8.960,22
10:30	2.216,09	2.216,09	2.216,09	2.216,09	2.216,09	9.709,63
10:40	1.705,57	1.705,57	1.705,57	1.705,57	1.705,57	9.745,91
10:50	863,70	863,70	863,70	863,70	863,70	9.174,70
11:00	-	-	-	-	-	8.137,96
11:10	-	-	-	-	-	6.729,80
11:20	-	-	-	-	-	5.074,02
11:30	-	-	-	-	-	3.203,64
11:40	-	-	-	-	-	1.268,88
11:50	-	-	-	-	-	-
12:00	-	-	-	-	-	-
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Delay hours	1.771,57	1.771,57	1.771,57	1.771,57	1.771,57	12.907,60
Late arrivers	-	-	-	-	-	-
Train						
Demand						
06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-

06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	56,03	56,03	56,03	56,03	56,03	35,02
07:50	60,03	60,03	60,03	60,03	60,03	37,52
08:00	180,09	180,09	180,09	180,09	180,09	112,55
08:10	258,12	258,12	258,12	258,12	258,12	161,33
08:20	518,25	518,25	518,25	518,25	518,25	323,90
08:30	818,39	818,39	818,39	818,39	818,39	511,49
08:40	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60	792,88
08:50	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87	1.145,55
09:00	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22	1.605,76
09:10	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64	2.146,02
09:20	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08	2.731,30
09:30	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68	3.521,68
09:40	5.634,68	5.634,68	5.634,68	5.634,68	5.634,68	3.521,68
09:50	4.370,08	4.370,08	4.370,08	4.370,08	4.370,08	2.731,30
10:00	3.433,64	3.433,64	3.433,64	3.433,64	3.433,64	2.146,02
10:10	2.569,22	2.569,22	2.569,22	2.569,22	2.569,22	1.605,76
10:20	1.832,87	1.832,87	1.832,87	1.832,87	1.832,87	1.145,55
10:30	1.268,60	1.268,60	1.268,60	1.268,60	1.268,60	792,88
10:40	818,39	818,39	818,39	818,39	818,39	511,49
10:50	518,25	518,25	518,25	518,25	518,25	323,90
11:00	258,12	258,12	258,12	258,12	258,12	161,33
11:10	180,09	180,09	180,09	180,09	180,09	112,55
11:20	60,03	60,03	60,03	60,03	60,03	37,52
11:30	56,03	56,03	56,03	56,03	56,03	35,02
11:40	-	-	-	-	-	-
11:50	-	-	-	-	-	-
12:00	-	-	-	-	-	-
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Cumulative sum						
06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	-	-	-	-	-	-
08:20	151,58	151,58	151,58	151,58	151,58	-
08:30	603,30	603,30	603,30	603,30	603,30	144,83
08:40	1.505,24	1.505,24	1.505,24	1.505,24	1.505,24	571,04
08:50	2.971,45	2.971,45	2.971,45	2.971,45	2.971,45	1.349,92
09:00	5.174,00	5.174,00	5.174,00	5.174,00	5.174,00	2.589,01
09:10	8.240,97	8.240,97	8.240,97	8.240,97	8.240,97	4.368,37
09:20	12.244,39	12.244,39	12.244,39	12.244,39	12.244,39	6.733,00
09:30	17.512,40	17.512,40	17.512,40	17.512,40	17.512,40	9.888,01
09:40	22.780,42	22.780,42	22.780,42	22.780,42	22.780,42	13.043,02
09:50	26.783,83	26.783,83	26.783,83	26.783,83	26.783,83	15.407,66
10:00	29.850,80	29.850,80	29.850,80	29.850,80	29.850,80	17.187,01

10:10	32.053,36	32.053,36	32.053,36	32.053,36	32.053,36	18.426,11
10:20	33.519,56	33.519,56	33.519,56	33.519,56	33.519,56	19.204,99
10:30	34.421,50	34.421,50	34.421,50	34.421,50	34.421,50	19.631,20
10:40	34.873,23	34.873,23	34.873,23	34.873,23	34.873,23	19.776,03
10:50	35.024,81	35.024,81	35.024,81	35.024,81	35.024,81	19.733,27
11:00	34.916,26	34.916,26	34.916,26	34.916,26	34.916,26	19.527,93
11:10	34.729,68	34.729,68	34.729,68	34.729,68	34.729,68	19.273,81
11:20	34.423,04	34.423,04	34.423,04	34.423,04	34.423,04	18.944,66
11:30	34.112,40	34.112,40	34.112,40	34.112,40	34.112,40	18.613,01
11:40	33.745,74	33.745,74	33.745,74	33.745,74	33.745,74	18.246,35
11:50	33.379,07	33.379,07	33.379,07	33.379,07	33.379,07	17.879,68
12:00	33.012,40	33.012,40	33.012,40	33.012,40	33.012,40	17.513,01
12:10	32.645,74	32.645,74	32.645,74	32.645,74	32.645,74	17.146,35
12:20	32.279,07	32.279,07	32.279,07	32.279,07	32.279,07	16.779,68
12:30	31.912,40	31.912,40	31.912,40	31.912,40	31.912,40	16.413,01
12:40	31.545,74	31.545,74	31.545,74	31.545,74	31.545,74	16.046,35
12:50	31.179,07	31.179,07	31.179,07	31.179,07	31.179,07	15.679,68
13:00	30.812,40	30.812,40	30.812,40	30.812,40	30.812,40	15.313,01
13:10	30.445,74	30.445,74	30.445,74	30.445,74	30.445,74	14.946,35
13:20	30.079,07	30.079,07	30.079,07	30.079,07	30.079,07	14.579,68
13:30	29.712,40	29.712,40	29.712,40	29.712,40	29.712,40	14.213,01
13:40	29.345,74	29.345,74	29.345,74	29.345,74	29.345,74	13.846,35
13:50	28.979,07	28.979,07	28.979,07	28.979,07	28.979,07	13.479,68
14:00	28.612,40	28.612,40	28.612,40	28.612,40	28.612,40	13.113,01
14:10	28.245,74	28.245,74	28.245,74	28.245,74	28.245,74	12.746,35
14:20	27.879,07	27.879,07	27.879,07	27.879,07	27.879,07	12.379,68
14:30	27.512,40	27.512,40	27.512,40	27.512,40	27.512,40	12.013,01
14:40	27.145,74	27.145,74	27.145,74	27.145,74	27.145,74	11.646,35
14:50	26.779,07	26.779,07	26.779,07	26.779,07	26.779,07	11.279,68
15:00	26.412,40	26.412,40	26.412,40	26.412,40	26.412,40	10.913,01
15:10	26.045,74	26.045,74	26.045,74	26.045,74	26.045,74	10.546,35
15:20	25.679,07	25.679,07	25.679,07	25.679,07	25.679,07	10.179,68
15:30	25.312,40	25.312,40	25.312,40	25.312,40	25.312,40	9.813,01
15:40	24.945,74	24.945,74	24.945,74	24.945,74	24.945,74	9.446,35
15:50	24.579,07	24.579,07	24.579,07	24.579,07	24.579,07	9.079,68
16:00	24.212,40	24.212,40	24.212,40	24.212,40	24.212,40	8.713,01
Delay hours	203.054,52	203.054,52	203.054,52	203.054,52	203.054,52	101.394,05
Late arrivers	32.645,74	32.645,74	32.645,74	32.645,74	32.645,74	17.146,35

Pedestrian

Demand

06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	2,80	2,80	2,80	2,80	2,80	2,80
08:20	3,00	3,00	3,00	3,00	3,00	3,00
08:30	9,00	9,00	9,00	9,00	9,00	9,00
08:40	12,91	12,91	12,91	12,91	12,91	12,91
08:50	25,91	25,91	25,91	25,91	25,91	25,91
09:00	40,92	40,92	40,92	40,92	40,92	40,92
09:10	63,43	63,43	63,43	63,43	63,43	63,43
09:20	91,64	91,64	91,64	91,64	91,64	91,64
09:30	128,46	128,46	128,46	128,46	128,46	128,46
09:40	171,68	171,68	171,68	171,68	171,68	171,68
09:50	218,50	218,50	218,50	218,50	218,50	218,50
10:00	281,73	281,73	281,73	281,73	281,73	281,73
10:10	281,73	281,73	281,73	281,73	281,73	281,73
10:20	218,50	218,50	218,50	218,50	218,50	218,50
10:30	171,68	171,68	171,68	171,68	171,68	171,68
10:40	128,46	128,46	128,46	128,46	128,46	128,46
10:50	91,64	91,64	91,64	91,64	91,64	91,64
11:00	63,43	63,43	63,43	63,43	63,43	63,43

11:10	40,92	40,92	40,92	40,92	40,92	40,92
11:20	25,91	25,91	25,91	25,91	25,91	25,91
11:30	12,91	12,91	12,91	12,91	12,91	12,91
11:40	9,00	9,00	9,00	9,00	9,00	9,00
11:50	3,00	3,00	3,00	3,00	3,00	3,00
12:00	2,80	2,80	2,80	2,80	2,80	2,80
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Cumulative sum						
06:00	-	-	-	-	-	-
06:10	-	-	-	-	-	-
06:20	-	-	-	-	-	-
06:30	-	-	-	-	-	-
06:40	-	-	-	-	-	-
06:50	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:10	-	-	-	-	-	-
07:20	-	-	-	-	-	-
07:30	-	-	-	-	-	-
07:40	-	-	-	-	-	-
07:50	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:10	-	-	-	-	-	-
08:20	-	-	-	-	-	-
08:30	-	-	-	-	-	-
08:40	-	-	-	-	-	-
08:50	-	-	-	-	-	-
09:00	-	-	-	-	-	-
09:10	-	-	-	-	-	-
09:20	-	-	-	-	-	-
09:30	-	-	-	-	-	-
09:40	-	-	-	-	-	-
09:50	-	-	-	-	-	-
10:00	-	-	-	-	-	-
10:10	-	-	-	-	-	-
10:20	-	-	-	-	-	-
10:30	-	-	-	-	-	-
10:40	-	-	-	-	-	-
10:50	-	-	-	-	-	-
11:00	-	-	-	-	-	-
11:10	-	-	-	-	-	-
11:20	-	-	-	-	-	-
11:30	-	-	-	-	-	-
11:40	-	-	-	-	-	-
11:50	-	-	-	-	-	-
12:00	-	-	-	-	-	-
12:10	-	-	-	-	-	-
12:20	-	-	-	-	-	-
12:30	-	-	-	-	-	-
12:40	-	-	-	-	-	-
12:50	-	-	-	-	-	-
13:00	-	-	-	-	-	-
13:10	-	-	-	-	-	-
13:20	-	-	-	-	-	-
13:30	-	-	-	-	-	-
13:40	-	-	-	-	-	-
13:50	-	-	-	-	-	-
14:00	-	-	-	-	-	-
Delay hours	-	-	-	-	-	-
Late arrivers	-	-	-	-	-	-

Appendix D

Solutions and Key Figures

D.1 Solutions for increasing network capacities

For the development of the CBA with flexibility Tool in Appendix E this appendix includes an extensive research for key figures for costs, capacities and effects. The first part will handle capacities for solutions, such as road capacities for vehicles. In all the sub sections different aspects will be handled. In the end the solutions that are used in the tool will be handled. All the costs and effects that are included within each solution will be justified.

D.1.1 Solutions for the car network

Parking

When the car network capacity need to be estimated the parking facilities can be seen as major bottlenecks. In 2004 two researchers investigated the main bottlenecks of the car network by looking at queuing at toll plazas and parking entries and exits (Ceballos & Curtis, 2004). Ceballos and Curtis (2004) found figures on the different capacities at those exit or entry points. Toll plazas drops the throughput of vehicles from 2000 vehicles per hour (on a motorway) down towards 350 to 500 vehicles per hour (vph). The service rate for a parking lot entry is higher with a throughput up to 660 vph. With a capacity of 2000 vehicles per hour on a motorway or arterial road it is clear to imagine that a parking entrance can generate a major spill back. The main problem is in the entrance which may led the reader think that a simple increase of amount of entries is the solution for this problem, but it a little more complicated than that according to Maršanić et al. (2011). Once the parking lot is filling the space becomes smaller in the parking lot and the queue within the facility comes closer to the entry and spill back can occur even though there is enough space and the capacity of the entry points are known. An increase of entry point therefore also can lead to an increase of spill back points. According to Maršanić et al. (2011) the amount of entries at a parking facility should be 1 entry per 250 parking places.

For the parking facilities the handling speed is important as it is to estimate the amount of cars that will be parked. For the amount of entrances the rule of thumb from Maršanić et al. (2011) could be used. Maršanić et al. (2011) say that the average amount of vehicles that can pass a parking entry is 600. Deviations of this number might be found in the literature, but this value will be used in this report.

The costs of car parking lots are high. According to GWWkompas (2011) the costs for a parking lot can be estimated in the amount of parking places which vary between €1,907 and €2,639. In the municipality of Haarlem the costs for ground level parking are estimated between €1,500 and €1,750 (van Spijk, 2016). These prices are given for parking places with facilities such as: sewerage, lights, pavements, color difference in parking places and access road. If the parking would be designed in a minimalistic way the price might be lower.

Solution 1: Extra Parking Places for the car

The first solution in the spreadsheet is the construction of extra parking places in Zandvoort. At this moment there are 12 big parking places with a total capacity of 7850 places, but 14000 are needed for all the expected visitors that come by car. A big investment is therefore needed since the price of a parking place comes down to €2000 per place. A little search for possible places was done and it became clear that there is space up to 11000 places in Zandvoort including the already existing places. This means that 3150 places will be build with this solution. It might be possible to do this for the lowest costs possible of €1,000 per parking place. Also €10,000 per year is needed to maintain these extra places. On top of that is an additional €15,000 for external costs for possible other functions that could have been build on the place of the parking lots.

Another way to make sure that the capacity of the car network goes up is to make sure the cars have as much as possible passengers 'on-board'. This is because the capacity is measured in people per hour and not in vehicles, because comparing with other networks would then be impossible. By giving cars with four or more passengers priority in parking close the cars might be filled more efficient since people can opt for car-pooling. This can be seen as non-infrastructurel, but this is a solution that is only possible for this network. In 2010 Laing and Frost (2010) did a research towards to possibility to host a 'green' event, which means an event that is as environmentally friendly as possible since visitors seem to value this more and more. Although they could not give a scientific source for the effect for car pooling at such an event they propose the event to stimulate this to reduce the amount of traffic. In their case this is done to reduce the amount of pollutant, but in this research the aim is specifically in increasing the capacity of the network for the car of another modality.

Solution 2: Parking restrictions for the car

The second solution in the spreadsheet represents a restriction for cars into Zandvoort. At this moment it is expected that the loading factor for the cars is 75%. With the restrictions people with less than three people in the car will be guided to parking places further away. This way people are more eager to use carpool locations and fill up their cars with more visitors. It is expected that this percentage increase will lead to a loading factor of 78%. The costs for this champagne will be estimated on €50,000 and on top of that approximately €25,000 per day to pay traffic controllers at the parking places.

Intersections

Intersections can be major bottlenecks in the car network. The throughput of this crossing can be capacity bound and another design might increase this value. Intersections can have specific throughput per branch or direction, which can be a bottleneck in the network or in the route towards the event. The capacity of an intersection can vary, but the standard values for an intersection can be found in table D.1. In figure D.1 the maximum capacities can be found for roundabouts and intersections with the amount of vehicles from the main and side directions per day.

Table D.1: Intersection Lane Capacities for standard intersection (Kennisplatform_CROW, 2018)

Capaciteiten	Pae/uur
Linksaf 1 rijstrook	1700
Linksaf 1 rijstrook	3400
Rechtdoor 1 rijstrook	1900
Rechtdoor 1 rijstrook	3800
Rechtsaf 1 rijstrook	1750
Rechtsaf 1 rijstrook	3500

At this moment the N200 is the northern access road towards the city of Zandvoort. The access to this road is granted by a small roundabout. This round about has a limited capacity of 15,000 vehicles per day, see figure D.1. Comparing this with the capacities for a standard intersection in table D.1 than the intersection is a much more efficient crossing for traffic that is going straight ahead over the crossing, because this is the case for the access road.

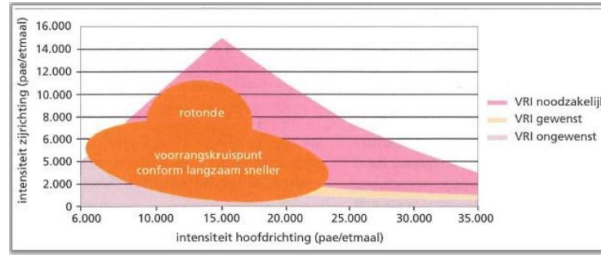


Figure D.1: Rule of thumb for determination of intersection type (Coffeng, 2016)

The costs for intersections or roundabout can vary a lot, since every situation has different problems that need be taken into account. Road blockage while building, sewerage, cables and pipes in the ground, space restrictions and many more aspects can increase the price. In the most ideal situation the price of a roundabout or intersection is between €400,000 and €600,000 (swovleidschendam_2012). This is probably way to less for an intersection at Zandvoort since this is one of the two access points to Zandvoort. Therefore the costs can go up for duration and traffic control which can make the price two to four times as high.

Links

The roads, also called links, also have a capacity, but this is depending on the type of road and the amount of lanes. For motorways there are different characteristics of the links compared with arterial roads. In table D.2 the capacities in vehicle per hour per lane are given for non motorway links based on a research by Zegeer et al. (2008).

Area Type	Default (veh/hr/ln)	Range (veh/hr/ln)
CBD	1700	1600-1800
Urban	1750	1700-1900
Suburban	1800	1800-1900
Rural	1700	1600-1900

Figure D.2: Adjusted saturation flow rate by area type (Zegeer et al., 2008)

For motorways a method to estimate the capacity of the motorways was developed by Federal Highway Administration (2017) to have a rule of thumb for the capacities on the roads. In the calculation the percentage of heavy vehicles (%HV) and the free flow speed (FFS) are used as input.

$$Capacity = \frac{(2,200 + 10 \times (\min(70, FFS) - 50))}{(1 + \%HV/100)}$$

For values especially in the Netherlands, dutch documents can be used like the report of Goemans et al. (2011). They wrote a report with values on motorway capacity in the Netherlands. The values in figure D.3 do have 15% of heavy vehicles, but this is an average on the motorways in the Netherlands.

Figure D.3: Capacity values for lanes at motorways (Goemans et al., 2011)

Wegvak	Invoeging	Rijstrook-beëindiging	Capaciteit in mvt/h	Opmerkingen
1 rijstrook	-	-	1.900	wegvaklengte > 1.500 m
1 rijstrook	-	Van 2 naar 1 rijstrook	2.100	wegvaklengte < 1.500 m
2 rijstroken	2 rijstroken + 1 invoegstrook	Van 3 naar 2 rijstroken	4.200	
3 rijstroken	3 rijstroken + 1 invoegstrook	Van 4 naar 3 rijstroken	6.300	
4 rijstroken	4 rijstroken + 1 invoegstrook	Van 5 naar 4 rijstroken	8.200	
5 rijstroken	5 rijstroken + 1 invoegstrook	Van 6 naar 5 rijstroken	10.000	
6 rijstroken	6 rijstroken + 1 invoegstrook	Van 7 naar 6 rijstroken	11.500	
7 rijstroken	7 rijstroken + 1 invoegstrook	Van 8 naar 7 rijstroken	13.000	

Solution 3: Infrastructure for car

The third solution does two investments at once. The current roundabout that gives access to the N200 has a limited capacity and also the first part of the N200 is a one lane road. Increasing the capacity by making a two lane access road and an intersection will increase the current capacity by approximately 2000 vehicles per hour. The costs expected will be €2,000,000 for the reconstruction of the roundabout and €1,000,000 for the doubling of the amount of lanes at the current access road. This way the 2000 vehicles per hour on the N200 can become 4000 vehicles per hour.



Figure D.4: Impression of the roundabout at N200 in Zandvoort

D.1.2 Solutions for the bicycle network

For the car network a lot of empirical evidence is given on the capacities of intersections and parking. For the slow modes such as bicycles and pedestrians this is not the case. Also the relevance to invest in slow modes such as bicycles and pedestrians seems not that relevant when the statistics on average walking and cycling distances are shown (figure D.2). In the table an overview is given of the average distance and travel time for recreational purposes for these two slow modes. Hallmark Events can have regional or national service levels and if the usage of bicycles stops after 5 kilometers the investment is hard to earn back.

Table D.2: Travel Statistics on Recreational Purposes in Zuid-Holland, (Centraal Bureau voor de Statistiek, 2018)

	Bicycle		Pedestrian	
	Distance	Travel Time	Distance	Travel Time
2010	3.44	18.35	1.60	21.36
2011	4.38	21.27	2.03	24.77
2012	3.67	18.06	1.94	19.72
2013	4.17	21.45	1.77	19.53
2014	3.63	20.01	2.32	27.97

Parking

Parking can be a main bottleneck for the entrance and the exit of the event, but there is not much information on the capacity of the outflow and inflow of these parking areas. In the usual daily travel behaviour the lack of parking facilities can be a major barrier (Heinen & Buehler, 2019). The empirical

evidence for this is however found in the parking of bicycles in cities which is not the case for Hallmark Events in the rural area. Another aspect is that the facilities are there used on a daily basis and people can become familiar with this over a longer period. For a Hallmark Event that has duration of a few days this is not the case.

The quality of the facilities for bicycle parking has also only a limited effect of the amount of extra cyclists (Heinen & Buehler, 2019). A study in Australia showed the same result with a new opened parking facility for bicycles and resulted in appreciation by the users, but not much new users were added by the new facility (Burke, 2011). For the Hallmark Event the facilities for bicycle parking might therefore not be that interesting, but it might be interesting for the image of the event itself to show the high quality of facilities. The monetization of quality of facilities is however unknown.

For leaving the area it is important that the outflow of the parking area for the bicycles is high to prevent queuing in the parking area. This might be prevented by dividing the area in a clear way that visitors can find their bike faster. This is also done in parking areas for cars by naming the different parking spots to make it more easy for people to find their car back. The effect is however very uncertain. Further research after this topic is recommended for the effects of such a solution.

Solution 4: Extra temporary parking places for bicycles This solution is based on the original DGP plans for the event. Their plan is to make temporary parking places for bicycles. The costs are hard to estimate, but are set to €20 per bicycle. And 14,000 places are needed, which results in an operational cost of €280,000. This is however a very uncertain value.

Intersections

The capacity of intersection for bicycles depends on the green time or available time that a cyclist can use to cross the street (Godefrooij et al., 2016). The company DTV did a research on the capacity of intersections for cyclists and came with the table D.5 below. The research is performed at multiple intersections in the Netherlands and gives the outflow capacity in seconds between the cyclists. Cyclists can wait next to each other in comparison with cars, this makes the outflow much higher (up to 1,6 seconds).

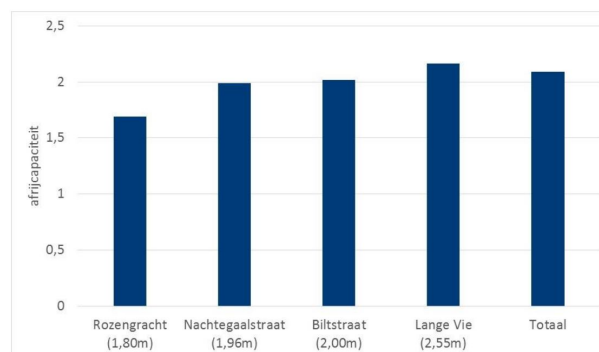


Figure D.5: Capacity values for lanes at motorways (Godefrooij et al., 2016)

The take-off capacity is measured in the period of the green phase in which there are no longer any acceleration losses and where the traffic starts from a queue. For the four investigated intersections this measurement period starts at the time when the ninth vehicle marks the stop line passes and the measurement period ends when the last vehicle still standing in the queue passes the stop line (Godefrooij et al., 2016).

Links

In the Netherlands the bicycle infrastructure is of a high level and number on capacities can easily be found at CROW (2019). For the minimum width for bicycle paths they made the 'Ontwerprijzer

Fietsverkeer'. In table D.3 the widths are given for specific capacities. One comment need to be made and that is that intensities are given for two directions.

Table D.3: Peak hour Intensities in two directions for bicycle paths (CROW, 2019)

Intensity (cyclists/hour)	Minimum width of cycle path
0 - 50	1.50 m.
50 - 150	2.50 m.
150 - 350	3.50 m.
> 350	4.50 m.

This report by CROW can be seen as a guideline, but not scientific evidence for the actual capacity of the road. Zhou et al. (2015) did a research towards the capacity of bicycle paths and found that the average capacity of a bicycle path is 2512 cyclists per hour per meter width. The width is not of big influence, so a linear relation can be used for the capacity of the cycle paths. The mix of bicycle traffic which included the age, gender and type of bike does have a significant influence on the capacity.

Solution 5: Rental Bikes and route guiding

This solution is again based on the original DPG plan. The DGP is hoping that the people in the area can come by bike and want rental bikes available at the parking places around Zandvoort. This solution unfortunately became unavailable since their is not company able to deliver 30,000 bicycles. The solution will be taken into account though for the testing of the methodology and because it is a clever solution if it would be possible. The costs are estimated on €500,000 for the operational costs for one day. Also traffic controllers and route guiding is included in this price.

D.1.3 solutions for public transport

Public transport has a broad understanding since it can be seen as train, bus and other vehicles that operate according to a timetable. The most basic approach is to increase the frequency to increase the capacity of the public transport line. The costs for busses are relatively low, but for trains the possibility depends on the railroad track and the capacity of the electricity network. In Zandvoort the main public transport is the train that has a frequency of four times per hour with a train capacity of 500 travellers. The solutions 6 and 7 will try to increase the frequency to have more people going to Zandvoort per hour.

Solution 6: More trains per hour (Electric)

Solution 6 is the upgrade of the overhead line that has the current capacity of four trains per hour. This can be extended to twelve trains per hour. Prorail estimated the costs for an upgrade of the overhead lines together with the lengthening of station Zandvoort on 7 million euro. CROW (2015) estimated costs for a new overhead line on 1.2 million per kilometer. This includes also the rails, but this is already present between station Haarlem and station Zandvoort. The overhead costs and the adjustment of some alternating tracks is estimated on €5,000,000.

Solution 7: More trains per hour (Diesel)

A cheaper temporary solution is the usage of diesel trains. These will be used in solution 7. The diesel trains are a little more expensive. According to CROW (2015) the costs for diesel trains are €1.20 per kilometer and the costs for electric trains are €0.30 per kilometer. The calculation method for costs of Public transport is done in diensregularen (DRU's). These DRU's take into account costs for personnel and usage of the vehicle also on the times that it has to wait for the next shift. The cost of personnel and vehicle usage will be the same per train and is estimated between €400 and €800 per hour. The highest costs will be used since the event is on a weekend, which means higher cost of personnel. There is also a costs for usage per kilometer between €6 and €13 per kilometer, but this is for this example included in the DRU's.

For the effects there are some differences between solution 6 and 7 and those are represented in the Appendix E.

Lengthening or the station platform

For safety reasons the train cannot be longer than the platform. Therefore it might be interesting to lengthen the platform to allow longer trains. Temporary platforms might also be an option to extend the trains or to let the train stop at a more efficient place to drop-off passengers. The lengthening of the station has an indirect effect on the capacity since the lengthening allows other types of trains to board from the station.

Capacity of vehicles

The vehicles might come at a higher capacity if the trains can be extended if the station allows that, but taking out places to sit might also increase capacity since standing places occupy less space. For safety reasons this might not be an option, but that is yet undecided.

Table D.4: Train Characteristics in the Netherlands, (Prorail, 2012)

Train name	Number of wagons	Length (m.)	Weight (tonnage)	Max Speed (km/h)	1st class seats	2nd class seats	Standing places
VIRM-III	3	82	179	160	64	330	186
VIRM-IV	4	108	234	160	132	442	276
VIRM-VI	6	162	349	140	132	494	188
SGM1	2	52	106	120	24	116	?
SGM2	3	78	142	120	36	186	?
SLT4	4	70	129	160	40	144	213
SLT6	6	100	176	160	56	244	348
DM90	1-3	52 - 95	140	12	157	160	

Solution 8: Lengthening of station Zandvoort

The station currently is able to handle train that are around 80 meters long. If the station is lengthened the trains with length up to 170 meters can board from station Zandvoort. This will increase the capacity of the trains. On top of the seats and standing places is an extra loading factor that can be used in peak hours. This means that the amount of travellers is actually higher than the train is calculated for. NS expect that a train can carry 1000 people in a full train of type VIRM-VI. This means a doubling of the amount of visitors per hour by lengthening the station. The costs are estimated on €2,000,000, by looking at the total costs of €7,000,000 for lengthening and overhead.

Temporary station could not be found in the literature or at Prorail, therefore the uncertainty about this solution become to high. Temporary station is therefore not a solution within the spreadsheet and calculations for the methodology.

D.1.4 Pedestrian network

In the world of pedestrian capacities the maximum capacity is often not used as a parameter, but the LOS (level of service). Multiple studies in different areas and with different types of pedestrians (age, gender, ect.) have been performed (Itami, 2002; Los, 2006; Roupail & Allen, 1998). There are some differences but it one average the values shown in table D.5.

Table D.5: Level of Service (LOS) criteria, (Itami, 2002)

Level of Service	Space (m ² /ped)	Flow Rate (ped/min/m)	Flow Rate (ped/hour/m)	Average Speed (m/s)
A	>5.6	<14	< 840	>1.3
B	3.7 - 5.6	14 - 21	840 - 1260	1.27 - 1.3
C	2.2 - 3.7	21 - 33	1260 - 1980	1.22 - 1.27
D	1.4 - 2.2	33 - 49	1980 - 2940	1.14 - 1.22
E	0.75 - 1.4	49 - 60	2940 - 3600	0.75 - 1.14
F	<0.75	var.	var.	< 0.75

For the calculations on the pedestrian network the LOS E is used to test the streets around the circuit of Zandvoort. Since the capacity of the pedestrian network gives no problems in terms of delay hours or latecomers there will be no changes to it.

D.1.5 Non-infrastructural Solutions

Some extra temporary solutions can be thought of when trying to reduce the amount of delay hours and latecomers. These solutions are described below.

Solution 9: Busses from Haarlem

The infrastructural investments could also be avoided by using busses from station Haarlem to the circuit. This way there are no investment costs, but only operational costs for the hiring of those busses. The capacity of a touring car is set to 60 persons and the back and forth time is estimated on 60 minutes. This means 60 persons per hour and with a number of 150 operational busses this leads to the same capacity as the station lengthening and overhead upgrade together. The costs for a touring car are set to €1000 per bus per day.

Solution 10: Modal Shift Management

Another champagne that could be held is the modal shift management champagne. This is solution 10 that tries to seduce people to take the train or bicycle instead of the car. This advertisement is estimated on €50,000 to send information to ticket holders.

Solution 11: Busses from the parking places in Zandvoort

Travel time is also an aspect that is valued. This VOT has an influence on the costs that visitors pay for the event. If the parking places for cars also have a P+R function with shuttle busses the total travel time of those visitors will go down. With the zero solution the average walking distance from the parking is 4 kilometer. With a bus from the parking this average distance is reduced to 1,2 kilometer. With 30 busses for the same price as solution 9 this comes down to €30,000.

Solution 12: Post and Pre Activity

Instead of increasing the capacity of persons per hour that can be transported by a network of a modality the demand could be spread out. If the event has multiple activities before and after the event there might be a group of visitors that will come earlier and a group that will leave not immediately after the main activity of the event. The costs for an 'after party' with artists and facilities is estimated on €100,000. The demand curve will spread out by a few hours and will decrease the maximum percentage of persons per 10 minutes from 13% to 9%, see Appendix C.

Solution 13: Busses from P+R location in region

The last solution is coming again from Organisation of DGP (2019), who propose to have visitors by car to park in the region. From those parking places busses will set off towards the circuit. This way the whole investments in the infrastructure and parking places in Zandvoort can be avoided. The amount of busses needed is set to 250 with a back and forth time of one hour. Operational costs are therefore set to €250,000.

D.2 Overview of possible options at Hallmark Event

Now that all the different (infrastructural) investment or solutions are discussed an overview is given in table D.6. There will probably be more options to think of, but since this research is mainly based at testing the ROA methodology at Hallmark Event these will be the options that are used.

Table D.6: List of possible investments at Zandvoort to facilitate the Hallmark Event

Solution Number	Name	Description	Type of flexibility	Cost type	Costs
1	Extra parking places for cars	In the current situation with the expected number of cars there are 15,000 parking places short, if parking would be facilitated in Zandvoort.	Waiting for Certainty	Investment Maintenance Operational External	€3,150,000 €9,450 €- €15,000
2	Parking restrictions for cars	Zandvoort expects an average of 2.7 persons per car. The restriction doesn't allow cars to pass when less than 3 persons are in.	Natural Flexibility	Investment Maintenance Operational External	€50,000 €- €25,920 €-
3	Car Infrastructure	The N200 is a 2x2 lane arterial road towards Zandvoort, but has a single lane roundabout connection in Overveen. This could be transformed into a turbo-roundabout for a higher capacity.	Waiting for Certainty	Investment Maintenance Operational External	€3,000,000 €20,000 €- €-
4	Extra parking places for bicycles	If every bicycle should have facilitated parking place there are 10,000 places short.	Natural Flexibility	Investment Maintenance Operational External	€- €- €280,000 €-
5	Route information guiding and rental bikes	Rental bikes at station Haarlem and regional P+R with route information.	Natural Flexibility	Investment Maintenance Operational External	€- €- €500,000 €-
6	More trains per hours (electric)	A change of overhead lines is needed to facilitate more than four trains per hour. With this change 12 trains per hour is possible.	Waiting for Certainty	Investment Maintenance Operational External	€5,000,000 €91,237 €43,200 €-
7	More trains per hours (diesel)	Diesel trains can increase the amount of trains per hour without a overhead line investment	Natural Flexibility	Investment Maintenance Operational External	€- €- €43,200 €-
8	Stations Lengthening	The station can only handle trains with 2 carriages (approx. 500 travellers) the lengthening makes this a 4 carriages train	Waiting for Certainty	Investment Maintenance Operational External	€2,000,000 €100,000 €- €-
9	Busses from Haarlem	Busses will transport the visitors from station Haarlem towards the event.	Natural Flexibility	Investment Maintenance Operational External	€- €- €150,000 €-
10	Traffic management	This marketing campaign will change the modality of the visitors. The impact is small, but can reduce delay time relatively cheap.	Natural Flexibility	Investment Maintenance Operational External	€50,000 €- €- €-
11	Busses from parkings	The walking distance from the parking places in Zandvoort are large and reducing the walking time reduces the total travel time.	Natural Flexibility	Investment Maintenance Operational External	€- €- €30,000 €-
12	Post and pre-activity	This investment spreads out the demand curve and therefore delay hours.	Natural Flexibility	Investment Maintenance Operational External	€- €- €100,000 €-
13	Busses from P+R (in region)	This solution bans the car from entering Zandvoort and park in the region where busses will transport the visitors towards the event	Natural Flexibility	Investment Maintenance Operational External	€- €- €250,000 €-

One major attention point are the side-effects of tackling a bottleneck. One can imagine that by re-designing an intersection for a better car flow the maximum capacity for the bicycle network can become

lower due to the barrier effect of improved car network. Anciaes and Jones (2015) did a research towards the influence of motorized traffic on pedestrian flows. He found a negative correlation between the level of motorized traffic and the pedestrian flows crossing the road. This is just an example of a measure that influences another modality, but this needs to be taken into account seriously. For simplicity reasons and the aim of this research, which is testing a methodology, this level of detail will be simplified or discharged.

D.3 Effects of options on comparison characteristics

Comparing solutions on one criteria is usually not preferred, otherwise the cheapest solutions always wins in the case of comparing on costs. Therefore other criteria need to be added to the new methodology at Hallmark Events. Because this will be the first attempt for applying ROA at Hallmark Events the methodology will be tested with only two criteria for simplicity reasons. In this section a decision will be made on the second criteria to test the solutions on.

D.3.1 Value of Time

The first costs for the individual visitors is cost for travel time. The solutions may effect the total travel time of all the visitors. The most common way for valuing (road)infrastructure is valuing the solution of travel time savings and up to 80% of the monetized benefits in these kind of projects are made up out of travel time savings. (P. J. Mackie et al., 2001; P. Mackie et al., 2018; Martens & Di Ciommo, 2017; WATTERS, 1992). This is done by researching the individual willingness to pay for a specific type of trip combined with a duration of the trip. This results in a VOT (value of time) that indicates the amount of money a person is willing to pay for a time reduction on a trip. This value can differ with the type of trip, for example commuting, business or shopping. In this research the main focus is on reducing the travel time and this is an even more complex aspect to monetize, because not only the travel time but also the quality of the travel influences the VOT. Another difficulty is that the VOT is constantly changing over time and therefore predictions in the long term need to be aware of deviations of travel behaviour over time due to the VOT changes (ITF (International Transport Forum), 2019).

The VOT per person is set on €9,00 with an additional factor for the status of the trip (CE Delft, 2014). The schedule delay early ratio (SDER) and schedule delay late ratio (SDLR). If a visitor is arriving a hour earlier than the money saved is $VOT \times SDER$. The other way around is the cost for extra an extra hour travel time which has the value $VOT \times SDLR$. $SDER = 0.748$ and $SDLR = 1.652$. These values are used for the calculations of delay hours when visitors encounter delay in the chosen network. For the travellers in PT the VOT is a little lower and estimated on €6.75 per hour (CE Delft, 2014).

The value of time needs to be estimated for a project every time, but to include the change of VOT the VOT can be adjusted over time with a discount rate. The discount rate is also used in projects to include the interest rate, which implies the loss of value of money over time. In the Netherlands the discount rate of 4 percent is used for infrastructural investments (Harrison, 2010). This type of discount rate is called the risk free discount rate which does not mean the projects are risk free, but the government can spread the risk in a way there is no risk for external investors or taxpayers. Several studies have been executed on the discount rate and different form, but this is not of big interest in this study. This report will be about the development of a methodology for applying ROA on Hallmark Events and therefore the discount rate will be set on 4 percent, because this is the Dutch discount rate, without further debate on the matter.

D.3.2 Latecomers

The capacity of the networks might be so low that there will be visitors that cannot make it on time. Those visitors are called latecomers in the report. For missing the event it would be nice to know the Value of Missing Out (VOMO). This is what the visitor is willing to pay extra for not missing the event. This value can then be multiplied by the amount of latecomers. Because there is nothing known about

this VOMO the value is set to €150, this is the additional amount of money the delayed visitor is willing to pay extra for being able to arrive on time. This value is €150 based what the value for the cheapest tickets is roughly D.6, however the value of VOMO is not described in literature and therefore highly uncertain.

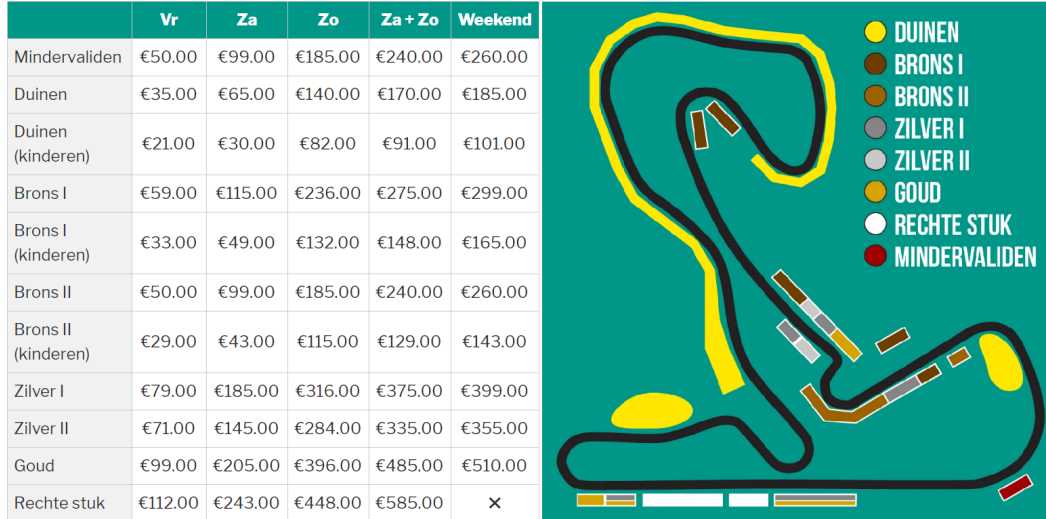


Figure D.6: Ticket prices for DGP

D.3.3 Traffic Safety

Traffic safety effects cannot be measured with big accuracy, but there is a way to monetize the effects of infrastructural changes to the network. SWOV (2017) made report for SWOV (Stichting Wetenschappelijk Onderzoek Verkeersveiligheid) about monetizing aspects like traffic safety and pollution. In table D.7 the value for fatalities can be found. The costs are made up out of the loss of life, hospital costs and loss of productivity, which means that the person has no more economic value for working.

Table D.7: Costs for traffic safety, (SWOV, 2017)

Country	Costs per death	Costs per heavily injured
The Netherlands	2,900,000	310,000

With the costs for the deaths and injuries one multiplier remains which is the amount of deaths and injured passengers per type of vehicle. In table D.8 the values found by SWOV (2011) can be found. Note: The values can be more specific, for example the chance for death in a car is higher for a passenger than for the driver.

Table D.8: Deaths and Injured per billion vehicle kilometer, (SWOV, 2011)

Modality	Deaths	Heavily injured
Car	2	200
Touring car	30	1400
Bus	30	1400
Bicycle	14	700
Pedestrian	16	225
Train (electric)	24	3000
Train (diesel)	24	3000

D.3.4 Environmental Aspects

Environmental effects are measured in the amount of pollutants that are produced by a vehicle. The value of these pollutants are calculated by van Essen et al. (2008) and given in table D.9. These values will be used to calculate the monetized effects on the environment by the usage of the different modalities to enter the Hallmark Event.

Table D.9: Emission costs per kilometer, (van Essen et al., 2008)

Modality	CO2	NOx	PM	SO2	Total €/km
Car	0.0045	0.0024	0.0087	0.0019	0.0175
Touring car	0.0318	0.0822	0.1657	0.0124	0.2921
Bus	0.0040	0.0030	0.0129	0.0020	0.0219
Bicycle	0.00	0.00	0.00	0.00	0.00
Pedestrian	0.00	0.00	0.00	0.00	0.00
Train (electric)	0.0005	0.0002	0.00	0.0002	0.0009
Train (diesel)	0.0022	0.0068	0.0560	0.0009	0.0659

D.3.5 Noise

Noise is another aspect that can be monetized for the loss of livability that it might generate (CE Delft, 2014). The CE Delft did another study to find the estimated costs for noise by different modalities. Their finding can be found in table D.10.

Table D.10: Noise costs per kilometer, (CE Delft, 2014)

Modality	€/km
Car	0.032
Touring car	0.014
Bus	0.097
Bicycle	0.00
Pedestrian	0.00
Train (electric)	0.013
Train (diesel)	0.017

D.3.6 Maintenance

Maintenance for the different networks can be another external aspect with potential high costs. Attracting more cars will lead to more maintenance costs than train users. In table D.11 the costs per kilometer for a specific modality are given.

Table D.11: Maintenance costs per kilometer, (CE Delft, 2014)

Modality	Variable	Fixed	€/km
Car	0.001	0.0061	0.0071
Touring car	0.0464	0.0182	0.0646
Bus	0.0377	0.0182	0.0559
Bicycle	0.00	0.00	0.00
Pedestrian	0.00	0.00	0.00
Train (electric)	-	-	0.044
Train (diesel)	-	-	0.041

At this point all the different effects are given with the costs to monetize the effects. There will be way more ways to estimate costs and values will vary throughout the literature probably and therefore these values need to be updated for every new Hallmark Event that is tested with the new methodology.

Appendix E

CBA with ROA Tool description

In this Appendix the tool that was developed will be explained for all the steps in the tool. The steps in the tool are based on the steps that were introduced in the new Methodology in Chapter 4.

E.1 0. Data Input

The first sheet in the excel tool includes the data that is needed to transform non-monetary values into monetary values. In Appendix D the input is given for all the different aspects. These values are all in this sheet to monetize the effects, what is performed in step 6 of the method. This sheet is brought to the front to let the reader immediately know what values are used to avoid creating a black box for the decision maker.

Values are given together with the sources where the value is based on. These sources are all mentioned in the bibliography and further explanation is found in Appendix D.

E.2 1. Hallmark Characteristics

Step 1 can be found in the spreadsheet pages. It contains some basis values that are used for the event. Some of the values did come from Appendix F where the DGP is explained with the characteristics that come with the event. It basically comes down to describing the demand for transport facilities by the amount of visitors and the modality they will use. An average of kilometers travelled is included to also give a value for the normal travel time expected from just the delay hours, which are calculated later on.

E.3 2. Network Qualities

The network qualities are the other part of the problem definition. For the four different networks the available network characteristics have been mentioned and described. The different bottlenecks of all the networks have been represented by the minimum of the different parts of the network. The main bottleneck for each modality determines the capacity and with the queuing theory from Appendix C the delay hours and latecomers are estimated.

E.4 3. Determine Solutions

In the same sheet '3. Determine Options' the different solutions are given for the problem that has been given. All the dark orange colored tabs are the ones changed compared with the 'option zero' and can be seen as solution specific changes.

For those solutions investment costs, maintenance costs, operational costs and external costs are presented. The solutions are explained in Chapter 3, that is dedicated to the case study of the DGP in Zandvoort.

E.5 4. Determine Effects

In this steps the effects on the network are given. With these effects also vehicles kilometers per modality will change. These cause effects on emissions, safety and travel time. Since the travel times are given at the Hallmark Characteristics there will be changes in total travel time once a modal shift takes place for example. The main purpose of the solutions is to give a positive effect to one or more of the network capacities. These effects will again have effect on the delay hours with the cumulative curve calculations and on the latecomer (with amount of parking places or amount of visitors in the network once the event starts).

E.6 5. Costs and Monetizing Effects

In this step the effects of the solutions on the networks are given. The values from the Data Input sheet are used to monetize the effects on:

- Travel Time
- Delay Hours
- Parking Shortage
- Latecomers
- Emissions
- Traffic Safety
- Maintenance

The way those effects are monetized can be found in Appendix D.

E.7 6. Risks and Scenarios

The risks are transformed into scenarios and with the probabilities for the different outcomes multiple scenario combinations are made. These can all be found in Chapter 3 about the case study. In the sheets on discounted cash flows and the NPV calculations the scenarios that have been developed are used. No further explanation about the development of the scenarios is given here.

E.8 Discounted Cash Flow

The discounted cash flow sheets that are in this appendix are just a small example of what the discounted cash flow sheet is doing. There are over 20 combinations with 4 investment moments that all have the discounted cash flow running over 29 years. Therefore only a few solutions are shown.

In the sheet the options for the solutions can be seen in the left column. The option represents the solution together with the decision moment in the 2nd column. The operational years can be seen in the rows and are on or off (1 or 0). The investment is done in the decision year (0, 1, 4 or 14) and from then on the operational years will be on. From that moment on all the monetized effects that come with the solution start running over the years and are discounted with the discount rate. All the costs or benefits

are relative to the zero options. This means that if a solution is deferred till the next decision moment the costs and benefits are zero. This is because they are the same for doing nothing.

The scenarios in the columns on the right will add up the years that are applicable to the scenario. So the scenario 14 years, will add up all the costs and benefits of the first 14 years in the discounted cash flow sheet. There is only one exception, which are the ongoing maintenance costs. If an investment is done the maintenance will go on till year 29 no matter the outcome of the scenario. This is done to make it more realistic since maintenance on the infrastructure is needed even if it is not used.

All the costs and benefits are added up for the different scenarios and give a value for the Expanded NPV. For the B/C-ratio all the benefits are divided by all the costs. If the costs are zero, which is possible for deferring a solution since it is relative to doing nothing, the formula will divide by zero. This is mathematically not possible so the spreadsheet will give an error. In a later sheet these values will be set to zero. In these cases the NPV is also 0 and there is therefore no improvement or impairment compared with doing nothing.

E.9 Net Present Value calculation with flexibility

In Chapter 2 the method has been developed which is the foundation of this spreadsheet. For the ROA it became clear the normal NPV calculation is not sufficient (van Aarle, 2013). The Expanded NPV is a better method since the value for flexibility can be distinguished in a proper way. This value for flexibility is called the Option Premium.

In this sheet the outcomes of the of all the Expanded NPV and B/C-ratio's are given for all the combinations of investment moments and scenarios. A brief explanation is needed to read this spreadsheet. The scenarios are given in row above the calculated values, respectively 1, 4, 14 and 29 years. The scenario in combination with the investment moment gives a value in the Expanded NPV columns or for the B/C-ratio in middle rows. On the right the columns are given with the value for the Option Premium.

The Option Premium is the difference between the saved investment costs and the benefits that have not been used, because the investment was not made. This is a positive value in the the case of having only a few repetitions and a big investment. However this value can also be negative if there are much more repetitions and the decision maker is missing out on the potential benefits of the solution that he refused to make.

E.10 Scenario Combinations

In the scenario combination sheet the chances for the different scenario outcomes are used to calculate an average value for Expanded NPV and B/C-ratio. One scenario combination is shown in this appendix. All the four scenarios have a same probability for turning out. For the outcome of a solution, with a specific investment moment in a scenario combination, the probabilities for a scenario are multiplied by the actual NPV or B/C-ratio outcome. This will give in the end an estimation for the Expanded NPV and the B/C-ratio when doing an investment in a specif year based on the chances for having a specific amount of repetitions in a scenario combination. The way the scenarios are designed is better explained in Chapter 2.

In the right columns the values for Expanded NPV and B/C-ratio are given. The way the scores are normally treated is implemented in the sheet. For the Expanded NPV the value must be positive and for the B/C-ratio the value must be higher than one.

E.11 Step 7. Determine Investment moments

For this step the Appendix G is used. In that Appendix the actual scores of the different investment moments for the solutions is given. It basically comes down to putting the B/C-ratio on the y-axis and

the Expanded NPV on the x-axis to visualise the score of that investment moment. Those values were given in the Scenario Combination sheets.

0. Data Input for the calculation

In this sheet all the value for transforming data into monetary values are given.

Emissions						Source
Emission costs in cents per kilometer						Essen, H., Davidson, F., Brouwer, F. (2008)
Modality	CO2	Nox	PM	SO2	Total €/km	
Car	0,45	0,24	0,87	0,19	0,0175	
Private Bus	3,18	8,22	16,57	1,24	0,2921	
Bus	0,4	0,3	1,29	0,2	0,0219	
Bicycle	0	0	0	0	0	
Pedestrian	0	0	0	0	0	
Train (electric)	0,05	0,02	0	0,02	0,0009	
Train (diesel)	0,22	0,68	5,6	0,09	0,0659	
Safety						SWOV(2017) SWOV(2017) SWOV(2011)
Costs per death	2900000					
Costs per heavily injured	310000					
Per billion travel kilometers						
Modality	Deaths	Heavily Injured				
Car	2	200				
Private Bus	30	1400				
Bus	30	1400				
Bicycle	14	700				
Pedestrian	16	225				
Train (electric)	24	3000				
Train (diesel)	24	3000				
Maintenance						CE Delft (2014)
Maintenance in cents per kilometer						
Modality	Variable	Fixed	Total €cents/k m			
Car	0,1	0,61	0,71			
Private Bus	4,64	1,82	6,46			
Bus	3,77	1,82	5,59			
Bicycle						
Pedestrian						
Train (electric)	-	-	4,4			
Train (diesel)	-	-	4,1			
Noise						
Modality	Costs					
Car	3,2	cents per km				
Private Bus	1,4	cents per km				
Bus	9,7	cents per km				
Bicycle	0	cents per km				
Pedestrian	0	cents per km				
Train (electric)	1,3	cents per km				
Train (diesel)	1,7	cents per km				
Value of Time						CE Delft (2014)
Traveler type	VOT	SDER	SDLR			
Person	9	0,748	1,652			
Person (in PT)	6,75	0,748	1,652			
Transport	42,2	0,748	1,652			
Value for Missing Out						
Person	€	150 euro				
Illegal Bike Parking Costs						
Person	€	0 euro				

1. Hallmark Characteristics

Determine traffic demand at the Hallmark Event

Input data	Data	Unit	Average kilometers travelled
Total amount of visitors	105000	#	
Share of car	40%	%	
	42.000	#	35 kilometers
Share of bicycle	18%	%	
	18.900	#	8,5 kilometers
Share of PT	40%	%	
	42.000	#	40 kilometers
Share of pedestrian	2%	%	
	2100	#	3 kilometers
Event duration	2	days	

2. Network Qualities

Indexate the combined capacity based on capacity per modality

Network	Capacity	Unit	Description
Car	12000	persons/h	Minimum of links, intersections and parking
Bicycle	10000	persons/h	Minimum of links, intersections and parking
Public Transport	1100	persons/h	Frequencies x Vehicle capacity x Loading factor
Pedestrian	72000	persons/h	Service level x street width
Total Capacity	23100	persons/h	

Car bottlenecks	Data	Unit	
Links	6600	Vehicles/h	Combined capacity of N200 and N201
Intersections	4000	Vehicles/h	Capacity of access intersections towards N200 and N201
Parking entrances	12	#	
Parking places	7850	places	Combined amount of parking places in Zandvoort
entrances capacity	600	Vehicles/h	Marvsanic (2011)
Vehicles capacity	4	Persons/vehicle	
Loading factor	75%	%	average amount of people in a car

Bicycles bottlenecks	Data	Unit	
Links	15000	Vehicles/h	Combined capacity bicycle paths
Intersections	10000	Vehicles/h	Combined capacity intersections towards bicycle paths
Parking places	5000		
Parking entrances	300	#	
entrances capacity	5000	Vehicles/h	

Rail bottlenecks	Data	Unit	
Frequency	2	Train/h	
Carriage capacity	500	Persons/carriage	
Loading factor	110,00%	%	

Pedestrian bottlenecks	Data	Unit	
Level of Service E	3600	Persons/hour/meter	
Meter of width	20		

Network	Share based on capacity
Car	52%
Bicycle	43%
Public Transport	5%
Pedestrian	-

3. Determine Solutions

Determine traffic demand at the Hallmark Event

Input data	Option zero	Car		Bicycle		Public T
		Option 1	Option 2	Option 3	Option 4	
	No action performed	Extra parking places for the car	Parking restrictions for the car	Infrastructure for the car	Extra temporary parking places for the bike	Route information guiding + available rental bikes
						More trains per hour (Electric)
						More trains per hour (Diesel)
Description						
Investment costs	€ -	€ 3.150.000,00	€ 50.000,00	€ 3.000.000,00	€ -	€ 5.000.000,00
Maintenance costs	€ -	€ 9.450,00	€ -	€ 20.000,00	€ -	€ 91.237,50
Operational costs	€ -	€ -	€ 25.920,00	€ -	€ 280.000,00	€ 43.200,00
External costs (reservation)	€ -	€ 15.000,00	€ -	€ -	€ -	€ -

Input data	Option zero	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6		Option 7	
		Option 1	Option 2	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12
Total amount of visitors	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000	105000
Share of car %	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Share of car #	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000
Average trip length	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Average duration (hour)	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40
Share of bicycle	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%
Share of bicycle #	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900	18.900
Average trip length	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5
Average duration (hour)	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57
Share of PT	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000
Share of pedestrian	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
# Visitors walking from car	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# Visitors walking from PT	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
Walking average from parking	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000	42.000
Walking time (hours)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Walking average from station	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8
Walking time	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Walking time	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2

Change in demand curve	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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4. Determine Effects

Indexate the combined capacity based on capacity per modality

Network	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Car		12000	12000	12480	19800	12000	12000	12000	12000
Bicycle		10000	10000	10000	10000	10000	12500	10000	10000
Public Transport		2200	2200	2200	2200	2200	2200	6600	6600
Pedestrian		72000	72000	72000	72000	72000	72000	72000	72000
Total Capacity		24200	24200	24680	32000	24200	26700	28600	28600

Car bottlenecks	Data	Data	Data	Data	Data	Data	Data	Data	Data
Links	4400	4400	4400	4400	6600	4400	4400	4400	4400
Intersections	4000	4000	4000	4000	6600	4000	4000	4000	4000
Parking entrances	12	12	12	12	12	12	12	12	12
Parking places	7850	11000	7850	7850	7850	7850	7850	7850	7850
entrances capacity	600	600	600	600	600	600	600	600	600
Vehides capacity	4	4	4	4	4	4	4	4	4
Loading factor	75%	75%	78%	75%	75%	75%	75%	75%	75%
Additional touring car									

Average trip length (km)	0	0	0	0	0	0	0	0	0
Duration of the trip (hour)	0	0	0	0	0	0	0	0	0
Percentage of other modality	0%	0%	0%	0%	0%	0%	0%	0%	0%
Amount of users	0	0	0	0	0	0	0	0	0
Capacity of the bus	60	60	60	60	60	60	60	60	60
Amount of trips	0	0	0	0	0	0	0	0	0
Amount of busses	0	0	0	0	0	0	0	0	0
Total capacity (persons per hour)	0	0	0	0	0	0	0	0	0
Total vehicles kilometers	0	0	0	0	0	0	0	0	0

Bicycles bottlenecks	Data	Data	Data	Data	Data	Data	Data	Data	Data
Links	15000	15000	15000	15000	15000	15000	15000	15000	15000
Intersections	10000	10000	10000	10000	10000	12500	10000	10000	10000
Parking places	5000	5000	5000	5000	19000	5000	5000	5000	5000
Parking entrances	300	300	300	300	300	300	300	300	300
entrances capacity	5000	5000	5000	5000	5000	5000	5000	5000	5000

Rail bottlenecks	Data	Data	Data	Data	Data	Data	Data	Data	Data
Frequency (4 + ADDITIONAL)	4	4	4	4	4	4	12	12	12
Amount of trains used	1	1	1	1	1	1	4	4	4
Carriage capacity	500	500	500	500	500	500	500	500	500
Loading factor	110,00%	110,00%	110,00%	110,00%	110,00%	110,00%	110,00%	110,00%	110,00%
Operational hours	18	18	18	18	18	18	18	18	18
Additional Diesel Train									
Frequency (ADDITIONAL)	0	0	0	0	0	0	0	0	8
Carriage capacity	0	0	0	0	0	0	0	0	500

DRU tariff	€	800,00	€	800,00	€	800,00	€	800,00	€	800,00	€	800,00	€	800,00
Operational hours (DRU's)		18		18		18		18		18		18		18
Trip length used		7,5		7,5		7,5		7,5		7,5		7,5		7,5

Pedestrian bottlenecks	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data
Level of Service E		3600		3600		3600		3600		3600		3600		3600
Meter of width		20		20		20		20		20		20		20

Network	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity
Car		50%		50%		51%		62%		50%		45%		42%
Bicycle		41%		41%		41%		31%		41%		47%		35%
Public Transport		9%		9%		9%		7%		9%		8%		23%
Pedestrian	-	-	-	-	-	-	-	-	-	-	-	-	-	-

5. Costs and Monetize Effects

Indexation of persons loss hours because of the capacity constraints

Travel time costs	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC	TTC
Car		529.200		529.200		529.200		529.200		529.200		529.200		529.200
Touringcar (private bus)		-	-	-	-	-	-	-	-	-	-	-	-	-
Bicycle		96.390		96.390		96.390		96.390		96.390		96.390		96.390
Pedestrian		389.340		389.340		389.340		389.340		389.340		389.340		389.340
Train (ELECTRIC		189.000		189.000		189.000		189.000		189.000		189.000		63.000
Train (Diesel)		-	-	-	-	-	-	-	-	-	-	-	-	126.000
total		1.203.930		1.203.930		1.203.930		1.203.930		1.185.030		1.203.930		1.203.930

Network	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours
Car		27.500		27.500		25.292		6.535		27.500		27.500		27.500
Bicycle		1.772		1.772		1.772		1.772		1.772		12.908		1.772
Public Transport		203.055		203.055		203.055		203.055		203.055		101.394		79.390
Pedestrian		-	-	-	-	-	-	-	-	-	-	-	-	-

Parking shortage	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours	Delay hours
Car		18450		9000		17508		18450		18450		18450		18450
Bicycle		13900		13900		13900		13900		0		29650		13900
Late arrivals		51096		41646		50154		51096		51096		35596		34359

Network	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs	Travel Costs
Car		292.929		292.929		269.410		69.606		292.929		292.929		292.929
Bicycle		18.871		18.871		18.871		18.871		18.871		137.492		18.871
Public Transport		1.706.064		1.706.064		1.706.064		1.706.064		1.706.064		851.913		667.037
Pedestrian		-	-	-	-	-	-	-	-	-	-	-	-	-

Total delay costs		9.807.324	8.389.824	9.642.505	9.584.001	9.682.224	6.888.636	6.257.802	6.257.802
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Emissions	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs
Car	51.450	51.450	51.450	51.450	51.450	51.450	51.450	51.450
Bicycle	0	0	0	0	0	0	0	0
Pedestrian	0	0	0	0	0	0	0	0
Touringcar	0	0	0	0	0	0	0	0
Train (Electric)	0	0	0	0	0	0	0	0
Train (Diesel)	0	0	0	0	0	0	1	0
total	51.451	51.451	51.451	51.451	51.451	51.451	51.451	51.522

Traffic Safety	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs
Car	199332	199332	199332	199332	199332	199332	199332	199332
Touringcar (private bus)	0	0	0	0	0	0	0	0
Bicycle	41383	41383	41383	41383	41383	75870	41383	41383
Pedestrian	5025	5025	5025	5025	5025	4659	5025	5025
Train (ELECTRIC	540	540	540	540	540	540	1619	540
Train (Diesel)	0	0	0	0	0	0	0	1080
total	246280	246280	246280	246280	246280	280400	247359	247359

Maintenance caused by use	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
Car	6958	6958	6690	6958	6958	6958	6958	6958
Touringcar (private bus)	0	0	0	0	0	0	0	0
Bicycle	0	0	0	0	0	0	0	0
Pedestrian	0	0	0	0	0	0	0	0
Train (ELECTRIC	704	704	704	704	704	704	2112	704
Train (Diesel)	0	0	0	0	0	0	0	246
Total maintenance costs	7668	7662	7394	7662	7662	7662	9070	7908

transport									

Option 8	Flexible non-infrastructurel solutions					Combination				
	Option 9	Option 10	Option 11	Option 12	Option 13	Option 14	Option 15	Option 16	Option 17	
Station Lengthening	Busses from Haarlem instead of trains	Modal Shift Management	Busses from the parkings for car users	Post and Pre activity	Busses from carpool locations for the car users	1 2 9 10 12 (13)	1 2 3 10 12	7 8 10 12	6 8 10 12 (9)	
€ 2.000.000,00	€ -	€ 50.000,00	€ -	€ -	€ -	€ 3.250.000,00	€ 6.250.000,00	€ 2.050.000,00	€ 7.050.000,00	
€ 100.000,00	€ -	€ -	€ -	€ -	€ -	€ 9.450,00	€ 29.450,00	€ 100.000,00	€ 191.237,50	
€ -	€ 150.000,00	€ -	€ 30.000,00	€ 100.000,00	€ 250.000,00	€ 175.920,00	€ 125.920,00	€ 143.200,00	€ 143.200,00	
€ -	€ -	€ -	€ -	€ -	€ -	€ 15.000,00	€ 15.000,00	€ -	€ -	

Option 8	Option 9	Option 10	Option 11	Option 12	Option 13	Option 14	Option 15	Option 16	Option 17
105000	105000	105000	105000	95000	105000	105000	105000	105000	105000
40%	37%	40%	40%	40%	37%	37%	37%	40%	40%
42.000	38.850	42.000	42.000	38.000	42.000	38.850	38.850	42.000	42.000
70	70	70	70	70	50	70	70	70	70
1,4	1,4	1,4	1,4	1,4	1,0	1,4	1,4	1,4	1,4
18%	19%	18%	18%	18%	18%	19%	19%	18%	18%
18.900	19.950	18.900	18.900	17.100	18.900	19.950	19.950	18.900	18.900
8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5	8,5
0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57	0,57
40%	42%	40%	40%	40%	40%	42%	42%	40%	40%
42.000	44.100	42.000	42.000	38.000	42.000	44.100	44.100	42.000	42.000
40	40	40	40	40	40	40	40	40	40
0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67
2%	2%	2%	2%	2%	13%	2%	2%	2%	2%
2100	2100	2100	2100	1900	13125	2100	2100	2100	2100
3	3	3	3	3	3	3	3	3	3
0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
42.000	38.850	42.000	42.000	38.000	42.000	38.850	38.850	42.000	42.000
42.000	44.100	42.000	42.000	38.000	42.000	44.100	44.100	42.000	42.000
4	4	4	1,2	4	4	4	4	4	4
0,8	0,8	0,8	0,24	0,8	0,8	0,8	0,8	0,8	0,8
1	1	1	1	1	1	1	1	1	1
0,2	0,2	0,2	0,4	0,2	0,2	0,2	0,2	0,2	0,2

0	0	0	0	1	1	1	1	1	1
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7.954.565	3.469.539	9.711.542	9.807.324	7.785.351	6.918.259	1.095.644	7.474.741	3.136.137	3.136.137
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Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs	Emission Costs
51.450	51.450	47.591	51.450	46.550	36.750	47.591	47.591	51.450	51.450
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	1.022	0	256	0	5.112	1.073	0	0	0
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	71	0
51.451	52.473	47.592	51.706	46.551	41.862	48.665	47.592	51.522	51.451

Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs
199332	199332	184382	199332	180348	142380	184382	184382	199332	199332
0	1824	0	456	0	9118	1915	0	0	0
41383	41383	43683	41383	37442	41383	43683	43683	41383	41383
5025	5025	4781	3268	4546	5793	4781	4781	5025	5025
540	540	540	540	540	540	540	540	540	1619
0	0	0	0	0	0	0	0	1080	0
246280	249927	233385	245435	222876	208331	237214	233385	247359	247359

Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
6958	6958	6436	6958	6295	4970	6189	6189	6958	6958
0	22610	0	5653	0	113050	23741	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
704	704	704	704	710	704	711	711	2136	2138
0	0	0	0	0	0	0	0	246	0
7662	30272	7140	13315	7011	118724	30640	6900	9340	9096

s of solutions				
Option 18	Option 19	Option 20	Option 21	
4 5 10 12	2 9 10 12	7 8 10 12 13	4 6 8 12 13	ORIGINAL DGP PLAN
€ 50.000,00	€ 50.000,00	€ 2.050.000,00	€ 7.000.000,00	
€ -	€ -	€ 100.000,00	€ 191.237,50	
€ 880.000,00	€ 280.000,00	€ 673.200,00	€ 673.200,00	
€ -	€ -	€ -	€ -	

Option 18	Option 19	Option 20	Option 21	
105000	105000	105000	105000	
35%	30%	37%	40%	
36.750	31.500	38.850	42.000	
70	70	70	50	
1,4	1,4	1,4	1,0	
21%	25%	19%	18%	
22.050	26.250	19.950	18.900	
8,5	8,5	8,5	8,5	
0,57	0,57	0,57	0,57	
42%	43%	42%	40%	
44.100	45.150	44.100	42.000	
40	40	40	40	
0,67	0,67	0,67	0,67	
2%	2%	2%	2%	
2100	2100	2100	2100	
3	3	3	3	
0,6	0,6	0,6	0,6	
36.750	31.500	38.850	42.000	
44.100	45.150	44.100	42.000	
4	4	4	4	
0,8	0,8	0,8	0,8	
1	1	1	1	
0,2	0,2	0,2	0,2	

1	1	1	1	1
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€	800.00	€	800.00	€	800.00	€	800.00
	18		18		18		18
	7,5		7,5		7,5		7,5

Data	Data	Data	Data
3600	3600	3600	3600
20	20	20	20

Share based on capacity	Share based on capacity	Share based on capacity	Share based on capacity
45%	29%	39%	39%
47%	23%	26%	26%
8%	47%	35%	35%
-	-	-	-

TTC	TTC	TTC	TTC
463.050	396.900	489.510	378.000
152	-	101.588	349.650
	133.875	101.745	96.390
	319.410	370.440	389.340
	203.175	66.150	189.000
	-	132.300	-
1.129.276	1.154.948	1.509.796	1.430.731

Delay hours	Delay hours	Delay hours	Delay hours
7.838	2.423	3.560	5.883
-	2.612	121	31
216.996	1.314	13.131	10.457
-	-	-	-

Delay hours	Delay hours	Delay hours	Delay hours
13200	7008	0	0
10050	21250	14950	0
45437	7008	0	0

Travel Costs	Travel Costs	Travel Costs	Travel Costs
83.486	25.813	37.919	62.669
-	27.820	1.290	334
1.823.204	11.042	110.324	87.862
-	-	-	-

8.812.683	1.307.126	284.082	150.864
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Emission Costs	Emission Costs	Emission Costs	Emission Costs
45.019	38.588	47.591	36.750
0	0	0	0
0	0	0	0
0	1.099	4.728	5.112
0	0	0	1
0	0	71	0
45.019	39.687	52.391	41.863

Traffic safety costs	Traffic safety costs	Traffic safety costs	Traffic safety costs
174416	149499	184382	142380
0	1960	8434	9118
48281	57477	43683	41383
4586	4122	4781	5025
540	540	540	1619
0	0	1080	0
227822	215558	251332	208642

Maintenance	Maintenance	Maintenance	Maintenance
6088	5018	6436	4970
153	24306	104571	113050
0	0	0	0
0	0	0	0
704	704	704	2112
0	0	246	0
6792	30028	111957	120132

Discounted Cash Flows

Discount rates applied to cash flows over time

Discount rate	0,04
Event duration in days	2
Decision moments	4

Year	1	2	3	4	5	6	7	8	9	10	11
Value of money	0,962	0,925	0,889	0,855	0,822	0,790	0,760	0,731	0,703	0,676	0,650
Decision moments	1	2	0	0	3	0	0	0	0	0	0

Decision moment	1										
Operational years	0	1	1	1	1	1	1	1	1	1	1
Investment costs	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	0	0	0	0	0	0	0	0	0	0	0
Operational costs	0	0	0	0	0	0	0	0	0	0	0
External costs	0	0	0	0	0	0	0	0	0	0	0
Travel time costs	-1203930	-1157625	-1113100,962	-1070289,386	-1029124,41	-98542,7016	-951483,367	-914887,8528	-879699,8585	-845865,2486	-813331,9698
Delay hour cost	-9807324,214	-9430119,436	-9067422,535	-8718675,514	-8383341,841	-8060905,616	-7750870,785	-7452760,37	-7166115,74	-6890495,904	-6625476,831
Emission	-51450,5079	-49471,64221	-47568,88674	-45739,31417	-43980,10978	-42288,5671	-40662,08375	-39098,15745	-37594,38216	-36148,44439	-34758,11961
Safety	-246279,873	-236807,5702	-227699,5867	-218941,9103	-210521,0676	-202424,1035	-194638,561	-187152,4625	-179954,2909	-173032,972	-166377,8577
Maintenance costs	-7667,59	-7372,682692	-7089,117973	-6816,45959	-6554,288067	-6302,200065	-6059,807754	-5826,738225	-5602,632909	-5387,147028	-5179,949065

Option zero

154

Decision moment	1										
Operational years	0	1	1	1	1	1	1	1	1	1	1
Investment costs	-3150000	-3150000	0	0	0	0	0	0	0	0	0
Maintenance costs	-9450	-9086,538462	-8737,056213	-8401,015589	-8077,899605	-7767,211159	-7468,472268	-7181,223335	-6905,022437	-6639,444651	-6384,081395
Operational costs	0	0	0	0	0	0	0	0	0	0	0
External costs	-15000	0	0	0	0	0	0	0	0	0	0
Travel time costs	-1203930	0	0	0	0	0	0	0	0	0	0
Delay hour cost	-8389824,214	1362980,769	1310558,432	1260152,338	1211684,941	1165081,674	1120270,84	1077183,5	1035753,366	995916,6977	957612,2093
Emission	-51450,5079	0	0	0	0	0	0	0	0	0	0
Safety	-246279,873	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-7662	5,375	5,168269231	4,969489645	4,778355428	4,594572527	4,417858199	4,247940576	4,084558246	3,927459852	3,776403704

Option 1

Decision moment	2										
Operational years	0	0	1	1	1	1	1	1	1	1	1
Investment costs	-3150000	0	-3150000	0	0	0	0	0	0	0	0
Maintenance costs	-9450	0	-8737,056213	-8401,015589	-8077,899605	-7767,211159	-7468,472268	-7181,223335	-6905,022437	-6639,444651	-6384,081395
Operational costs	0	0	0	0	0	0	0	0	0	0	0
External costs	-15000	-14423,07692	0	0	0	0	0	0	0	0	0
Travel time costs	-1203930	0	0	0	0	0	0	0	0	0	0
Delay hour cost	-8389824,214	0	1310558,432	1260152,338	1211684,941	1165081,674	1120270,84	1077183,5	1035753,366	995916,6977	957612,2093
Emission	-51450,5079	0	0	0	0	0	0	0	0	0	0

Option 1

Safety	-246279,873	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-7662	0	5,168269231	4,969489645	4,778355428	4,594572527	4,417858199	4,247940576	4,084558246	3,9274559852	3,776403704	3,631157407							

Option 1

Decision moment	3																		
Operational years	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Investment costs	-3150000	0	0	0	0	0	-3150000	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-9450	0	0	0	0	0	-7767,211159	-7468,472268	-6905,022437	-6639,444651	-6384,081395	-6138,539803							
Operational costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External costs	-15000	-14423,07692	-13868,3432	-13334,94538	-12822,06287	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Travel time costs	-1203930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delay / hour cost	-8389824,214	0	0	0	0	0	1165081,674	1120270,84	1035753,366	995916,6977	957612,2093	920780,9705							
Emission	-51450,5079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Safety	-246279,873	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-7662	0	0	0	0	0	4,594572527	4,417858199	4,247940576	4,084558246	3,9274559852	3,776403704	3,631157407						

Option 1

Decision moment	4																		
Operational years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Investment costs	-3150000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-9450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External costs	-15000	-14423,07692	-13868,3432	-13334,94538	-12822,06287	-12328,9066	-11854,71789	-11398,7672	-10960,35308	-10538,80103	-10133,46253	-9743,713973							
Travel time costs	-1203930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delay / hour cost	-8389824,214	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emission	-51450,5079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Safety	-246279,873	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-7662	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Option 2

Decision moment	1																		
Operational years	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment costs	-50000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational costs	-25920	-24923,07692	-23964,49704	-23042,78562	-22156,52463	-21304,35061	-20484,95251	-19697,06972	-18939,49011	-18211,04819	-17510,62326	-16837,13775							
External costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Travel time costs	-1203930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delay / hour cost	-9642505,268	158479,7559	152384,3807	146523,4429	140887,9259	135469,1595	130258,8072	125248,8531	120431,5895	115799,6053	111345,7743	107063,2446							
Emission	-51450,5079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Safety	-246279,873	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	-7394,384615	262,6974852	252,5937358	242,8785921	233,5371078	224,5549113	215,918184	207,6136384	199,6284985	191,9504793	184,5677686	177,4690082							

Option 2

Decision moment	2																		
Operational years	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment costs	-50000	0	-50000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational costs	-25920	0	-23964,49704	-23042,78562	-22156,52463	-21304,35061	-20484,95251	-19697,06972	-18939,49011	-18211,04819	-17510,62326	-16837,13775							
External costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

102945,4275	98985,98795	95178,83457	91518,11016	87998,18284	84613,63735	81359,26668	78230,06412	75221,2155	72328,09183	69546,24214	66871,38667	64299,41026	61826,35602	59448,41925
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170,6432772	164,0800742	157,7693021	151,701252	145,8665885	140,2563351	134,8618607	129,674866	124,6873712	119,891703	115,2804837	110,8466189	106,5832874	102,4839302	98,54224061

-16189,5553	-15566,88031	-14968,15415	-14392,45591	-13838,89991	-13306,63453	-12794,8409	-12302,73163	-11829,54965	-11374,56697	-10937,08362	-10516,42656	-10111,94861	-9723,027514	-9349,064918
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
102945,4275	98985,98795	95178,83457	91518,11016	87998,18284	84613,63735	81359,26668	78230,06412	75221,2155	72328,09183	69546,24214	66871,38667	64299,41026	61826,35602	59448,41925
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170,6432772	164,0800742	157,7693021	151,701252	145,8665885	140,2563351	134,8618607	129,674866	124,6873712	119,891703	115,2804837	110,8466189	106,5832874	102,4839302	98,54224061

[illegible][illegible][illegible]

27	28	29
0,347	0,333	0,321
0	0	0

Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	4	14	29

0	0	0
1	1	1
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
-417542,8733	-401483,532	-386041,8577
-3401342,546	-3270521,679	-3144732,384
-17843,88868	-17157,58527	-16497,67814
-85413,94085	-82128,78928	-78969,98969
-265247265	-2556,968524	-2458,623581
B/C-Ratio		
Total		

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
-2315250	-8740279,515	-25434521,18	-40894407,12
-18860238,87	-71199118,65	-207191942,6	-333129591,5
-98943,28442	-373519,9058	-1086956,079	-1747641,488
-473615,1404	-1787940,27	-5202969,147	-8365494,166
-14745,36538	-55665,09665	-161987,3915	-260448,321
-	-	-	-
B/C-Ratio			
Total			

0	0	0
1	1	1
0	0	0
-3277,416588	-3151,362104	-3030,155869
0	0	0
0	0	0
0	0	0
491612,4882	472704,3155	454523,3803
0	0	0
0	0	0
1,938704627	1,864139064	1,792441408
B/C-Ratio		
Total		

-3150000	-3150000	-3150000	-3150000
-166211,2641	-166211,2641	-166211,2641	-166211,2641
0	0	0	0
0	0	0	0
0	0	0	0
2725961,538	10290752,96	29946453,51	48148830,98
0	0	0	0
0	0	0	0
10,75	40,58222861	118,0957144	189,8779296
0,82	3,10	9,03	14,52
-590238,9757	6974582,279	26630360,34	44832809,6
B/C-Ratio			
Total			

0	0	0
1	1	1
0	0	0
-3277,416588	-3151,362104	-3030,155869
0	0	0
0	0	0
0	0	0
491612,4882	472704,3155	454523,3803
0	0	0

0	-3150000	-3150000	-3150000
0	-157124,7257	-157124,7257	-157124,7257
0	0	0	0
-14423,07692	-14423,07692	-14423,07692	-14423,07692
0	0	0	0
0	7564791,422	27220491,97	45422869,45
0	0	0	0

[illegible][illegible]

	0	0	0	0	0	0	0	-50000
	1	1	1	1	1	1	1	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
-8989485498	-8643,736056	-8311,284669						-166421,7369
662	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
57161,94159	54963,40537	52849,42824						2116470,316
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
94,75215443	91,1078408	87,60369308	#DEEL/0!	#DEEL/0!	#DEEL/0!	#DEEL/0!	#DEEL/0!	3508,280451
B/C-Ratio								9.80
Total								1903556,86

	0	0	0	0	-3000000	-3000000	-3000000	-3000000	-3000000
	1	1	1	0	-351769,8712	-351769,8712	-351769,8712	-351769,8712	-351769,8712
-6936,331403		-6669,549426	-6413,028294	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
77452,22647	74473,29468	71608,9372		429467,9153	1621280,476	4717983,279	7585718,938		
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
1,938704627	1,864139064	1,792441408		10,75	40,58222861	118,0957144	189,8779296		
B/C-Ratio				0,13	0,48	1,41	2,26		
Total	-2922291,206	-1730448,813	1366331,504	-351769,8712	-351769,8712	-351769,8712	-351769,8712	-351769,8712	-351769,8712

0	0	0
1	1	1
0	0	0
0	0	0

0	-3000000	-3000000
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Net Present Value calculation with flexibility

Flexibility added based on the

Option	Decision moment	Scenario (amount of repetitions)				Benefit/Cost-Ratio				Option Premium			
		1	4	14	29	1	4	14	29	1	4	14	29
Option zero	1	-21.762.793	-82.156.523	-239.078.376	-384.397.583	-	-	-	-	-	-	-	-
Option 1	1	-590.239	6.974.582	26.630.360	44.832.810	0,82	3,10	9,03	14,52	-	-	-	-
Option 1	2	-14.423	4.243.273	23.899.052	42.101.501	-	2,28	8,20	13,68	575.816	-2.731.309	-2.731.309	-2.731.309
Option 1	3	-14.423	-54.448	16.319.421	34.521.870	-	-	5,89	11,35	575.816	-7.029.031	-10.310.939	-10.310.939
Option 1	4	-14.423	-54.448	-158.447	14.827.613	-	-	-	5,39	575.816	-7.029.031	-26.788.807	-30.005.197
Option 2	1	242.562	1.054.448	3.163.981	5.117.538	4,24	8,32	10,77	11,44	-	-	-	-
Option 2	2	-	761.886	2.871.419	4.824.976	#DEEL/O!	7,39	10,61	11,37	-242.562	-292.562	-292.562	-292.562
Option 2	3	-	-	2.059.534	4.013.091	#DEEL/O!	#DEEL/O!	9,97	11,13	-242.562	-1.054.448	-1.104.448	-1.104.448
Option 2	4	-	-	-	1.903.557	#DEEL/O!	#DEEL/O!	#DEEL/O!	9,80	-242.562	-1.054.448	-3.163.981	-3.213.981
Option 3	1	-2.922.291	-1.730.449	1.366.332	4.234.139	0,13	0,48	1,41	2,26	-	-	-	-
Option 3	2	-	-2.140.697	956.084	3.823.891	#DEEL/O!	0,36	1,29	2,15	2.922.291	-410.248	-410.248	-410.248
Option 3	3	-	-	-182.392	2.685.416	#DEEL/O!	#DEEL/O!	0,94	1,82	2.922.291	1.730.449	-1.548.723	-1.548.723
Option 3	4	-	-	-	-272.700	#DEEL/O!	#DEEL/O!	#DEEL/O!	0,91	2.922.291	1.730.449	-1.366.332	-4.506.839
Option 4	1	-28.643	-108.130	-314.663	-505.925	0,89	0,89	0,89	0,89	-	-	-	-
Option 4	2	-	-79.487	-286.020	-477.282	#DEEL/O!	0,89	0,89	0,89	28.643	28.643	28.643	28.643
Option 4	3	-	-	-206.533	-397.795	#DEEL/O!	#DEEL/O!	0,89	0,89	28.643	108.130	108.130	108.130
Option 4	4	-	-	-	-191.262	#DEEL/O!	#DEEL/O!	#DEEL/O!	0,89	28.643	108.130	314.663	314.663
Option 5	1	5.102.834	19.263.664	56.057.941	90.131.685	10,34	10,34	10,34	10,34	-	-	-	-
Option 5	2	-	14.160.830	50.955.107	85.028.851	#DEEL/O!	10,34	10,34	10,34	-5.102.834	-5.102.834	-5.102.834	-5.102.834
Option 5	3	-	-	36.794.277	70.868.021	#DEEL/O!	#DEEL/O!	10,34	10,34	-5.102.834	-19.263.664	-19.263.664	-19.263.664
Option 5	4	-	-	-	34.073.744	#DEEL/O!	#DEEL/O!	#DEEL/O!	10,34	-5.102.834	-19.263.664	-56.057.941	-56.057.941
Option 6	1	174.961	18.989.221	67.874.570	113.145.385	1,03	3,80	10,54	16,24	-	-	-	-
Option 6	2	-	12.297.259	61.182.607	106.453.422	#DEEL/O!	2,85	9,77	15,61	-174.961	-6.691.963	-6.691.963	-6.691.963
Option 6	3	-	-	42.611.801	87.882.616	#DEEL/O!	#DEEL/O!	7,45	13,71	-174.961	-18.989.221	-25.262.769	-25.262.769
Option 6	4	-	-	-	39.629.837	#DEEL/O!	#DEEL/O!	#DEEL/O!	7,66	-174.961	-18.989.221	-67.874.570	-73.515.548
Option 7	1	6.781.791	25.601.878	74.502.366	119.787.201	154,39	154,39	154,39	154,39	-	-	-	-
Option 7	2	-	18.820.087	67.720.575	113.005.410	#DEEL/O!	154,39	154,39	154,39	-6.781.791	-6.781.791	-6.781.791	-6.781.791
Option 7	3	-	-	48.900.488	94.185.323	#DEEL/O!	#DEEL/O!	154,39	154,39	-6.781.791	-25.601.878	-25.601.878	-25.601.878
Option 7	4	-	-	-	45.284.834	#DEEL/O!	#DEEL/O!	#DEEL/O!	154,39	-6.781.791	-25.601.878	-74.502.366	-74.502.366
Option 8	1	-195.841	9.691.832	35.383.107	59.174.795	0,95	3,58	10,41	16,74	-	-	-	-
Option 8	2	-	6.224.977	31.916.252	55.707.940	#DEEL/O!	2,70	9,71	16,21	195.841	-3.466.855	-3.466.855	-3.466.855
Option 8	3	-	-	22.295.415	46.087.103	#DEEL/O!	#DEEL/O!	7,57	14,57	195.841	-9.691.832	-13.087.692	-13.087.692
Option 8	4	-	-	-	21.089.151	#DEEL/O!	#DEEL/O!	#DEEL/O!	8,80	195.841	-9.691.832	-35.383.107	-38.085.644
Option 9	1	11.627.906	43.896.403	127.740.079	205.384.437	21,76	21,76	21,76	21,76	-	-	-	-
Option 9	2	-	32.268.497	116.112.173	193.756.531	#DEEL/O!	21,76	21,76	21,76	-11.627.906	-11.627.906	-11.627.906	-11.627.906
Option 9	3	-	-	83.843.676	161.488.033	#DEEL/O!	#DEEL/O!	21,76	21,76	-11.627.906	-43.896.403	-43.896.403	-43.896.403
Option 9	4	-	-	-	77.644.357	#DEEL/O!	#DEEL/O!	#DEEL/O!	21,76	-11.627.906	-43.896.403	-127.740.079	-127.740.079
Option 10	1	251.631	1.088.683	3.263.607	5.277.719	6,03	22,77	66,27	106,55	-	-	-	-

Option 10	2	-	787.052	2.961.976	4.976.088	#DEEL/0!	16,74	60,24	100,52	-251.631	-301.631	-301.631	-301.631
Option 10	3	-	-	2.124.924	4.139.036	#DEEL/0!	#DEEL/0!	43,50	83,78	-251.631	-1.088.683	-1.138.683	-1.138.683
Option 10	4	-	-	-	1.964.112	#DEEL/0!	#DEEL/0!	#DEEL/0!	40,28	-251.631	-1.088.683	-3.263.607	-3.313.607
Option 11	1	163.146	615.891	1.792.265	2.881.659	5,06	5,06	5,06	5,06	-	-	-	-
Option 11	2	-	452.745	1.629.119	2.718.513	#DEEL/0!	5,06	5,06	5,06	-163.146	-163.146	-163.146	-163.146
Option 11	3	-	-	1.176.374	2.265.768	#DEEL/0!	#DEEL/0!	5,06	5,06	-163.146	-615.891	-615.891	-615.891
Option 11	4	-	-	-	1.089.394	#DEEL/0!	#DEEL/0!	#DEEL/0!	5,06	-163.146	-615.891	-1.792.265	-1.792.265
Option 12	1	4.065.709	15.348.422	44.664.450	71.812.879	43,28	43,28	43,28	43,28	-	-	-	-
Option 12	2	-	11.282.713	40.598.741	67.747.170	#DEEL/0!	43,28	43,28	43,28	-4.065.709	-4.065.709	-4.065.709	-4.065.709
Option 12	3	-	-	29.316.027	56.464.457	#DEEL/0!	#DEEL/0!	43,28	43,28	-4.065.709	-15.348.422	-15.348.422	-15.348.422
Option 12	4	-	-	-	27.148.429	#DEEL/0!	#DEEL/0!	#DEEL/0!	43,28	-4.065.709	-15.348.422	-44.664.450	-44.664.450
Option 13	1	4.642.713	17.526.665	51.003.212	82.004.536	5,62	5,62	5,62	5,62	-	-	-	-
Option 13	2	-	12.883.952	46.360.499	77.361.823	#DEEL/0!	5,62	5,62	5,62	-4.642.713	-4.642.713	-4.642.713	-4.642.713
Option 13	3	-	-	33.476.547	64.477.871	#DEEL/0!	#DEEL/0!	5,62	5,62	-4.642.713	-17.526.665	-17.526.665	-17.526.665
Option 13	4	-	-	-	31.001.324	#DEEL/0!	#DEEL/0!	#DEEL/0!	5,62	-4.642.713	-17.526.665	-51.003.212	-51.003.212

Scenario Combination 1

Same probability for all outcomes

		Expanded NPV value			
Option	Decision moment	Scenario probabilities			
		0,25	0,25	0,25	0,25
Option zero	1	-5.440.698	-20.539.131	-59.769.594	-96.099.396
Option 1	1	-147.560	1.743.646	6.657.590	11.208.202
Option 1	2	-3.606	1.060.818	5.974.763	10.525.375
Option 1	3	-3.606	-13.612	4.079.855	8.630.468
Option 1	4	-3.606	-13.612	-39.612	3.706.903
Option 2	1	60.640	263.612	790.995	1.279.385
Option 2	2	-	190.471	717.855	1.206.244
Option 2	3	-	-	514.883	1.003.273
Option 2	4	-	-	-	475.889
Option 3	1	-730.573	-432.612	341.583	1.058.535
Option 3	2	-	-535.174	239.021	955.973
Option 3	3	-	-	-45.598	671.354
Option 3	4	-	-	-	-68.175
Option 4	1	-7.161	-27.033	-78.666	-126.481
Option 4	2	-	-19.872	-71.505	-119.320
Option 4	3	-	-	-51.633	-99.449
Option 4	4	-	-	-	-47.815
Option 5	1	1.275.709	4.815.916	14.014.485	22.532.921
Option 5	2	-	3.540.207	12.738.777	21.257.213
Option 5	3	-	-	9.198.569	17.717.005
Option 5	4	-	-	-	8.518.436
Option 6	1	43.740	4.747.305	16.968.643	28.286.346
Option 6	2	-	3.074.315	15.295.652	26.613.355
Option 6	3	-	-	10.652.950	21.970.654
Option 6	4	-	-	-	9.907.459
Option 7	1	1.695.448	6.400.469	18.625.592	29.946.800
Option 7	2	-	4.705.022	16.930.144	28.251.352
Option 7	3	-	-	12.225.122	23.546.331
Option 7	4	-	-	-	11.321.209
Option 8	1	-48.960	2.422.958	8.845.777	14.793.699
Option 8	2	-	1.556.244	7.979.063	13.926.985
Option 8	3	-	-	5.573.854	11.521.776
Option 8	4	-	-	-	5.272.288
Option 9	1	2.906.976	10.974.101	31.935.020	51.346.109
Option 9	2	-	8.067.124	29.028.043	48.439.133
Option 9	3	-	-	20.960.919	40.372.008
Option 9	4	-	-	-	19.411.089
Option 10	1	62.908	272.171	815.902	1.319.430
Option 10	2	-	196.763	740.494	1.244.022
Option 10	3	-	-	531.231	1.034.759
Option 10	4	-	-	-	491.028
Option 11	1	40.787	153.973	448.066	720.415

Option 11	2	-	113.186	407.280	679.628
Option 11	3	-	-	294.093	566.442
Option 11	4	-	-	-	272.348
Option 12	1	1.016.427	3.837.106	11.166.112	17.953.220
Option 12	2	-	2.820.678	10.149.685	16.936.792
Option 12	3	-	-	7.329.007	14.116.114
Option 12	4	-	-	-	6.787.107
Option 13	1	1.160.678	4.381.666	12.750.803	20.501.134
Option 13	2	-	3.220.988	11.590.125	19.340.456
Option 13	3	-	-	8.369.137	16.119.468
Option 13	4	-	-	-	7.750.331



Total	B/C-Ratio				Total
	Scenario probabilities				
1,00	0,25	0,25	0,25	0,25	1,00
-181.848.819	-	-	-	-	-
19.461.878	0,206	0,776	2,258	3,630	6,869
17.557.351	-	0,569	2,049	3,419	6,037
12.693.105	-	-	1,473	2,837	4,310
3.650.074	-	-	-	1,348	1,348
2.394.632	1,059	2,080	2,693	2,860	8,692
2.114.570	-	1,848	2,652	2,842	7,343
1.518.156	-	-	2,491	2,783	5,274
475.889	-	-	-	2,449	2,449
236.933	0,032	0,121	0,352	0,566	1,071
659.819	-	0,089	0,322	0,537	0,948
625.756	-	-	0,236	0,455	0,691
-68.175	-	-	-	0,228	0,228
-239.340	0,223	0,223	0,223	0,223	0,894
-210.697	-	0,223	0,223	0,223	0,670
-151.082	-	-	0,223	0,223	0,447
-47.815	-	-	-	0,223	0,223
42.639.031	2,585	2,585	2,585	2,585	10,339
37.536.197	-	2,585	2,585	2,585	7,754
26.915.574	-	-	2,585	2,585	5,170
8.518.436	-	-	-	2,585	2,585
50.046.034	0,257	0,950	2,635	4,061	7,903
44.983.322	-	0,713	2,442	3,901	7,055
32.623.604	-	-	1,862	3,426	5,289
9.907.459	-	-	-	1,915	1,915
56.668.309	38,597	38,597	38,597	38,597	154,386
49.886.518	-	38,597	38,597	38,597	115,790
35.771.453	-	-	38,597	38,597	77,193
11.321.209	-	-	-	38,597	38,597
26.013.473	0,237	0,895	2,603	4,186	7,921
23.462.292	-	0,675	2,428	4,052	7,156
17.095.630	-	-	1,891	3,643	5,534
5.272.288	-	-	-	2,201	2,201
97.162.206	5,440	5,440	5,440	5,440	21,759
85.534.300	-	5,440	5,440	5,440	16,319
61.332.927	-	-	5,440	5,440	10,879
19.411.089	-	-	-	5,440	5,440
2.470.410	1,508	5,693	16,568	26,639	50,408
2.181.279	-	4,185	15,060	25,130	44,376
1.565.990	-	-	10,875	20,945	31,820
491.028	-	-	-	10,071	10,071
1.363.240	1,265	1,265	1,265	1,265	5,059

1.200.094	-	1,265	1,265	1,265	3,794
860.535	-	-	1,265	1,265	2,529
272.348	-	-	-	1,265	1,265
33.972.865	10,821	10,821	10,821	10,821	43,283
29.907.156	-	10,821	10,821	10,821	32,463
21.445.121	-	-	10,821	10,821	21,642
6.787.107	-	-	-	10,821	10,821
38.794.281	1,405	1,405	1,405	1,405	5,621
34.151.568	-	1,405	1,405	1,405	4,216
24.488.605	-	-	1,405	1,405	2,811
7.750.331	-	-	-	1,405	1,405



X-Axis			Y-Axis		
Option	Decision moment	Expanded NPV	Option	Decision moment	B/C-ratio
Option zero	1	-181848819	Option zero	1	0
Option 1	1	19461878	Option 1	1	6,868708824
Option 1	2	17557351	Option 1	2	6,036979889
Option 1	3	12693105	Option 1	3	4,309640892
Option 1	4	3650074	Option 1	4	1,348394859
Option 2	1	2394632	Option 2	1	8,691612665
Option 2	2	2114570	Option 2	2	7,342701647
Option 2	3	1518156	Option 2	3	5,274135898
Option 2	4	475889	Option 2	4	2,448897493
Option 3	1	236933	Option 3	1	1,070688805
Option 3	2	659819	Option 3	2	0,947993022
Option 3	3	625756	Option 3	3	0,690827453
Option 3	4	-68175	Option 3	4	0,228291727
Option 4	1	-239340	Option 4	1	0,893611357
Option 4	2	-210697	Option 4	2	0,670208518
Option 4	3	-151082	Option 4	3	0,446805679
Option 4	4	-47815	Option 4	4	0,223402839
Option 5	1	42639031	Option 5	1	10,33926084
Option 5	2	37536197	Option 5	2	7,75444563
Option 5	3	26915574	Option 5	3	5,16963042
Option 5	4	8518436	Option 5	4	2,58481521
Option 6	1	50046034	Option 6	1	7,902978916
Option 6	2	44983322	Option 6	2	7,055439484
Option 6	3	32623604	Option 6	3	5,288696534
Option 6	4	9907459	Option 6	4	1,915054615
Option 7	1	56668309	Option 7	1	154,3864658
Option 7	2	49886518	Option 7	2	115,7898493
Option 7	3	35771453	Option 7	3	77,19323289
Option 7	4	11321209	Option 7	4	38,59661645
Option 8	1	26013473	Option 8	1	7,920594778
Option 8	2	23462292	Option 8	2	7,155744732
Option 8	3	17095630	Option 8	3	5,534256523
Option 8	4	5272288	Option 8	4	2,200865986
Option 9	1	97162206	Option 9	1	21,7588595
Option 9	2	85534300	Option 9	2	16,31914462
Option 9	3	61332927	Option 9	3	10,87942975
Option 9	4	19411089	Option 9	4	5,439714874
Option 10	1	2470410	Option 10	1	50,40819285
Option 10	2	2181279	Option 10	2	44,37558259
Option 10	3	1565990	Option 10	3	31,81980062
Option 10	4	491028	Option 10	4	10,07056112
Option 11	1	1363240	Option 11	1	5,05865091

Option 11	2	1200094	Option 11	2	3,793988183
Option 11	3	860535	Option 11	3	2,529325455
Option 11	4	272348	Option 11	4	1,264662728
Option 12	1	33972865	Option 12	1	43,28337589
Option 12	2	29907156	Option 12	2	32,46253192
Option 12	3	21445121	Option 12	3	21,64168795
Option 12	4	6787107	Option 12	4	10,82084397
Option 13	1	38794281	Option 13	1	5,621462631
Option 13	2	34151568	Option 13	2	4,216096973
Option 13	3	24488605	Option 13	3	2,810731315
Option 13	4	7750331	Option 13	4	1,405365658

Appendix F

Network Visualisation and Data of Zandvoort

This appendix will consist of a summary of the 'mobiliteitsplan' written by Organisation of DGP (2019). For this research the information on the modal split and the spread of the event are most important together with the plans that the DGP have made for managing the visitor flows towards the event.

F.1 Traffic flows towards the Dutch Gran Prix

The DGP consists of two days of races that are held on Saturday 2nd of May and Sunday 3rd of May. On the first day the qualification races will be held for the F1, F2 and F3. On the Sunday the actual races will be held.

Saturday

The modal split on Saturday and Sunday is expected to be the same as expected from the DGP Mobility Survey. Extra DGP inflow traffic is expected on Saturday DGP takes into account extra inflow traffic consisting of visitors who spend the night locally in Zandvoort and Bloemendaal aan Zee. This group of people first travels to their home address and from there they go on as a pedestrian in the modal split. Programming Race programming starts at 9 a.m. (qualification F3 / first race F2). As a result, the DGP expects an early intake, which runs until 12:00 (the start of the third training session F1). The DGP expects everyone to arrive by noon. The outflow starts at 4 p.m. immediately after the F1 qualification. A gradual outflow, due to the various activities that take place on and next to the track, is expected.

Sunday

Race programming starts at 9 a.m. (second race F3 and two race F2). Partly due to the fact that this is the competition day, DGP expects an early intake. However, because the program around F1 really starts at 1.30 pm, DGP expects a longer throughput. The outflow starts around 5 pm, immediately after the F1 race. Because the DGP subsequently organizes an extensive music program, we try to encourage a gradual outflow. Points for attention here are possibly rainy weather and / or early failure of Max Verstappen.

The total number of visitors in the modal split (111,500) consists of:

- 104,000 ticket buyers: people who have a ticket for the DGP.
- 7,500 "fortune seekers": people who come to Zandvoort without a DGP ticket.

In figure F.1 the visitors flow and the percentages of modal split are given for the morning peak. Figure F.2 gives the modal split for the afternoon and evening peak. The amount of visitors are the same, but the DGP expects that the spread in the morning peak is wider than the spread in the evening peak which

causes capacity problems in for the train users. No solution for this is given and it will probably lead to a longer waiting time for those people.

Zondag - MODAL SPLIT INSTROOM = 5 uur							
Type voertuig	%	Bezoekers	Voertuigen	Fietsen	Per voertuig	Max capaciteit	Saldo
Lopen (Inwoners lokaal)	4,0%	4.460				onbeperkt	onbeperkt
Lopen (Overnachting lokaal)	7,5%	8.363				onbeperkt	onbeperkt
Lopen (DGP camping Zandvoort)	4,0%	4.460				onbeperkt	onbeperkt
Fiets (Inwoners regio)	14,0%	15.610		15.610			
Fiets (Overnachting regio)	2,5%	2.788		2.788			
Auto (P+B georganiseerd DGP) > fiets	4,4%	4.906	2.453	4.906	2		
Auto (P+B ongeorganiseerd) > fiets	8,0%	8.920	4.460	8.920	2	40.500	8.277
Trein	27,0%	30.105			1000	50.000	19.895
Pendelbus Park & Ride (P+R)	13,0%	14.495	5.798		2,5	11.000	5.202
Touringcars (georganiseerd landelijk vervoer)	4,5%	5.018	100		50	150	50
Brommer/Scooter	2,5%	2.788	1.858		1	3.100	1.242
Motor	2,0%	2.230	1.487		1,5	0	0
Taxi	0,5%	558	279		2	0	0
Mindervaliden	0,1%	112	56		2	150	94
DGP parkeren	6,0%	6.690	2.230		3	3.300	1.070
Totaal	100,0%	111.500	18.721	32.224			
Auto camping en overnachting lokaal (zie tab lokaal)		0	0		2		
Trein camping en overnachting lokaal (zie tab lokaal)		0					
Totaal		111.500	18.721	32.224			

Figure F.1: Modal split of DGP visitors sunday morning

Zondag - MODAL SPLIT UITSTROOM = 3 uur							
Type voertuig	%	Bezoekers	Voertuigen	Fietsen	Per voertuig	Max capaciteit	Saldo
Lopen (Inwoners lokaal)	4,0%	4.460				onbeperkt	onbeperkt
Lopen (Overnachting lokaal)	7,5%	8.363				onbeperkt	onbeperkt
Lopen (DGP camping Zandvoort)	4,0%	4.460				onbeperkt	onbeperkt
Fiets (Inwoners regio)	14,0%	15.610		15.610			
Fiets (Overnachting regio)	2,5%	2.788		2.788			
Auto (P+B georganiseerd DGP) > fiets	4,4%	4.906	2.453	4.906	2		
Auto (P+B ongeorganiseerd) > fiets	8,0%	8.920	4.460	8.920	2	40.500	8.277
Trein	27,0%	30.105			1000	30.000	-1.227
Pendelbus Park & Ride (P+R)	13,0%	14.495	5.798		2,5	11.000	5.202
Touringcars (georganiseerd landelijk vervoer)	4,5%	5.018	100		50	150	50
Brommer/Scooter	2,5%	2.788	1.858		1	3.100	1.242
Motor	2,0%	2.230	1.487		1,5	0	0
Taxi	0,5%	558	279		2	0	0
Mindervaliden	0,1%	112	56		2	150	94
DGP parkeren	6,0%	6.690	2.230		3	3.300	1.070
Totaal	100,0%	111.500	18.721	32.224			
Auto camping en overnachting lokaal (zie tab lokaal)		2.084	1.042		2		
Trein camping en overnachting lokaal (zie tab lokaal)		1.122					
Totaal		114.706	19.763	32.224			

Figure F.2: Modal split of DGP visitors sunday evening

Pedestrians

Looking at the tables F.1 and F.2 the share of pedestrians is 15.5%. Visitors stay in Zandvoort itself as a resident or camping visitor as well as a hotel guest. This group will therefore not have any influence on the inflow of visitors on the Sunday of the festival.

Bicycle + Moped 16.5% Of the visitors will come by bike or moped. Since this group will probably use the same network for calculation simplifications the groups are joined together.

Car + motorcycle

The users of the car network are the car users and the motorcyclists. They add up to 36.5% + 2% of the visitors. Furthermore is it expected that every car will have 2,5 visitors on average. For simplicity reasons taxi's and other car network using vehicles are added to this share of visitors.

Train

The percentage of train users to enter the event is estimated on 27%.

F.2 Mobility plans for the DGP

In this section the plan that the DGP have made will be discussed and how they will be implemented in the CBA. For the whole plan the 'Mobiliteitsplan DGP 2020' (Organisation of DGP, 2019) can be

found on the website of the municipality of Zandvoort.

Social Traffic Management

The DGP introduces its own events app with various functionalities (floor plan, travel advice, customized routes, Q&A, location analysis, push notifications). In this app becomes a link made with well-known applications such as Waze, Google Maps and the NS travel planner travel information is unambiguous and consistent and a maximum audience is reached. This app is one ready and usable one month prior to the event. The processing of personal data in this app will be in accordance with applicable AVG regulations. With this application the visitors can be informed at fore hand what modality is best for them and when to leave.

Side events

The municipality of Zandvoort is organizing various side events in the run-up to and at the time of the DGP. Side events are aimed at the already present DGP visitors. This mobility plan is that the side events have no influence on the total number of DGP visitors comes to Zandvoort. These side events will mainly have a positive influence on the arrival and departure profile: visitors will come earlier and leave later, causing the peak in both arrival if departure is flattened.

Pedestrian

In accordance with the principles, the DGP encourages visitors to spend the night in the area. This one overnight stays take the form of regular hotels, Airbnbs, campsites, temporary campsites and additional created overnight places with private individuals (such as a tent in the garden or a camper in the driveway). Our estimate is that it has an average of two visitors per household Zandvoort and the surrounding area (7,000 households in Zandvoort, 14,000 sleeping places). DGP encourages visitors living in the region at a distance of between 7.5 kilometers and 25 kilometers to come to the circuit on foot or by bike.

Bicycle + Moped

The DGP expects a large number of cyclists. We can subdivide cyclists into cyclists from the region (live and stay) and cyclists in the area on an (un) organized P+B park your car and cycle the last part. The organized P+B are located at one maximum distance of 15 kilometers. For visitors on bicycles, the routes to the bicycle parking facilities in the vicinity of the circuit are clearly indicated by signs. The bicycle routes to Zandvoort are free of obstacles and there is mechanical assistance / flat tire service in the event of a breakdown.

DGP uses multiple locations in Zandvoort and for the placement of bicycle parking facilities in Bloemendaal aan Zee. The bicycle parking facilities are spread over all wind directions. In addition to racks, for placing standard bicycles, bicycle parking facilities also have free spaces for them placing abnormal bicycles. DGP expects little to none based on the target group cargo bikes. There are no charging points for electric bicycles in the bicycle parking facilities. With every bicycle parking is supervised in the form of parking attendants and security.

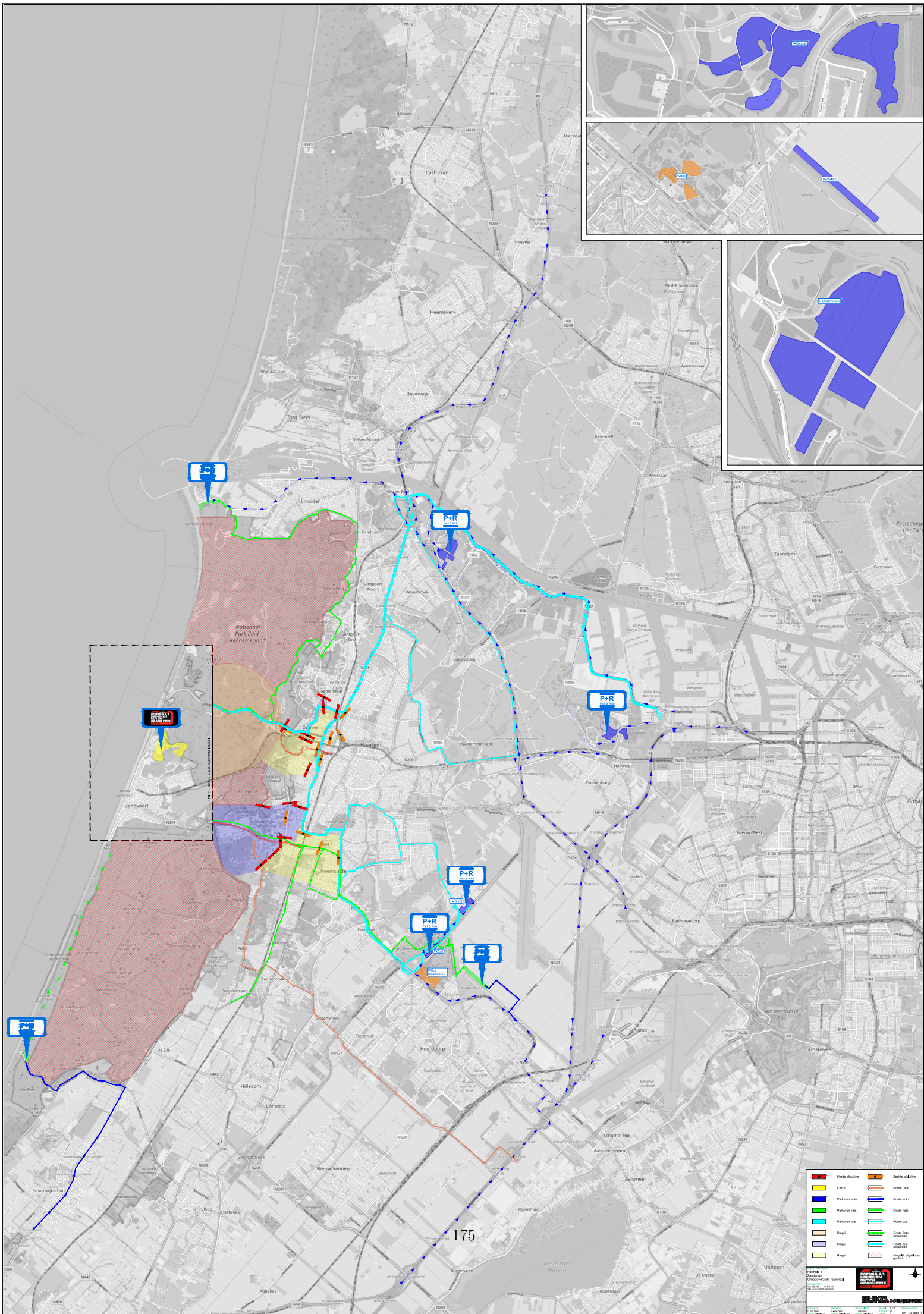
Car + motorcycle

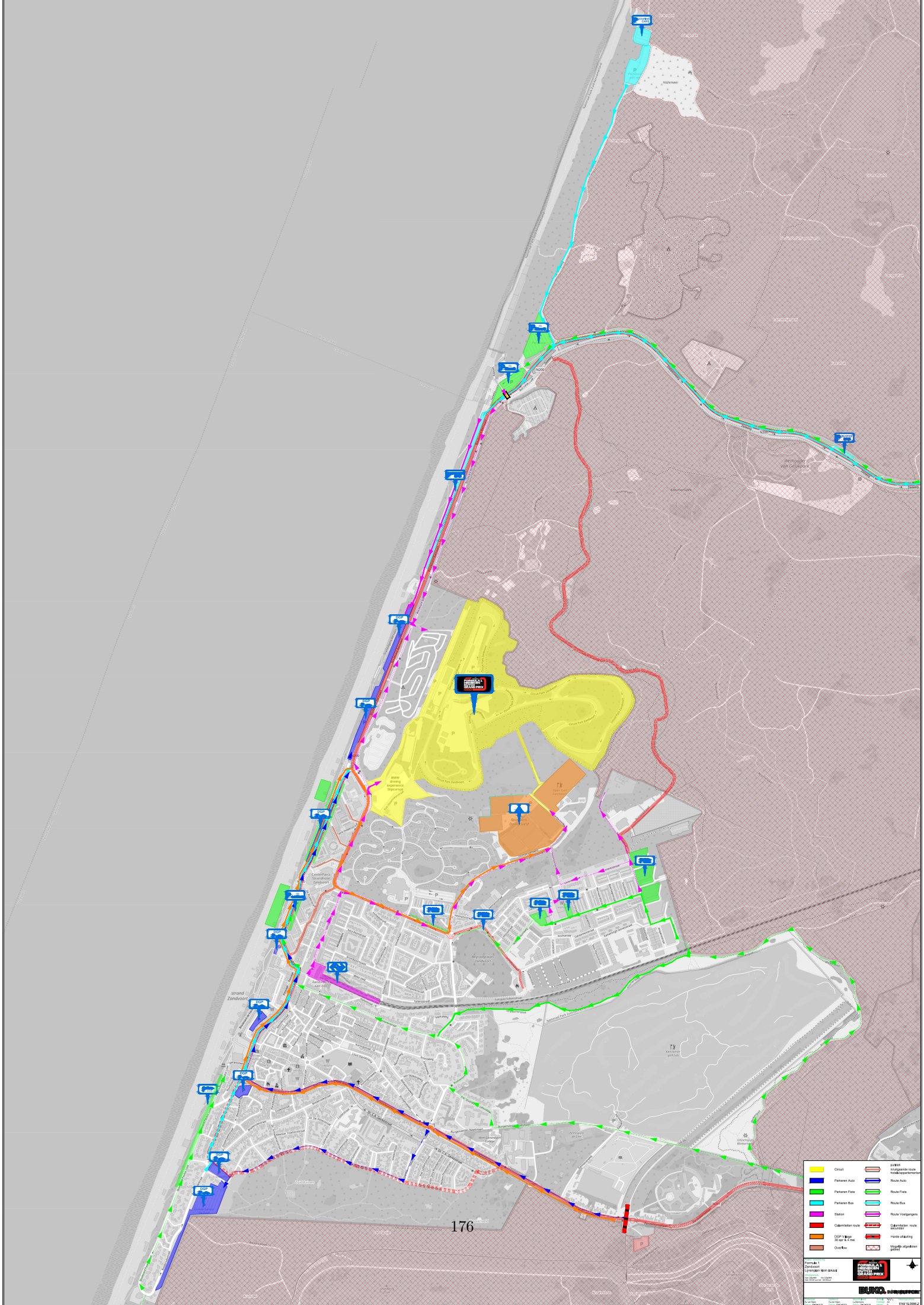
The main access roads towards Zandvoort will not be open for DGP visitors. The car users will need to ride to a P+R location. From those locations touring cars will be used to transport the visitors towards the event. A reservation for this bus need to be made at front, which makes sure that the car driver will park at the right P+R. Those locations can be found in the regional map in figure F.2. There are also a few P+B locations where a visitor cannot make use of a touring car, but is able to rent a bike or bring his/her own bike.

Train

The municipality of Zandvoort has reached an agreement with ProRail, the government, the province of Noord-Holland and the neighboring municipalities about making adjustments to the track, the level crossings and the platforms to structurally improve the accessibility of Zandvoort. Together (ProRail / NS / DGP / municipality of Zandvoort) we work on the following principles:

- 50,000 visitors per train
- 1,000 travelers per train (two linked SLT sets)
- 12 trains per hour
- Minimum discharge time is four hours with continuous passenger flow
- Three days: Friday to Sunday





	Circuit		Buiten
	Parkeren Auto		Inkomende route
	Parkeren Fiets		Route Auto
	Parkeren Bus		Route Fiets
	Station		Route Bus
	Cultuurlaan route		Route Voetgangers
	OOP' route		Cultuurlaan route
	Overloop		Route stalling
			Inkomende route

Formaat: A3
Zetel: 176
Levering: 176
176

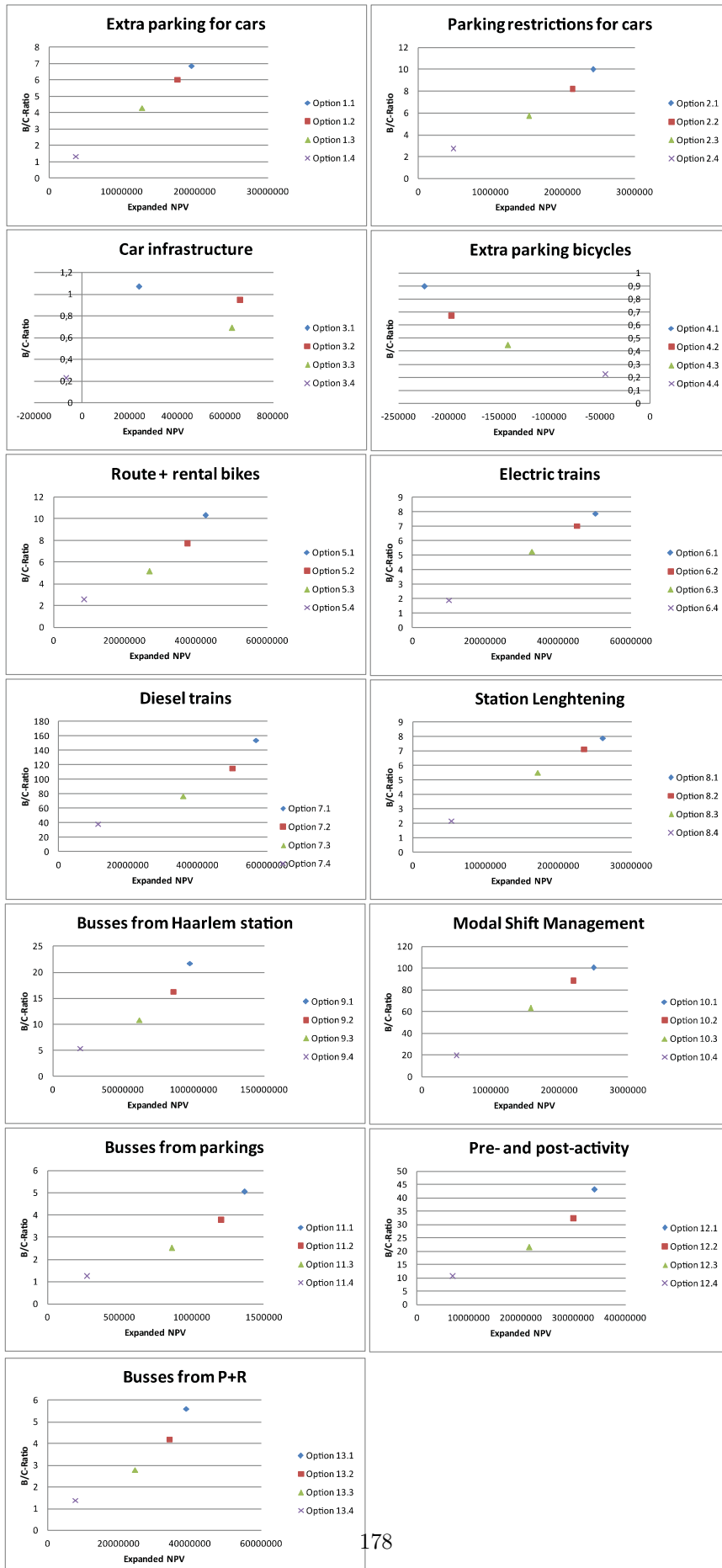
DURO

Appendix G

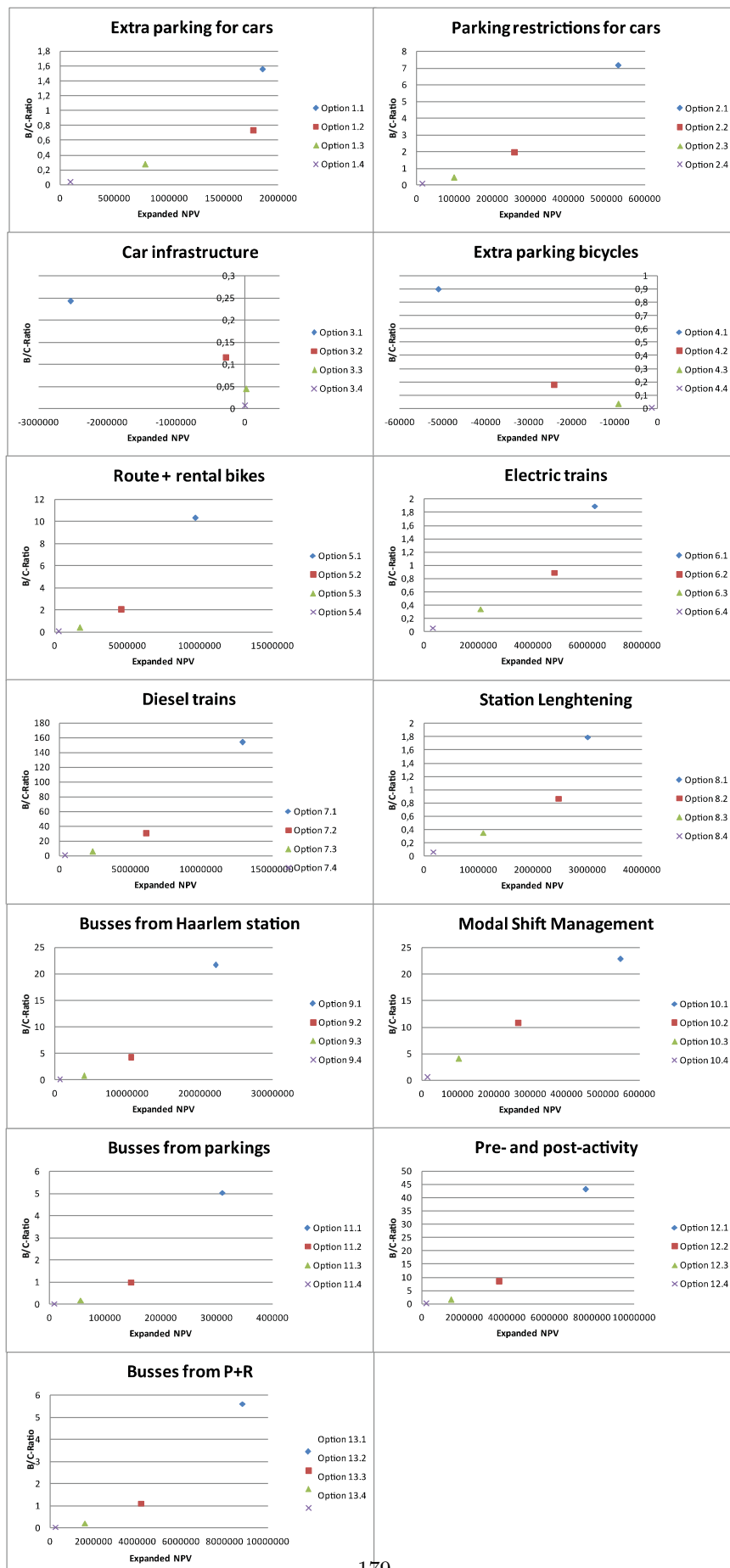
Result Sheets

G.1 Individual Solutions

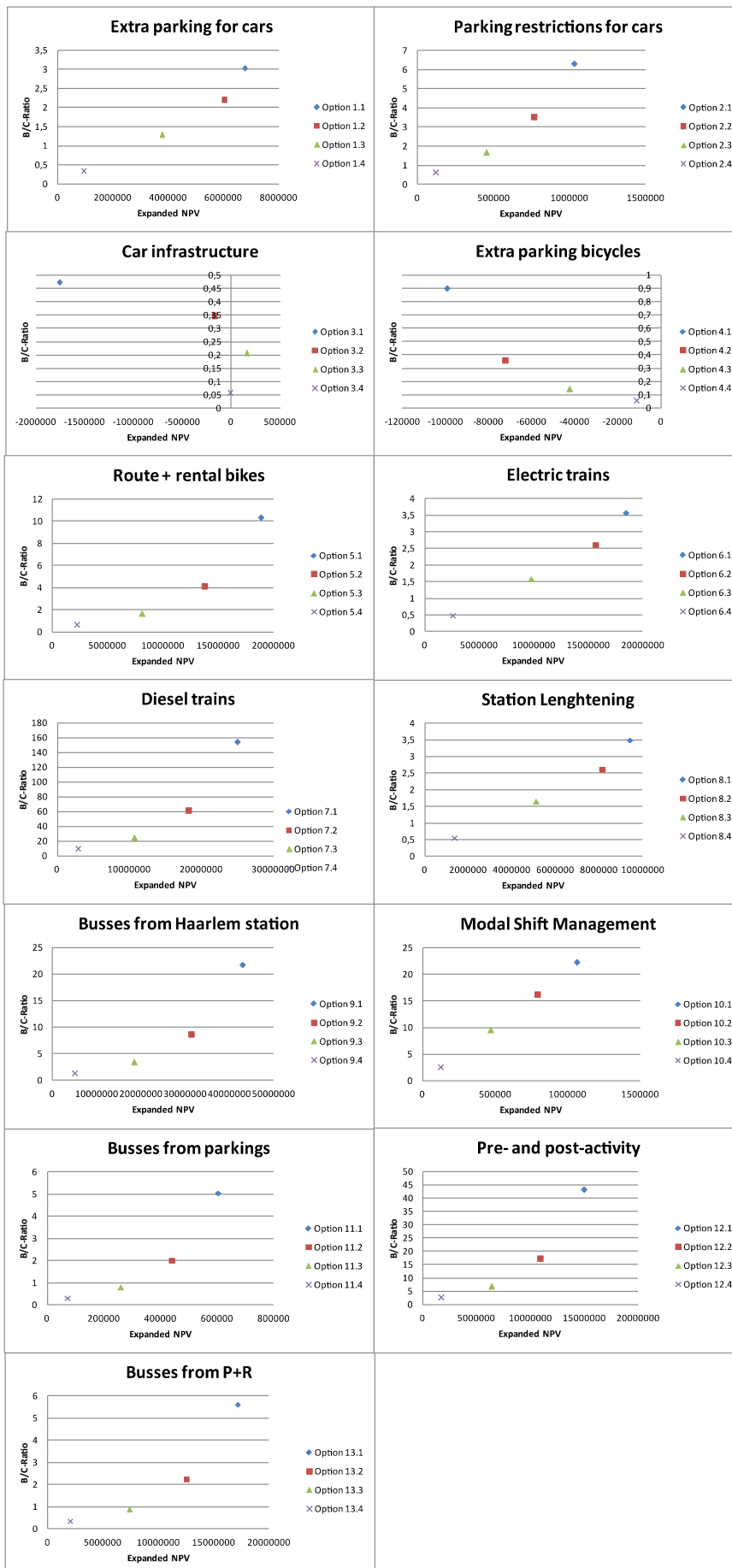
Scenario Combination 1



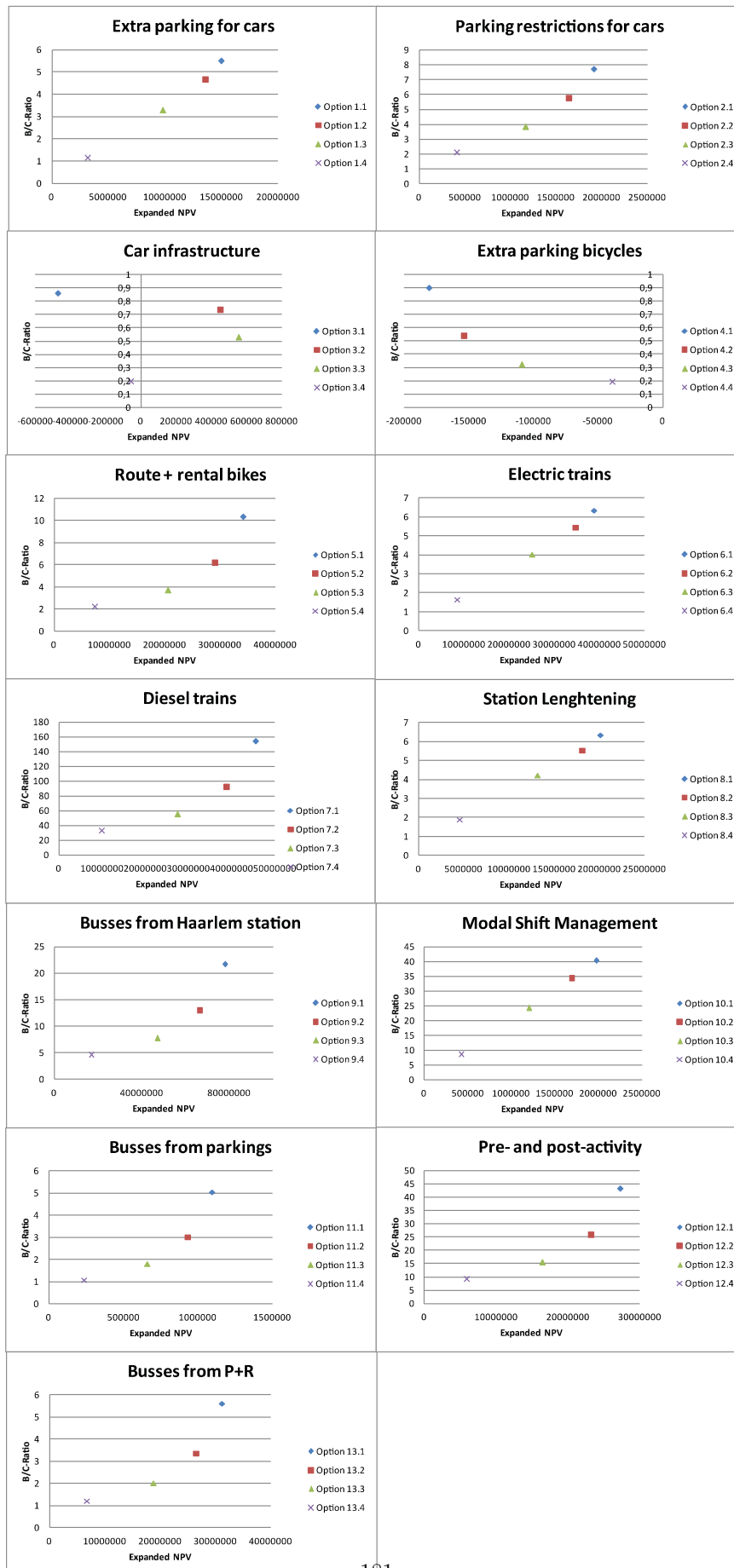
Scenario Combination 2



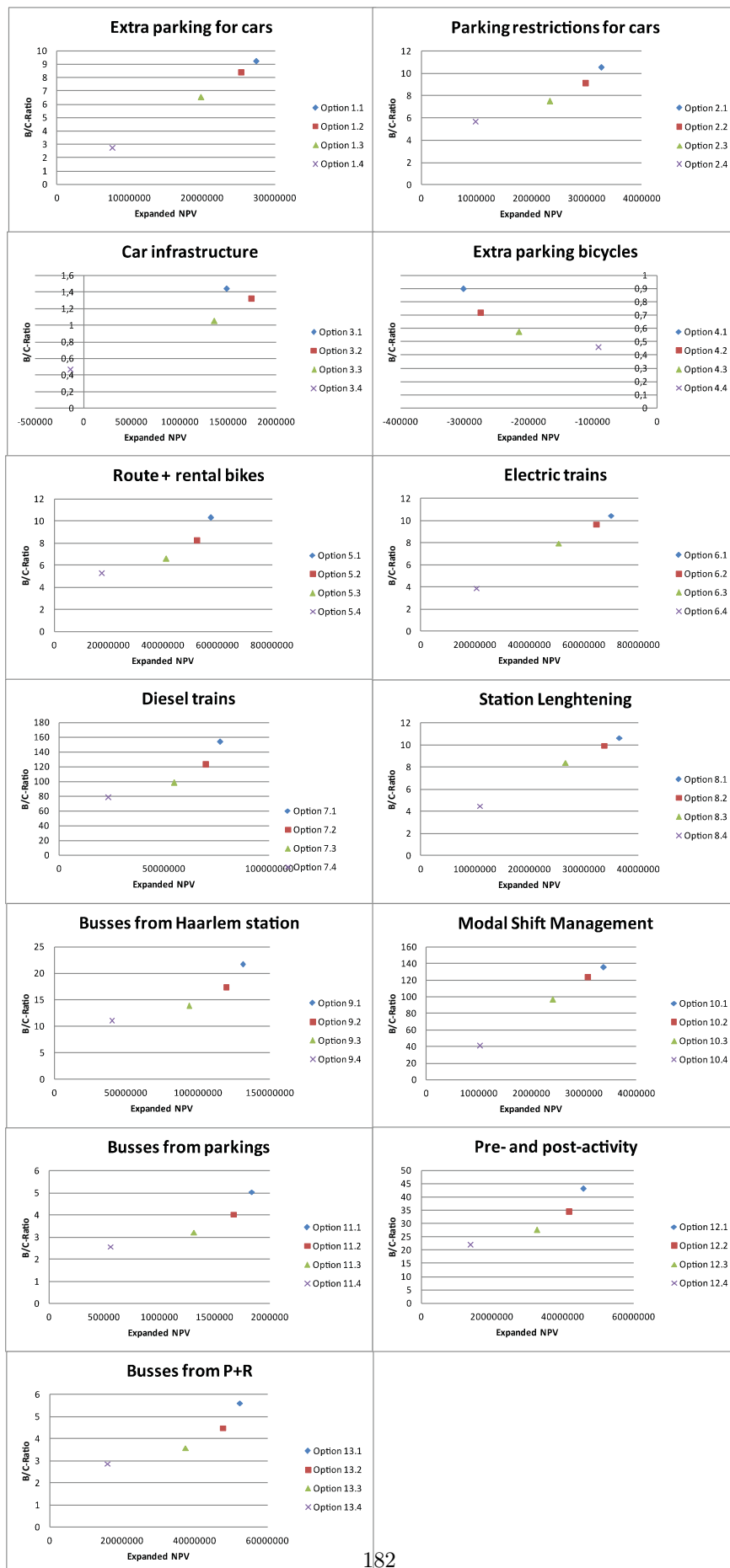
Scenario Combination 3



Scenario Combination 4



Scenario Combination 5



Scenario Combination 1					
Option	Decision moment	Total NPV	Option	Decision moment	B/C-Ratio
Option 9	1	97162206,25	Option 7	1	154,38647
Option 9	2	85534300,37	Option 7	2	115,78985
Option 9	3	61332927,36	Option 10	1	100,81639
Option 7	1	56668308,82	Option 10	2	88,751165
Option 6	1	50046034,36	Option 7	3	77,193233
Option 7	2	49886517,97	Option 10	3	63,639601
Option 6	2	44983321,94	Option 12	1	43,283376
Option 5	1	42639031,15	Option 7	4	38,596616
Option 13	1	38794281,41	Option 12	2	32,462532
Option 5	2	37536196,82	Option 9	1	21,758859
Option 7	3	35771452,74	Option 12	3	21,641688
Option 13	2	34151568,25	Option 10	4	20,141122
Option 12	1	33972865,09	Option 9	2	16,319145
Option 6	3	32623604,23	Option 9	3	10,87943
Option 12	2	29907155,87	Option 12	4	10,820844
Option 5	3	26915574,49	Option 5	1	10,339261
Option 8	1	26013473,22	Option 2	1	10,037665
Option 13	3	24488604,52	Option 2	2	8,236907
Option 8	2	23462292,47	Option 8	1	7,9205948
Option 12	3	21445120,97	Option 6	1	7,9029789
Option 1	1	19461878,31	Option 5	2	7,7544456
Option 9	4	19411089,37	Option 8	2	7,1557447
Option 1	2	17557350,66	Option 6	2	7,0554395
Option 8	3	17095629,52	Option 1	1	6,8687088
Option 1	3	12693104,88	Option 1	2	6,0369799
Option 7	4	11321208,62	Option 2	3	5,7658495
Option 6	4	9907459,305	Option 13	1	5,6214626
Option 5	4	8518436,089	Option 8	3	5,5342565
Option 13	4	7750331,043	Option 9	4	5,4397149
Option 12	4	6787107,311	Option 6	3	5,2886965
Option 8	4	5272287,633	Option 5	3	5,1696304
Option 1	4	3650073,579	Option 11	1	5,0586509
Option 10	1	2495409,643	Option 1	3	4,3096409
Option 2	1	2419632,175	Option 13	2	4,216097
Option 10	2	2200029,13	Option 11	2	3,7939882
Option 2	2	2133320,346	Option 13	3	2,8107313
Option 10	3	1578490,031	Option 2	4	2,7687276
Option 2	3	1530656,063	Option 5	4	2,5848152
Option 11	1	1363240,234	Option 11	3	2,5293255
Option 11	2	1200094,194	Option 8	4	2,200866
Option 11	3	860535,3609	Option 6	4	1,9150546
Option 3	2	659819,4869	Option 13	4	1,4053657
Option 3	3	625756,0352	Option 1	4	1,3483949
Option 10	4	497278,0559	Option 11	4	1,2646627
Option 2	4	482139,2149	Option 3	1	1,0706888
Option 11	4	272348,4679	Option 3	2	0,947993
Option 3	1	236932,6075	Option 4	1	0,9000399
Option 4	4	-44926,19637	Option 3	3	0,6908275
Option 3	4	-68174,99279	Option 4	2	0,6750299
Option 4	3	-141952,6275	Option 4	3	0,45002
Option 4	2	-197965,7453	Option 3	4	0,2282917
Option 4	1	-224878,0723	Option 4	4	0,22501
Option zero	1	-181848818,8	Option zero	1	0

Scenario Combination 2					
Option	Decision moment	Total NPV	Option	Decision moment	B/C-Ratio
Option 9	1	22056507,25	Option 7	1	154,38647
Option 7	1	12864106,45	Option 12	1	43,283376
Option 9	2	10428601,37	Option 7	2	30,877293
Option 5	1	9679361,307	Option 10	1	22,886032
Option 13	1	8806575,953	Option 9	1	21,758859
Option 12	1	7712080,388	Option 10	2	10,820811
Option 6	1	6255393,596	Option 5	1	10,339261
Option 7	2	6082315,601	Option 12	2	8,6566752
Option 6	2	4777032,178	Option 2	1	7,1678455
Option 5	2	4576526,982	Option 7	3	6,1754586
Option 13	2	4163862,8	Option 13	1	5,6214626
Option 9	3	3974901,899	Option 11	1	5,0586509
Option 12	2	3646371,167	Option 9	2	4,3517719
Option 8	1	2999678,205	Option 10	3	4,1243942
Option 8	2	2462979,979	Option 5	2	2,0678522
Option 7	3	2318298,205	Option 2	2	1,963597
Option 6	3	2066638,565	Option 6	1	1,8964731
Option 1	1	1854575,992	Option 8	1	1,798031
Option 1	2	1768966,945	Option 12	3	1,731335
Option 5	3	1744361,027	Option 1	1	1,5592454
Option 13	3	1587072,472	Option 7	4	1,2350917
Option 12	3	1389828,527	Option 13	2	1,1242925
Option 8	3	1082150,11	Option 11	2	1,0117302
Option 1	3	778146,219	Option 4	1	0,9000399
Option 9	4	621154,8598	Option 6	2	0,8934295
Option 10	1	547150,7951	Option 8	2	0,8724501
Option 2	1	529948,7746	Option 9	3	0,8703544
Option 7	4	362278,6758	Option 1	2	0,7360469
Option 6	4	317038,6978	Option 10	4	0,6445159
Option 11	1	309465,1641	Option 2	3	0,4528968
Option 5	4	272589,9548	Option 5	3	0,4135704
Option 10	2	265520,2821	Option 8	3	0,3586675
Option 2	2	257386,9448	Option 6	3	0,3480146
Option 13	4	248010,5934	Option 12	4	0,346267
Option 12	4	217187,434	Option 1	3	0,2793018
Option 8	4	168713,2042	Option 3	1	0,2430539
Option 11	2	146319,1246	Option 13	3	0,2248585
Option 10	3	102109,8558	Option 11	3	0,202346
Option 2	3	99009,80269	Option 4	2	0,180008
Option 1	4	93300,39223	Option 9	4	0,1740709
Option 11	3	55770,10242	Option 3	2	0,1155822
Option 10	4	15912,89779	Option 2	4	0,0885993
Option 3	3	15646,79352	Option 5	4	0,0827141
Option 2	4	15428,45488	Option 8	4	0,0704277
Option 11	4	8715,150971	Option 6	4	0,0612817
Option 4	4	-1437,638284	Option 13	4	0,0449717
Option 3	4	-2181,599769	Option 3	3	0,0447716
Option 4	3	-9199,752774	Option 1	4	0,0431486
Option 4	2	-24136,5842	Option 11	4	0,0404692
Option 4	1	-51048,91112	Option 4	3	0,0360016
Option 3	2	-281325,6696	Option 3	4	0,0073053
Option 3	1	-2537109,055	Option 4	4	0,0072003
Option zero	1	-41280966,58	Option zero	1	0

Scenario Combination 3					
Option	Decision moment	Total NPV	Option	Decision moment	B/C-Ratio
Option 9	1	161220967,4	Option 7	1	154,38647
Option 9	2	142895387,7	Option 7	2	61,754586
Option 9	3	111401334,3	Option 10	1	44,533695
Option 7	1	94029560,68	Option 12	1	43,283376
Option 6	1	83591394,74	Option 10	2	32,468475
Option 7	2	83341458,3	Option 7	3	24,701835
Option 6	2	76955062,34	Option 9	1	21,758859
Option 5	1	70750820,87	Option 10	3	19,075641
Option 7	3	64973053,4	Option 12	2	17,31335
Option 13	1	64371238,76	Option 5	1	10,339261
Option 5	2	62708753,98	Option 7	4	9,8807338
Option 6	3	60335606,96	Option 9	2	8,7035438
Option 13	2	57054322,83	Option 2	1	8,1231821
Option 12	1	56371076,64	Option 12	3	6,9253401
Option 12	2	49963518,91	Option 13	1	5,6214626
Option 9	4	49692388,78	Option 10	4	5,1561273
Option 5	3	48887784,11	Option 11	1	5,0586509
Option 13	3	44479586,03	Option 5	2	4,1357043
Option 8	1	43477182,03	Option 2	2	4,1258279
Option 8	2	40211036,43	Option 6	1	3,579562
Option 12	3	38951590,82	Option 8	1	3,4987701
Option 1	1	32569269,1	Option 9	3	3,4814175
Option 8	3	31636105,68	Option 1	1	3,0341197
Option 1	2	30249001,22	Option 12	4	2,7701361
Option 7	4	28982294,07	Option 6	2	2,6203875
Option 6	4	25363095,82	Option 8	2	2,6178374
Option 1	3	23638939,82	Option 13	2	2,2485851
Option 5	4	21807196,39	Option 1	2	2,2085516
Option 13	4	19840847,47	Option 11	2	2,0234604
Option 12	4	17374994,72	Option 2	3	1,8339102
Option 8	4	13497056,34	Option 8	3	1,6588647
Option 1	4	9452739,739	Option 5	3	1,6542817
Option 10	1	4142708,419	Option 6	3	1,5922747
Option 2	1	4016971,087	Option 9	4	1,392567
Option 10	2	3682338,731	Option 1	3	1,2917925
Option 2	2	3570893,644	Option 4	1	0,9000399
Option 10	3	2871375,85	Option 13	3	0,899434
Option 2	3	2784493,19	Option 11	3	0,8093841
Option 11	1	2262020,571	Option 2	4	0,7087943
Option 3	2	2025307,087	Option 5	4	0,6617127
Option 11	2	2004902,413	Option 8	4	0,5634217
Option 3	3	1701156,508	Option 6	4	0,490254
Option 11	3	1563023,184	Option 3	1	0,4729561
Option 10	4	1273031,823	Option 4	2	0,360016
Option 2	4	1234276,39	Option 13	4	0,3597736
Option 11	4	697212,0777	Option 3	2	0,3468111
Option 3	1	672334,3105	Option 1	4	0,3451891
Option 4	4	-115011,0627	Option 11	4	0,3237537
Option 3	4	-174527,9816	Option 3	3	0,2070719
Option 4	3	-257833,9693	Option 4	3	0,1440064
Option 4	2	-330725,7067	Option 3	4	0,0584427
Option 4	1	-373139,5339	Option 4	4	0,0576026
Option zero	1	-301741218,2	Option zero	1	0

Scenario Combination 4					
Option	Decision moment	Total NPV	Option	Decision moment	B/C-Ratio
Option 9	1	77943908,86	Option 7	1	154,386466
Option 9	2	66316002,98	Option 7	2	92,6318795
Option 9	3	46954904,57	Option 10	1	80,8753062
Option 7	1	45459543,05	Option 10	2	68,8100857
Option 6	1	38840738,78	Option 7	3	55,5791277
Option 7	2	38677752,2	Option 10	3	48,7208345
Option 6	2	34755576,63	Option 12	1	43,2833759
Option 5	1	34205200,62	Option 7	4	33,3474766
Option 13	1	31120927,06	Option 12	2	25,9700255
Option 5	2	29102366,3	Option 9	1	21,7588595
Option 7	3	27385700,01	Option 10	4	17,4019296
Option 12	1	27253167,69	Option 12	3	15,5820153
Option 13	2	26478213,91	Option 9	2	13,0553157
Option 6	3	25118744,37	Option 5	1	10,3392608
Option 12	2	23187458,47	Option 12	4	9,34920919
Option 5	3	20605868,43	Option 2	1	9,24379286
Option 8	1	20124626,4	Option 9	3	7,83318942
Option 13	3	18747842,93	Option 2	2	6,5077895
Option 8	2	18122849,97	Option 8	1	6,35393268
Option 9	4	16771181,21	Option 6	1	6,3492388
Option 12	3	16417830,55	Option 5	2	6,2035565
Option 1	1	14956462,92	Option 13	1	5,62146263
Option 1	2	13548003,98	Option 8	2	5,54795429
Option 8	3	13165354,01	Option 1	1	5,51010558
Option 1	3	9787883,702	Option 6	2	5,46115283
Option 7	4	9781524,247	Option 11	1	5,05865091
Option 6	4	8560044,84	Option 9	4	4,69991365
Option 5	4	7359928,781	Option 1	2	4,68055943
Option 13	4	6696286,021	Option 8	3	4,23688381
Option 12	4	5864060,717	Option 2	3	4,17652526
Option 8	4	4555256,515	Option 6	3	4,03310493
Option 1	4	3161111,136	Option 5	3	3,7221339
Option 10	1	1996882,654	Option 13	2	3,37287758
Option 2	1	1936093,668	Option 1	3	3,29934972
Option 10	2	1705252,141	Option 11	2	3,03519055
Option 2	2	1653531,838	Option 2	4	2,39218066
Option 10	3	1209020,862	Option 5	4	2,23328034
Option 2	3	1172400,412	Option 13	3	2,02372655
Option 11	1	1093596,745	Option 8	4	1,90154821
Option 11	2	930450,7059	Option 11	3	1,82111433
Option 11	3	658803,6392	Option 6	4	1,65460719
Option 3	3	553785,4132	Option 13	4	1,21423593
Option 3	2	449869,2959	Option 1	4	1,16501316
Option 10	4	429648,2403	Option 11	4	1,0926686
Option 2	4	416568,2817	Option 4	1	0,90003993
Option 11	4	235309,0762	Option 3	1	0,85891082
Option 4	4	-38816,23366	Option 3	2	0,73499295
Option 3	4	-58903,19377	Option 4	2	0,54002396
Option 4	3	-108675,2641	Option 3	3	0,52887965
Option 4	2	-153485,7584	Option 4	3	0,32401437
Option 4	1	-180398,0853	Option 3	4	0,19724405
Option 3	1	-472898,4488	Option 4	4	0,19440862
Option zero	1	-145879846,7	Option zero	1	0

Scenario Combination 5					
Option	Decision moment	Total NPV	Option	Decision moment	B/C-Ratio
Option 9	1	130856567,4	Option 7	1	154,38647
Option 9	2	119228661,5	Option 10	1	135,77796
Option 9	3	93413863,66	Option 10	2	123,71274
Option 7	1	76320008,16	Option 7	2	123,50917
Option 6	1	69691649,61	Option 7	3	98,807338
Option 7	2	69538217,31	Option 10	3	96,927071
Option 6	2	64303087,1	Option 7	4	79,04587
Option 5	1	57425592,41	Option 12	1	43,283376
Option 7	3	54482147,72	Option 10	4	41,249018
Option 5	2	52322758,09	Option 12	2	34,626701
Option 13	1	52247542,5	Option 12	3	27,701361
Option 6	3	50450209,79	Option 12	4	22,161088
Option 13	2	47604829,34	Option 9	1	21,758859
Option 12	1	45754133,04	Option 9	2	17,407088
Option 12	2	41688423,82	Option 9	3	13,92567
Option 5	3	40994094,26	Option 9	4	11,140536
Option 9	4	39753911,03	Option 8	1	10,667335
Option 13	3	37297668,03	Option 2	1	10,547979
Option 8	1	36338057,53	Option 6	1	10,47917
Option 8	2	33603741,99	Option 5	1	10,339261
Option 12	3	32662253,26	Option 8	2	9,9745934
Option 1	1	27360970,01	Option 6	2	9,6960041
Option 8	3	26450409,8	Option 1	1	9,2506716
Option 1	2	25291086,12	Option 2	2	9,1305789
Option 7	4	23185835,25	Option 8	3	8,4290169
Option 6	4	20290476,66	Option 1	2	8,4151157
Option 1	3	19752487,02	Option 5	2	8,2714087
Option 5	4	17445757,11	Option 6	3	7,9708298
Option 13	4	15872677,98	Option 2	3	7,5142267
Option 12	4	13899995,77	Option 5	3	6,6171269
Option 8	4	10797645,07	Option 1	3	6,5638512
Option 1	4	7559860,124	Option 2	4	5,6703542
Option 10	1	3369449,005	Option 13	1	5,6214626
Option 2	1	3267393,076	Option 5	4	5,2937016
Option 10	2	3072818,492	Option 11	1	5,0586509
Option 2	2	2979831,246	Option 8	4	4,5073735
Option 10	3	2407176,786	Option 13	2	4,4971701
Option 2	3	2334322,677	Option 11	2	4,0469207
Option 11	1	1835991,014	Option 6	4	3,9220319
Option 3	2	1737699,445	Option 13	3	3,5977361
Option 11	2	1672844,974	Option 11	3	3,2375366
Option 3	1	1481439,521	Option 13	4	2,8781889
Option 3	3	1351586,754	Option 1	4	2,7615127
Option 11	3	1310648,885	Option 11	4	2,5900293
Option 10	4	1018425,458	Option 3	1	1,4419872
Option 2	4	987421,1121	Option 3	2	1,3214341
Option 11	4	557769,6622	Option 3	3	1,0521732
Option 4	4	-92008,85016	Option 4	1	0,9000399
Option 3	4	-139622,3852	Option 4	2	0,7200319
Option 4	3	-216202,682	Option 4	3	0,5760256
Option 4	2	-275950,0077	Option 3	4	0,4675415
Option 4	1	-302862,3346	Option 4	4	0,4608204
Option zero	1	-244911196,8	Option zero	1	0

G.2 Extension Combinations

The first combination is a relatively cheap solution which has the highest Expanded NPV score, but it should be said that the actual capacity of the access roads is lower. This is because the whole N201 will be used as a safety route for Zandvoort. The investment of parking lots was altered over the decision moments and had a higher costs than the busses used for parking in the region. Which makes it debatable if the investment in parking places is a good combination of measures.

The second combination is has a very uncertain best decision moment. For the high costs that it comes with, this would lead to high risks in terms of earning the investment back. Therefore this combination of solutions is not preferable. Also the Expanded NPV and B/C-ratio is the lowest of all combinations for all the decision moments.

Combination 3 is the best scoring combination in term of B/C-ratio. This means that this is the most efficient investment to make, because it solves a big part of the accessibility problem for the least amount of money. The combination on its own does not solve the delay hours and latecomer for visitors by car. But the station lengthening with diesel trains only is relatively the most financial efficient combination of solutions.

The fourth combination is less efficient and costly than combination 3. This is caused by the high costs (€5 million) that the overhead needs for an upgrade. Almost all the scenarios point out that a later investment is financially beneficial. The interpretation of this outcome is that the investment for the overhead line is way much more expensive than the temporary solution (diesel trains). Therefore there is actually no best investment moment, since the latest investment moment possible will always be the best one. The advise is therefore to not invest in an upgrade of the overhead line. By jsut looking at the B/C-ratio and the Expanded NPV a decision maker might choose otherwise, but if it is compared with the diesel option it is not the most financially attractive solution.

For combination 5,6,7,8 there is only one investment moment and it is clear to see that if the probability p for more repetitions is positively correlated with the Expanded NPV and B/C-ratio. This is not an unexpected outcome, but what is interesting is the actual B/C-ratio and Expanded NPV. For combination 5 and 6 the solutions are all added with 'Natural Flexibility' which causes the same B/C-ratio for every scenario combination. The Expanded NPV will increase with a higher chance of more repetitions because the benefits can be harvest for more years. For the DGP plan and the suggested DGP plan, based on the earlier outcomes of the individual solutions, it is clear to see that the originally DGP plan is scoring systematically lower on both aspects than the adjusted DGP plan. The adjustment on the original plan by looking at the individual solutions is therefore justified.

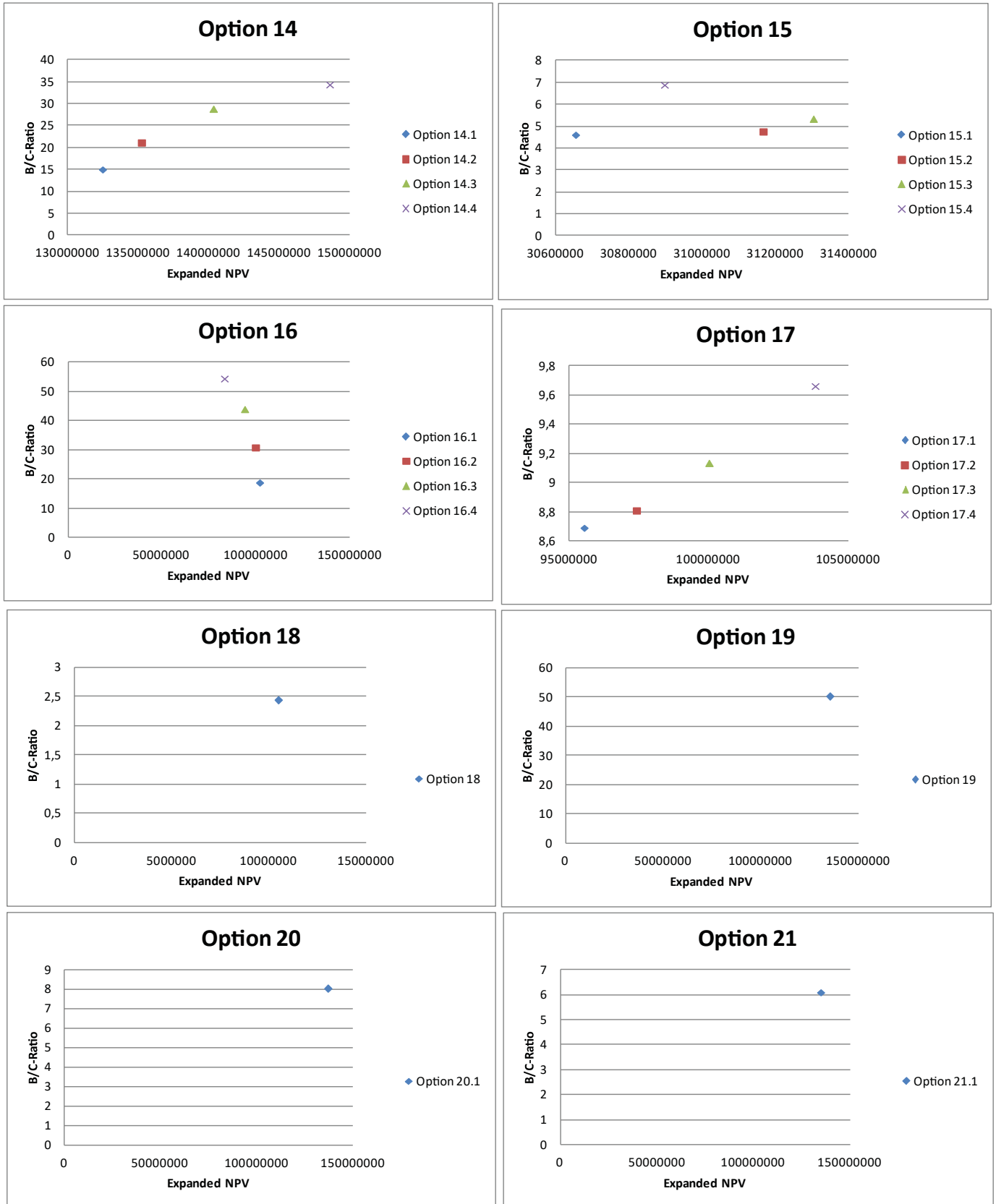
Combination 5 is based on the bicycle, but it is clear to see in the Expanded NPV and B/C-ratio tables in Appendix G.2 that this combination is the least profitable one. This holds for all the scenarios by looking at Expanded NPV and B/C-ratio. The investment in parking places for bicycles is not financially beneficial since the hindrance for illegal parking is impossible to monetize. On top of the pour outcomes the combination is also impossible to execute. Drs. Erik Verschoor pointed out that there is no company able to rent 30 thousand bicycles. This makes the combination not possible, but also the parking solution as an individual solutions is not financially beneficial. Therefore bicycle investments are not recommended.

Combination 6 a combination of only 'Natural Flexibility' solutions. The combination is made up out all of the best scoring individual solutions. This makes the combination also totally flexible, so all the solutions can be stopped once the event ends. This makes the combination very efficient and there is hardly any B/C-ratio difference for the different investment moments. This is again because there are no ongoing maintenance costs or a big investment cost for these solution. The problem in with this combination is that this combination will not eliminate all the latecomers or delay hours. A totally 'Natural Flexibel' combination is therefore not good enough to solve the problem.

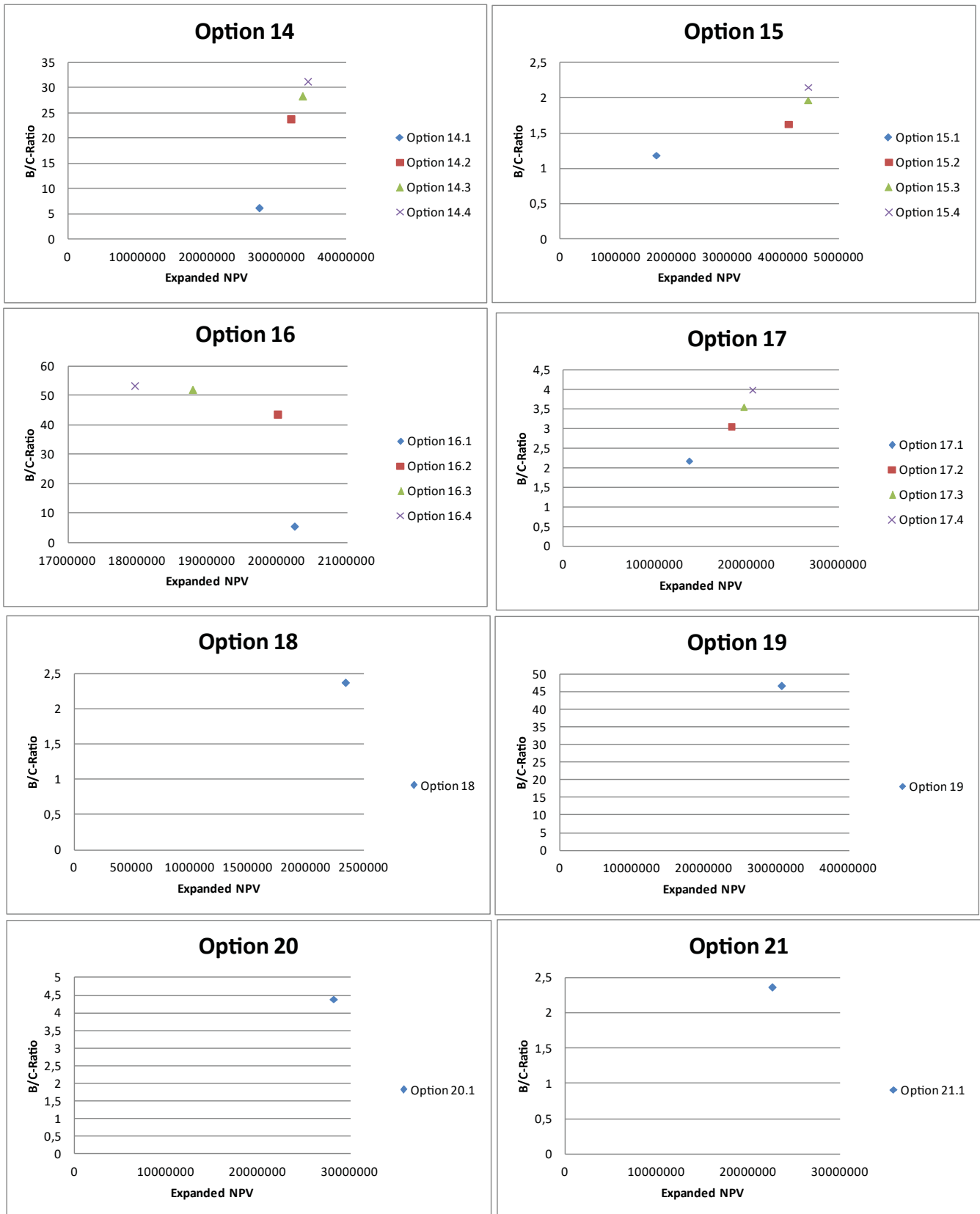
The last two combinations are the original DGP plan (combination 8) and the adjusted DGP plan (solution 7) based on the findings of the individual solutions. It is clear to see that in every possible outcome of the future the adjusted DGP plan scores better. The main difference can be found in the parking shortage for bicycles, which is discussed before. The costs are lower in the adjusted plan because the trains are diesel trains, which prevents the decision maker from investing in a new overhead

line.

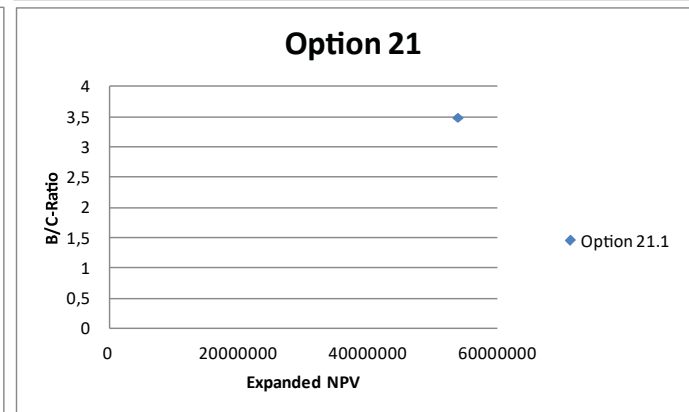
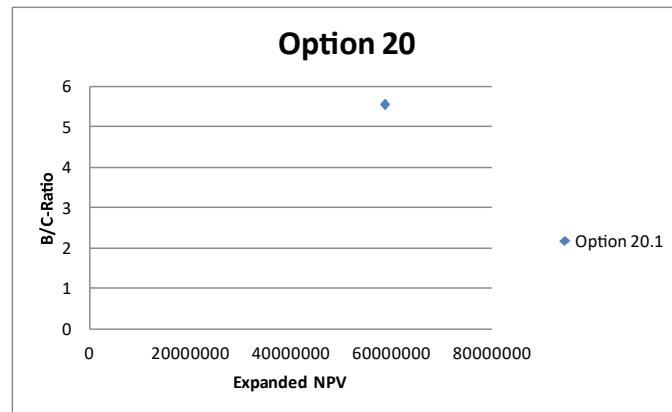
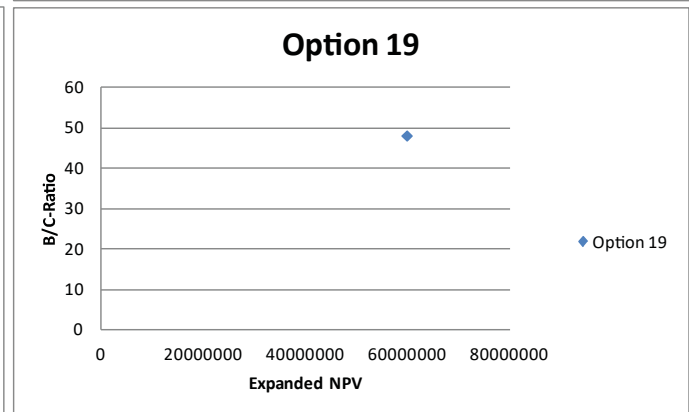
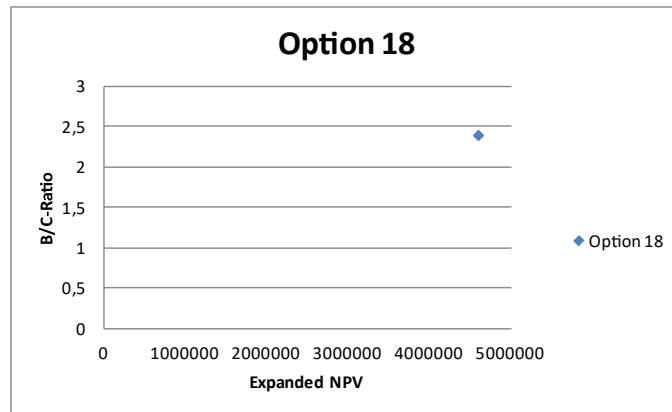
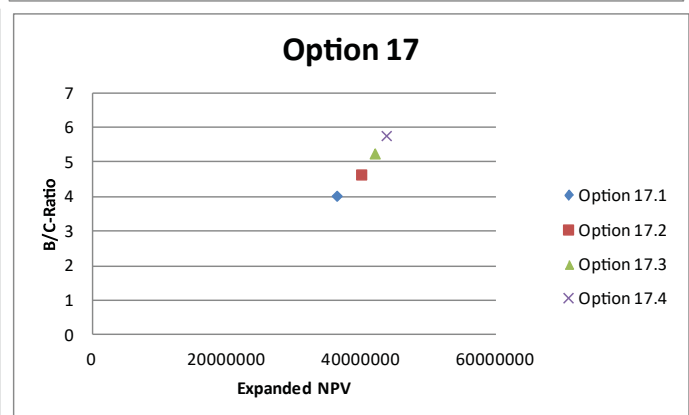
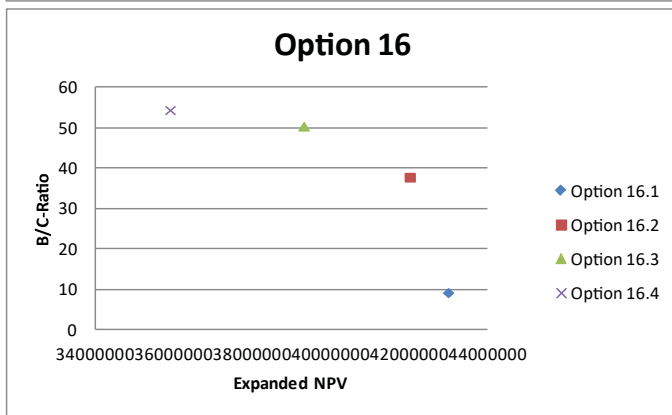
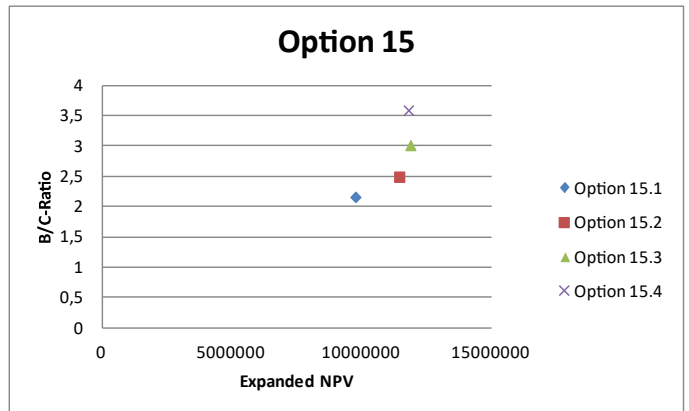
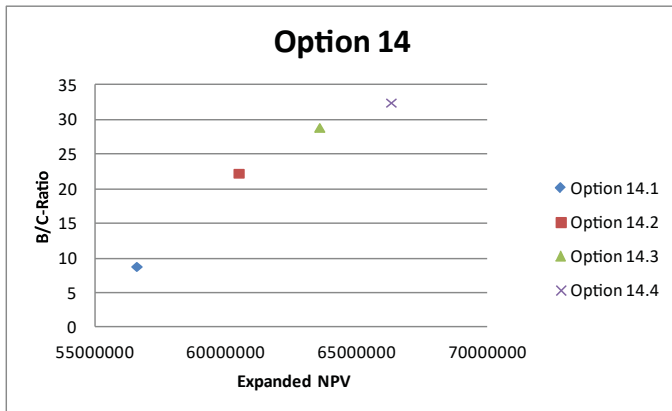
Scenario Combination 1



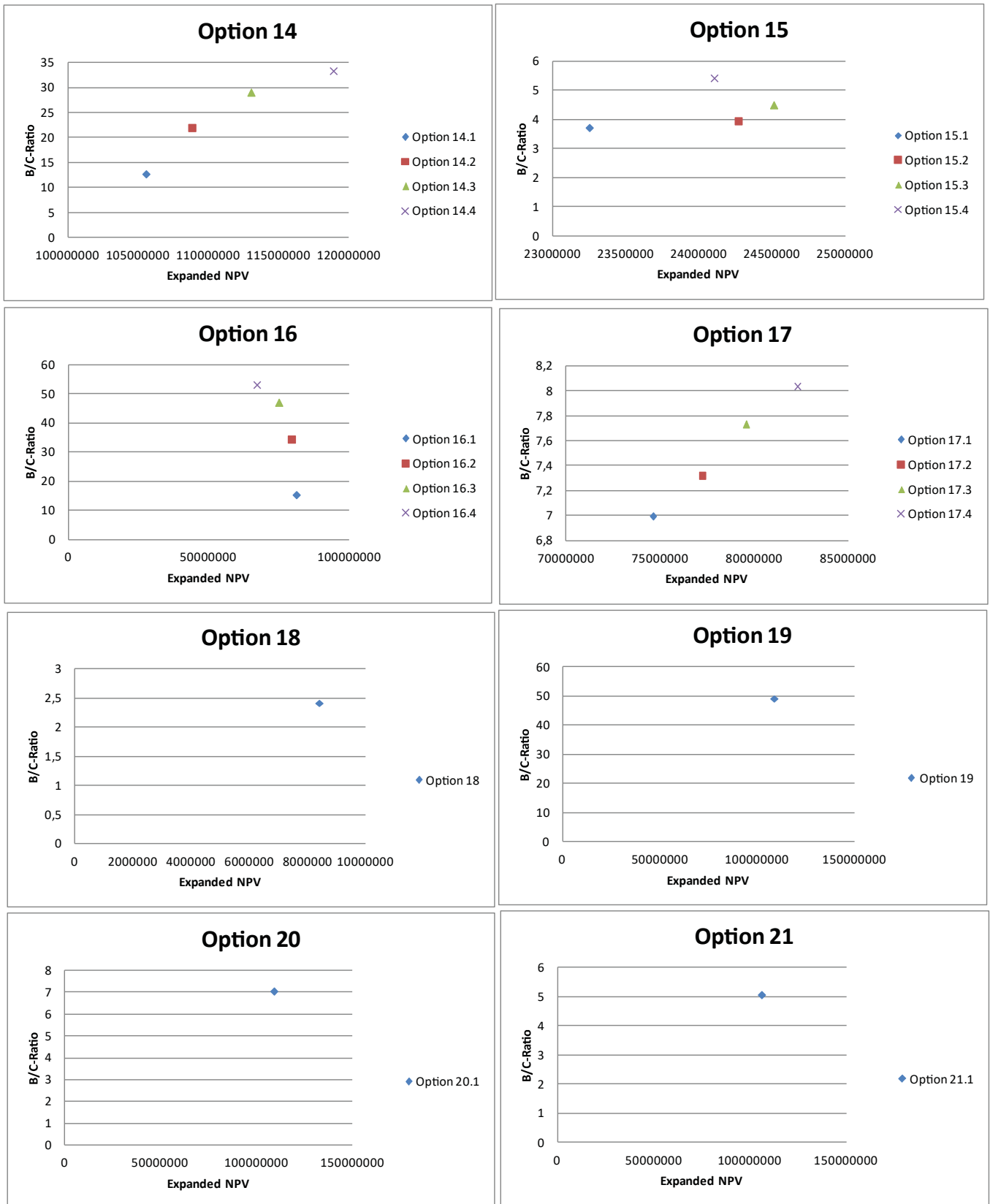
Scenario Combination 2



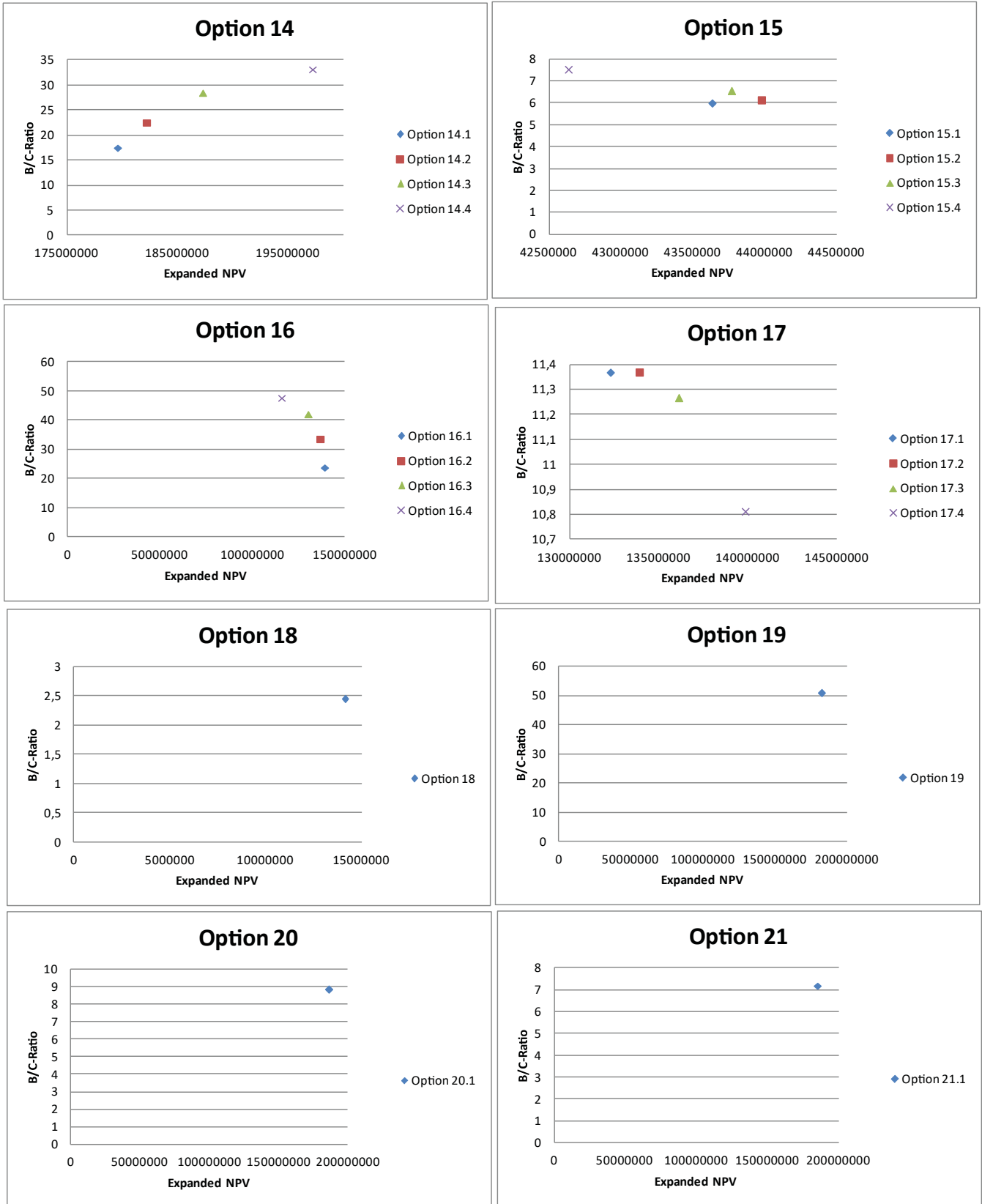
Scenario Combination 3



Scenario Combination 4



Scenario Combination 5



Scenario Combination 1					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	148583635	Combi 3	4	54,49
Combi 1	3	140329375	Combi 6	1	50,24
Combi 7	1	137125397	Combi 3	3	44,04
Combi 6	1	135401654	Combi 1	4	34,39
Combi 1	2	135233373	Combi 3	2	30,91
DGP	1	134705685	Combi 1	3	28,88
Combi 1	1	132465830	Combi 1	2	21,18
Combi 4	4	103820645	Combi 3	1	18,92
Combi 3	1	102161371	Combi 1	1	15,03
Combi 4	3	100024998	Combi 4	4	9,66
Combi 3	2	99904707	Combi 4	3	9,14
Combi 4	2	97427129	Combi 4	2	8,81
Combi 4	1	95558768	Combi 4	1	8,69
Combi 3	3	94151028	Combi 7	1	8,04
Combi 3	4	83389503	Combi 2	4	6,89
Combi 2	3	31304262	DGP	1	6,11
Combi 2	2	31167018	Combi 2	3	5,34
Combi 2	4	30897921	Combi 2	2	4,76
Combi 2	1	30655329	Combi 2	1	4,61
Combi 5	1	10476251	Combi 5	1	2,44

Scenario Combination 2					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	34425392	Combi 3	4	53,28
Combi 1	3	33665774	Combi 3	3	51,95
Combi 1	2	31985015	Combi 6	1	46,70
Combi 6	1	30698482	Combi 3	2	43,54
Combi 7	1	28184220	Combi 1	4	31,20
Combi 1	1	27429972	Combi 1	3	28,30
DGP	1	22568168	Combi 1	2	23,75
Combi 4	4	20544834	Combi 1	1	6,15
Combi 3	1	20247139	Combi 3	1	5,48
Combi 3	2	20004958	Combi 7	1	4,39
Combi 4	3	19599218	Combi 4	4	4,01
Combi 3	3	18787591	Combi 4	3	3,57
Combi 4	2	18261253	Combi 4	2	3,07
Combi 3	4	17959099	Combi 5	1	2,37
Combi 4	1	13642892	DGP	1	2,36
Combi 2	4	4452560	Combi 4	1	2,19
Combi 2	3	4446781	Combi 2	4	2,16
Combi 2	2	4099460	Combi 2	3	1,97
Combi 5	1	2339533	Combi 2	2	1,63
Combi 2	1	1727375	Combi 2	1	1,19

Scenario Combination 3					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	66326322,33	Combi 3	4	54,51
Combi 1	3	63588406,01	Combi 3	3	50,51
Combi 1	2	60512104,19	Combi 6	1	47,91
Combi 6	1	59783157,4	Combi 3	2	37,90
Combi 7	1	58446137,66	Combi 1	4	32,49
Combi 1	1	56607061,47	Combi 1	3	28,92
DGP	1	53717971,74	Combi 1	2	22,32
Combi 4	4	43773253,67	Combi 3	1	9,37
Combi 3	1	43001452,75	Combi 1	1	8,87
Combi 4	3	42048498,54	Combi 4	4	5,77
Combi 3	2	42026732,69	Combi 7	1	5,56
Combi 4	2	40016023,1	Combi 4	3	5,25
Combi 3	3	39320329,07	Combi 4	2	4,64
Combi 4	1	36397662,37	Combi 4	1	4,03
Combi 3	4	35919881,63	Combi 2	4	3,59
Combi 2	3	11886931,08	DGP	1	3,50
Combi 2	4	11807949,86	Combi 2	3	3,01
Combi 2	2	11458622,1	Combi 2	2	2,49
Combi 2	1	9763044,713	Combi 5	1	2,39
Combi 5	1	4599768,641	Combi 2	1	2,16

Scenario Combination 4					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	118900204	Combi 3	4	53,13
Combi 1	3	113055791,1	Combi 6	1	49,27
Combi 7	1	109249164,7	Combi 3	3	47,07
Combi 1	2	108843946,3	Combi 3	2	34,44
Combi 6	1	108609856,4	Combi 1	4	33,25
DGP	1	106011562	Combi 1	3	28,94
Combi 1	1	105588903,6	Combi 1	2	21,86
Combi 4	4	82273192,54	Combi 3	1	15,34
Combi 3	1	81200883,11	Combi 1	1	12,59
Combi 4	3	79543206,45	Combi 4	4	8,03
Combi 3	2	79493623,96	Combi 4	3	7,73
Combi 4	2	77216220,39	Combi 4	2	7,32
Combi 3	3	75026515,34	Combi 7	1	7,03
Combi 4	1	74597859,66	Combi 4	1	7,00
Combi 3	4	67180925,94	Combi 2	4	5,42
Combi 2	3	24515179,55	DGP	1	5,08
Combi 2	2	24272216,73	Combi 2	3	4,49
Combi 2	4	24107755,26	Combi 2	2	3,94
Combi 2	1	23253147,16	Combi 2	1	3,71
Combi 5	1	8394200,752	Combi 5	1	2,42

Scenario Combination 5					
Combination	Decision moment	Total NPV	Combination	Decision moment	B/C-Ratio
Combi 1	4	197203174	Combi 6	1	50,77
Combi 1	3	187280066	Combi 3	4	47,66
Combi 7	1	185999230	Combi 3	3	42,12
DGP	1	185013478	Combi 3	2	33,64
Combi 6	1	182374208	Combi 1	4	33,14
Combi 1	2	182192678	Combi 1	3	28,46
Combi 1	1	179587636	Combi 3	1	23,85
Combi 4	4	139869518	Combi 1	2	22,53
Combi 3	1	138910216	Combi 1	1	17,48
Combi 3	2	136470417	Combi 4	2	11,37
Combi 4	3	136148208	Combi 4	1	11,37
Combi 4	2	133926711	Combi 4	3	11,27
Combi 4	1	132308351	Combi 4	4	10,81
Combi 3	3	129970935	Combi 7	1	8,83
Combi 3	4	115677296	Combi 2	4	7,52
Combi 2	2	43975720	DGP	1	7,19
Combi 2	3	43767003	Combi 2	3	6,55
Combi 2	1	43633158	Combi 2	2	6,13
Combi 2	4	42634308	Combi 2	1	5,99
Combi 5	1	14126594	Combi 5	1	2,45

Appendix H

Sensitivity Analysis

In this appendix the relative changes are given for the five scenarios. The 6 most uncertain variables have been used as parameters that have been changed. In the following tables the different outcomes are given. They are all based on table 4.1 out of Chapter 4.

Sensitivity Analysis

Increase Value of time from 9 euro per hour to 18 euro per hour (200% increase)
In the tables are the relative changes compared with the original values

Option	Decision moment	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio	
Option zero	1	1,2508	-		0,2467	-		0,2976	-		1,2508	-		1,2508	-	
Option 1	1	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 1	2	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 1	3	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 1	4	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 2	1	1,1333	1,1204		1,1436	1,1204		1,1370	1,1204		1,1340	1,1204		1,1326	1,1204	
Option 2	2	1,1329	1,1204		1,1358	1,1204		1,1340	1,1204		1,1330	1,1204		1,1324	1,1204	
Option 2	3	1,1328	1,1204		1,1333	1,1204		1,1329	1,1204		1,1326	1,1204		1,1324	1,1204	
Option 2	4	1,1341	1,1204		1,1341	1,1204		1,1341	1,1204		1,1341	1,1204		1,1341	1,1204	
Option 3	1	13,7971	1,8449		0,7287	1,8449		0,2418	1,8449		-4,1435	1,8449		3,7565	1,8449	
Option 3	2	5,0453	1,8449		-0,1568	1,8449		-4,5090	1,8449		5,6002	1,8449		3,1411	1,8449	
Option 3	3	4,0586	1,8449		8,9276	1,8449		4,7167	1,8449		3,6459	1,8449		3,1568	1,8449	
Option 3	4	-7,8852	1,8449		-7,8852	1,8449		-7,8852	1,8449		-7,8852	1,8449		-7,8852	1,8449	
Option 4	1	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	2	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	3	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	4	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 5	1	1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059	
Option 5	2	1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059	
Option 5	3	1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059	
Option 5	4	1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059		1,2280	1,2059	
Option 6	1	1,2680	1,2352		1,4868	1,2352		1,3217	1,2352		1,2770	1,2352		1,2592	1,2352	
Option 6	2	1,2625	1,2352		1,3014	1,2352		1,2762	1,2352		1,2634	1,2352		1,2560	1,2352	
Option 6	3	1,2595	1,2352		1,2655	1,2352		1,2612	1,2352		1,2581	1,2352		1,2556	1,2352	
Option 6	4	1,2705	1,2352		1,2705	1,2352		1,2705	1,2352		1,2705	1,2352		1,2705	1,2352	
Option 7	1	1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352	
Option 7	2	1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352	
Option 7	3	1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352	
Option 7	4	1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352		1,2367	1,2352	
Option 8	1	1,2804	1,2450		1,5520	1,2450		1,3430	1,2450		1,2908	1,2450		1,2703	1,2450	
Option 8	2	1,2737	1,2450		1,3179	1,2450		1,2892	1,2450		1,2747	1,2450		1,2664	1,2450	
Option 8	3	1,2693	1,2450		1,2758	1,2450		1,2712	1,2450		1,2678	1,2450		1,2651	1,2450	
Option 8	4	1,2764	1,2450		1,2764	1,2450		1,2764	1,2450		1,2764	1,2450		1,2764	1,2450	
Option 9	1	1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172	
Option 9	2	1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172	
Option 9	3	1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172		1,1602	0,7172	

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Option 9	4	1,1602	0,7172	1,1602	0,7172	1,1602	0,7172	1,1602	0,7172	1,1602	0,7172	1,1602	0,7172	1,1602	0,7172	0,7172
Option 10	1	1,0056	1,0055	1,0060	1,0055	1,0057	1,0055	1,0057	1,0055	1,0056	1,0055	1,0056	1,0055	1,0055	1,0055	1,0055
Option 10	2	1,0056	1,0055	1,0057	1,0055	1,0057	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0055	1,0055	1,0055
Option 10	3	1,0055	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0055	1,0055	1,0055
Option 10	4	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0056	1,0055	1,0055	1,0055	1,0055
Option 11	1	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	1,9920
Option 11	2	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	1,9920
Option 11	3	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	1,9920
Option 11	4	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	2,2364	1,9920	1,9920
Option 12	1	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2231
Option 12	2	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2231
Option 12	3	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2231
Option 12	4	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2283	1,2231	1,2231
Option 13	1	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,6685
Option 13	2	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,6685
Option 13	3	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,6685
Option 13	4	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,9239	0,6685	0,6685

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Combi 1	1	1,1513	0,8737	1,1659	1,0090	1,1564	0,9445	1,1503	0,8483	1,1503	0,8483	1,1503	0,8483	1,1503	0,8483	0,8483
Combi 1	2	1,1524	0,9836	1,1601	1,1392	1,1558	1,0974	1,1513	0,9394	1,1513	0,9394	1,1513	0,9394	1,1513	0,9394	0,9394
Combi 1	3	1,1554	1,0781	1,1615	1,1532	1,1582	1,1347	1,1540	1,0292	1,1540	1,0292	1,1540	1,0292	1,1540	1,0292	1,0292
Combi 1	4	1,1606	1,1572	1,1627	1,1582	1,1616	1,1579	1,1605	1,1596	1,1605	1,1596	1,1605	1,1596	1,1605	1,1596	1,1596
Combi 2	1	1,1098	1,0876	1,4423	1,0876	1,1523	1,0876	1,1161	1,0876	1,1161	1,0876	1,1161	1,0876	1,1039	1,0876	1,0876
Combi 2	2	1,0967	1,0765	1,1006	1,0372	1,0991	1,0587	1,0967	1,0796	1,0967	1,0796	1,0967	1,0796	1,0951	1,0796	1,0796
Combi 2	3	1,0729	1,0538	1,0488	1,0198	1,0627	1,0346	1,0719	1,0627	1,0719	1,0627	1,0719	1,0627	1,0777	1,0627	1,0627
Combi 2	4	1,0328	1,0230	1,0260	1,0134	1,0287	1,0176	1,0353	1,0325	1,0353	1,0325	1,0353	1,0325	1,0417	1,0325	1,0325
Combi 3	1	1,2249	1,2042	1,2576	1,2105	1,2360	1,2073	1,2047	1,2027	1,2073	1,2027	1,2047	1,2027	1,2228	1,2027	1,2027
Combi 3	2	1,2212	1,2060	1,2169	1,1970	1,2206	1,1992	1,2208	1,2081	1,2208	1,2081	1,2208	1,2081	1,2203	1,2081	1,2081
Combi 3	3	1,2153	1,2011	1,2050	1,1963	1,2110	1,1974	1,2145	1,2038	1,2145	1,2038	1,2145	1,2038	1,2163	1,2038	1,2038
Combi 3	4	1,2052	1,1974	1,2004	1,1961	1,2028	1,1964	1,2056	1,1993	1,2056	1,1993	1,2056	1,1993	1,2081	1,1993	1,1993
Combi 4	1	1,2404	1,2091	1,3823	1,2125	1,2788	1,2107	1,2470	1,2082	1,2470	1,2082	1,2470	1,2082	1,2338	1,2082	1,2082
Combi 4	2	1,2306	1,1755	1,2579	1,1466	1,2410	1,1626	1,2321	1,1773	1,2321	1,1773	1,2321	1,1773	1,2272	1,1773	1,1773
Combi 4	3	1,2141	1,0962	1,2260	1,0913	1,2160	1,0873	1,2147	1,1058	1,2147	1,1058	1,2147	1,1058	1,2153	1,1058	1,1058
Combi 4	4	1,1887	0,9783	1,2085	1,0587	1,1941	1,0169	1,1917	0,9922	1,1917	0,9922	1,1917	0,9922	1,1929	0,9922	0,9922
Combi 5	1	1,2661	1,1584	1,2704	1,1584	1,2677	1,1584	1,2664	1,1584	1,2664	1,1584	1,2664	1,1584	1,2657	1,1584	1,1584
Combi 6	1	1,1933	1,1896	1,1936	1,1896	1,1934	1,1896	1,1933	1,1896	1,1933	1,1896	1,1933	1,1896	1,1933	1,1896	1,1896
Combi 7	1	1,1414	0,8998	1,1561	0,9967	1,1465	0,9543	1,1424	0,8839	1,1424	0,9165	1,1404	0,8839	1,1404	0,8839	0,8839
DGP	1	1,1531	0,9797	1,2074	1,0695	1,1696	1,0264	1,1561	0,9614	1,1561	0,9903	1,1501	0,9614	1,1501	0,9614	0,9614

Sensitivity Analysis

Increase Value of Missing Out from €150 to €300 (200% increase)

In the tables are the relative changes compared with the original values

Option	Decision moment	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio	
Option zero		1,6773	-		0,3309	-		0,3990	-		1,6773	-		1,6773	-	
Option 1	1	2,1704	2,0000		3,7881	2,0000		2,4916	2,0000		2,2217	2,0000		2,1212	2,0000	
Option 1	2	2,1421	2,0000		2,3821	2,0000		2,2229	2,0000		2,1475	2,0000		2,1052	2,0000	
Option 1	3	2,1328	2,0000		2,1975	2,0000		2,1480	2,0000		2,1246	2,0000		2,1087	2,0000	
Option 1	4	2,2467	2,0000		2,5608	2,0000		2,2773	2,0000		2,2438	2,0000		2,2328	2,0000	
Option 2	1	1,9482	1,8559		2,0208	1,8559		1,9739	1,8559		1,9531	1,8559		1,9431	1,8559	
Option 2	2	1,9453	1,8559		1,9656	1,8559		1,9530	1,8559		1,9458	1,8559		1,9413	1,8559	
Option 2	3	1,9441	1,8559		1,9478	1,8559		1,9451	1,8559		1,9432	1,8559		1,9416	1,8559	
Option 2	4	1,9532	1,8559		1,9532	1,8559		1,9532	1,8559		1,9532	1,8559		1,9532	1,8559	
Option 3	1	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 3	2	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 3	3	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 3	4	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	1	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	2	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	3	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 4	4	1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000	
Option 5	1	1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914	
Option 5	2	1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914	
Option 5	3	1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914	
Option 5	4	1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914		1,8762	1,7914	
Option 6	1	1,8061	1,7073		2,4640	1,7073		1,9674	1,7073		1,8332	1,7073		1,7796	1,7073	
Option 6	2	1,7895	1,7073		1,9064	1,7073		1,8308	1,7073		1,7922	1,7073		1,7698	1,7073	
Option 6	3	1,7806	1,7073		1,7986	1,7073		1,7857	1,7073		1,7761	1,7073		1,7688	1,7073	
Option 6	4	1,8135	1,7073		1,8135	1,7073		1,8135	1,7073		1,8135	1,7073		1,8135	1,7073	
Option 7	1	1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073	
Option 7	2	1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073	
Option 7	3	1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073	
Option 7	4	1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073		1,7119	1,7073	
Option 8	1	1,7955	1,6950		2,5660	1,6950		1,9732	1,6950		1,8249	1,6950		1,7669	1,6950	
Option 8	2	1,7764	1,6950		1,9018	1,6950		1,8204	1,6950		1,7793	1,6950		1,7556	1,6950	
Option 8	3	1,7641	1,6950		1,7823	1,6950		1,7692	1,6950		1,7596	1,6950		1,7521	1,6950	
Option 8	4	1,7841	1,6950		1,7841	1,6950		1,7841	1,6950		1,7841	1,6950		1,7841	1,6950	
Option 9	1	1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726	
Option 9	2	1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726	
Option 9	3	1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726		1,8099	1,7726	

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Option 9	4	1,8099	1,7726	1,8099	1,7726	1,8099	1,7726	1,8099	1,7726	1,8099	1,7726	1,8099	1,7726	1,8099	1,7726	1,7726
Option 10	1	2,0515	2,0307	2,1294	2,0307	2,0791	2,0307	2,0791	2,0307	2,0568	2,0307	2,0461	2,0307	2,0461	2,0307	2,0307
Option 10	2	2,0484	2,0307	2,0702	2,0307	2,0567	2,0307	2,0567	2,0307	2,0490	2,0307	2,0442	2,0307	2,0442	2,0307	2,0307
Option 10	3	2,0471	2,0307	2,0510	2,0307	2,0482	2,0307	2,0482	2,0307	2,0461	2,0307	2,0445	2,0307	2,0445	2,0307	2,0307
Option 10	4	2,0569	2,0307	2,0569	2,0307	2,0569	2,0307	2,0569	2,0307	2,0569	2,0307	2,0569	2,0307	2,0569	2,0307	2,0307
Option 11	1	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Option 11	2	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Option 11	3	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Option 11	4	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Option 12	1	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7194
Option 12	2	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7194
Option 12	3	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7194
Option 12	4	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7364	1,7194	1,7194
Option 13	1	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	1,9424
Option 13	2	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	1,9424
Option 13	3	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	1,9424
Option 13	4	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	2,1463	1,9424	1,9424

Sensitivity Analysis

Increase Social Costs for all types of emissions by 400%

In the tables are the relative changes compared with the original values

Option	Decision moment	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio		Total NPV	B/C-Ratio	
Option zero	1	1,0019	-		0,1976	-		0,2384	-		1,0019	-		1,0019	-	
Option 1	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 1	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 1	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 1	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 2	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 2	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 2	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 2	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 3	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 3	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 3	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 3	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 4	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 4	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 4	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 4	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 5	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 5	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 5	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 5	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 6	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 6	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 6	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 6	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 7	1	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990
Option 7	2	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990
Option 7	3	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990
Option 7	4	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990	1,0000		0,9990
Option 8	1	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 8	2	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 8	3	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 8	4	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000	1,0000		1,0000
Option 9	1	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970
Option 9	2	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970
Option 9	3	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970
Option 9	4	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970	0,9999		0,9970

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Option 10	1	1,0103	1,0101	1,0111	1,0101	1,0106	1,0101	1,0101	1,0104	1,0101	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101
Option 10	2	1,0103	1,0101	1,0105	1,0101	1,0104	1,0101	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101
Option 10	3	1,0103	1,0101	1,0103	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101	1,0101	1,0103	1,0101
Option 10	4	1,0104	1,0101	1,0104	1,0101	1,0104	1,0101	1,0101	1,0104	1,0101	1,0101	1,0104	1,0101	1,0101	1,0104	1,0101
Option 11	1	0,9975	0,9898	0,9975	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898
Option 11	2	0,9975	0,9898	0,9975	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898
Option 11	3	0,9975	0,9898	0,9975	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898
Option 11	4	0,9975	0,9898	0,9975	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898	0,9898	0,9975	0,9898
Option 12	1	1,0010	1,0009	1,0010	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009
Option 12	2	1,0010	1,0009	1,0010	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009
Option 12	3	1,0010	1,0009	1,0010	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009
Option 12	4	1,0010	1,0009	1,0010	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009	1,0009	1,0010	1,0009
Option 13	1	1,0007	1,0006	1,0007	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006
Option 13	2	1,0007	1,0006	1,0007	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006
Option 13	3	1,0007	1,0006	1,0007	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006
Option 13	4	1,0007	1,0006	1,0007	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006	1,0006	1,0007	1,0006
Combi 1	1	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001
Combi 1	2	1,0002	1,0003	1,0004	1,0006	1,0003	1,0006	1,0005	1,0002	1,0005	1,0004	1,0002	1,0004	1,0001	1,0001	1,0003
Combi 1	3	1,0003	1,0005	1,0006	1,0006	1,0004	1,0006	1,0006	1,0003	1,0006	1,0005	1,0003	1,0005	1,0003	1,0003	1,0004
Combi 1	4	1,0006	1,0006	1,0006	1,0006	1,0006	1,0006	1,0006	1,0005	1,0006	1,0006	1,0005	1,0005	1,0005	1,0005	1,0004
Combi 2	1	1,0008	1,0007	1,0034	1,0007	1,0012	1,0007	1,0007	1,0009	1,0007	1,0007	1,0008	1,0007	1,0007	1,0008	1,0005
Combi 2	2	1,0007	1,0006	1,0007	1,0002	1,0007	1,0002	1,0004	1,0007	1,0004	1,0005	1,0007	1,0005	1,0005	1,0007	1,0006
Combi 2	3	1,0005	1,0004	1,0002	1,0001	1,0004	1,0001	1,0002	1,0005	1,0002	1,0003	1,0006	1,0003	1,0004	1,0004	1,0004
Combi 2	4	1,0002	1,0001	1,0000	1,0000	1,0001	1,0000	1,0000	1,0002	1,0001	1,0001	1,0002	1,0002	1,0002	1,0002	1,0002
Combi 3	1	1,0000	0,9999	1,0000	1,0000	1,0000	1,0000	0,9999	1,0000	0,9999	0,9999	1,0000	0,9999	1,0000	0,9999	0,9999
Combi 3	2	1,0000	1,0001	1,0001	1,0003	1,0001	1,0003	1,0003	1,0000	1,0003	1,0002	1,0000	1,0002	1,0001	1,0001	1,0001
Combi 3	3	1,0001	1,0002	1,0002	1,0003	1,0002	1,0003	1,0003	1,0001	1,0003	1,0001	1,0001	1,0001	1,0001	1,0001	1,0002
Combi 3	4	1,0002	1,0003	1,0003	1,0003	1,0003	1,0003	1,0003	1,0002	1,0003	1,0003	1,0002	1,0003	1,0002	1,0002	1,0003
Combi 4	1	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Combi 4	2	1,0000	1,0000	1,0001	1,0001	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Combi 4	3	1,0000	1,0000	1,0001	1,0001	1,0001	1,0001	1,0001	1,0000	1,0001	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Combi 4	4	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001	1,0001
Combi 5	1	1,0041	1,0024	1,0041	1,0024	1,0041	1,0024	1,0024	1,0041	1,0024	1,0024	1,0041	1,0024	1,0024	1,0041	1,0024
Combi 6	1	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005	1,0005
Combi 7	1	0,9997	0,9977	0,9997	0,9987	0,9997	0,9987	0,9982	0,9997	0,9982	0,9979	0,9997	0,9979	0,9975	0,9997	0,9975
DGP	1	1,0002	1,0002	1,0003	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002	1,0002

Sensitivity Analysis

Increase Value of Hindrance by Illegal bicycle parking from €9 to €18 (200% increase)
In the tables are the relative changes compared with the original values

Option	Decision moment	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	1	Total NPV	B/C-Ratio	0,20 -	Total NPV	B/C-Ratio	0,24 -	Total NPV	B/C-Ratio	1,01 -	Total NPV	B/C-Ratio	1,01 -
Option zero	1	1,01 -														
Option 1	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 1	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 1	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 1	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 2	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 2	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 2	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 2	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 3	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 3	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 3	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 3	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 4	1	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00
Option 4	2	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00
Option 4	3	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00
Option 4	4	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00	-7,40		2,00
Option 5	1	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95
Option 5	2	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95
Option 5	3	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95
Option 5	4	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95	0,95		0,95
Option 6	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 6	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 6	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 6	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 7	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 7	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 7	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 7	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 8	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 8	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 8	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 8	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 9	1	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 9	2	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 9	3	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00
Option 9	4	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00	1,00		1,00

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Option 10	1	0,94	0,94	0,94	0,94	0,93	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
Option 10	2	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
Option 10	3	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
Option 10	4	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94
Option 11	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 11	2	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 11	3	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 11	4	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 12	1	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Option 12	2	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Option 12	3	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Option 12	4	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Option 13	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 13	2	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 13	3	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Option 13	4	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Combi 1	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Combi 1	2	1,00	1,00	1,00	1,01	1,01	1,00	1,01	1,00	1,01	1,00	1,00	1,01	1,00	1,00	1,00
Combi 1	3	1,00	1,00	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,00	1,01	1,01
Combi 1	4	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Combi 2	1	1,00	1,00	1,00	1,00	0,98	1,00	1,00	0,99	1,00	1,00	0,99	1,00	1,00	1,00	1,00
Combi 2	2	1,00	1,00	1,01	1,04	1,05	1,04	1,02	1,02	1,02	1,01	1,01	1,01	1,00	1,00	1,00
Combi 2	3	1,02	1,02	1,02	1,05	1,08	1,04	1,04	1,04	1,04	1,02	1,02	1,03	1,01	1,02	1,02
Combi 2	4	1,05	1,05	1,05	1,10	1,10	1,06	1,07	1,05	1,05	1,05	1,05	1,05	1,04	1,04	1,04
Combi 3	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Combi 3	2	1,00	1,01	1,01	1,01	1,01	1,02	1,01	1,01	1,02	1,00	1,00	1,02	1,00	1,01	1,01
Combi 3	3	1,01	1,02	1,02	1,02	1,02	1,02	1,01	1,01	1,02	1,01	1,01	1,02	1,01	1,01	1,01
Combi 3	4	1,02	1,02	1,02	1,02	1,02	1,03	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02
Combi 4	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Combi 4	2	1,00	1,00	1,00	1,01	1,01	1,01	1,01	1,01	1,01	1,00	1,00	1,00	1,00	1,00	1,00
Combi 4	3	1,01	1,01	1,01	1,02	1,02	1,02	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
Combi 4	4	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,01	1,01	1,01
Combi 5	1	1,05	1,03	1,03	1,05	1,05	1,03	1,05	1,05	1,03	1,05	1,05	1,03	1,05	1,03	1,03
Combi 6	1	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99
Combi 7	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
DGP	1	1,01	1,01	1,01	1,02	1,02	1,01	1,02	1,02	1,01	1,02	1,02	1,01	1,01	1,01	1,01

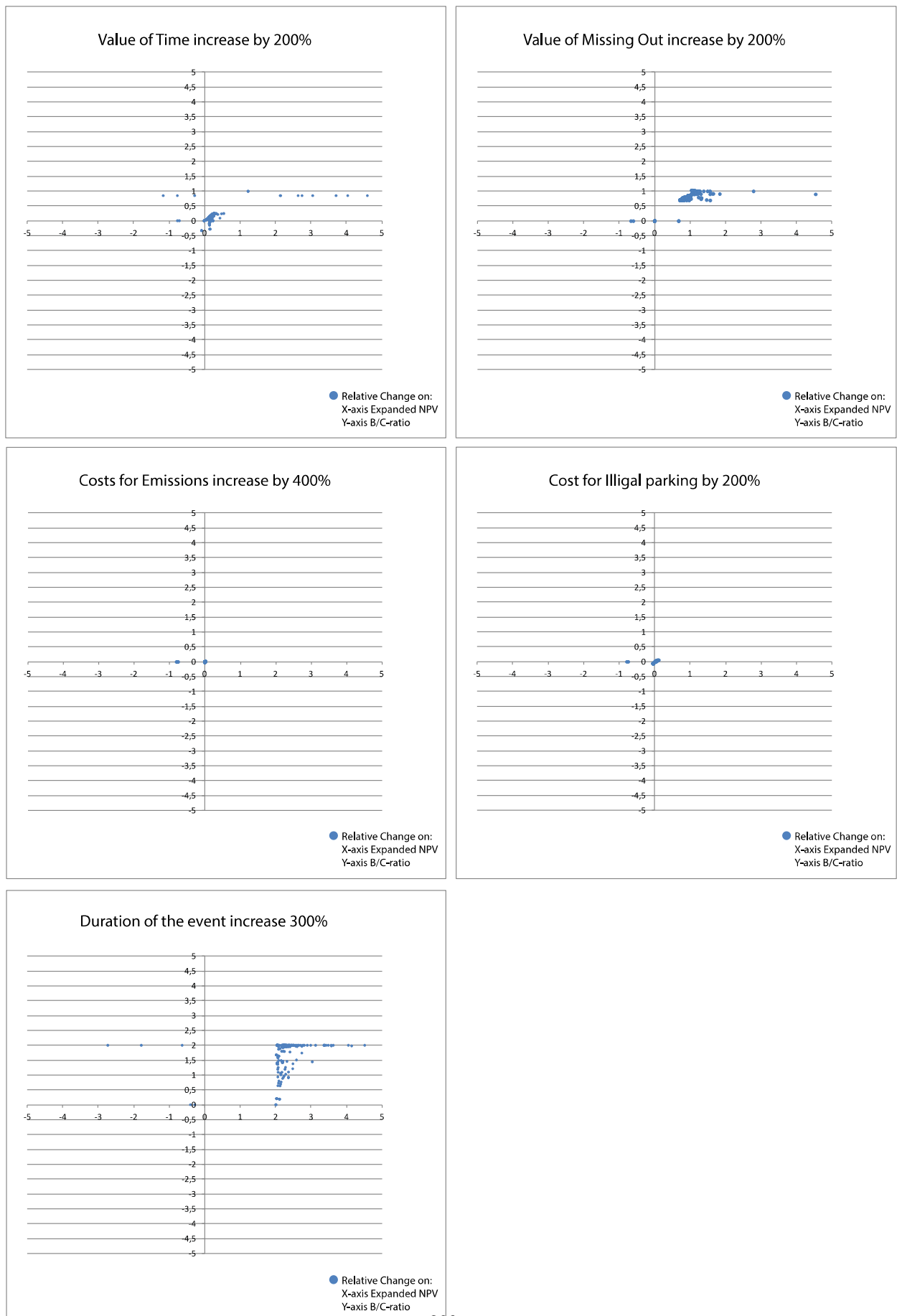
Sensitivity Analysis

Increase Duration of the event from 2 days per year to 6 days per year (300% increase)
In the tables are the relative changes compared with the original values

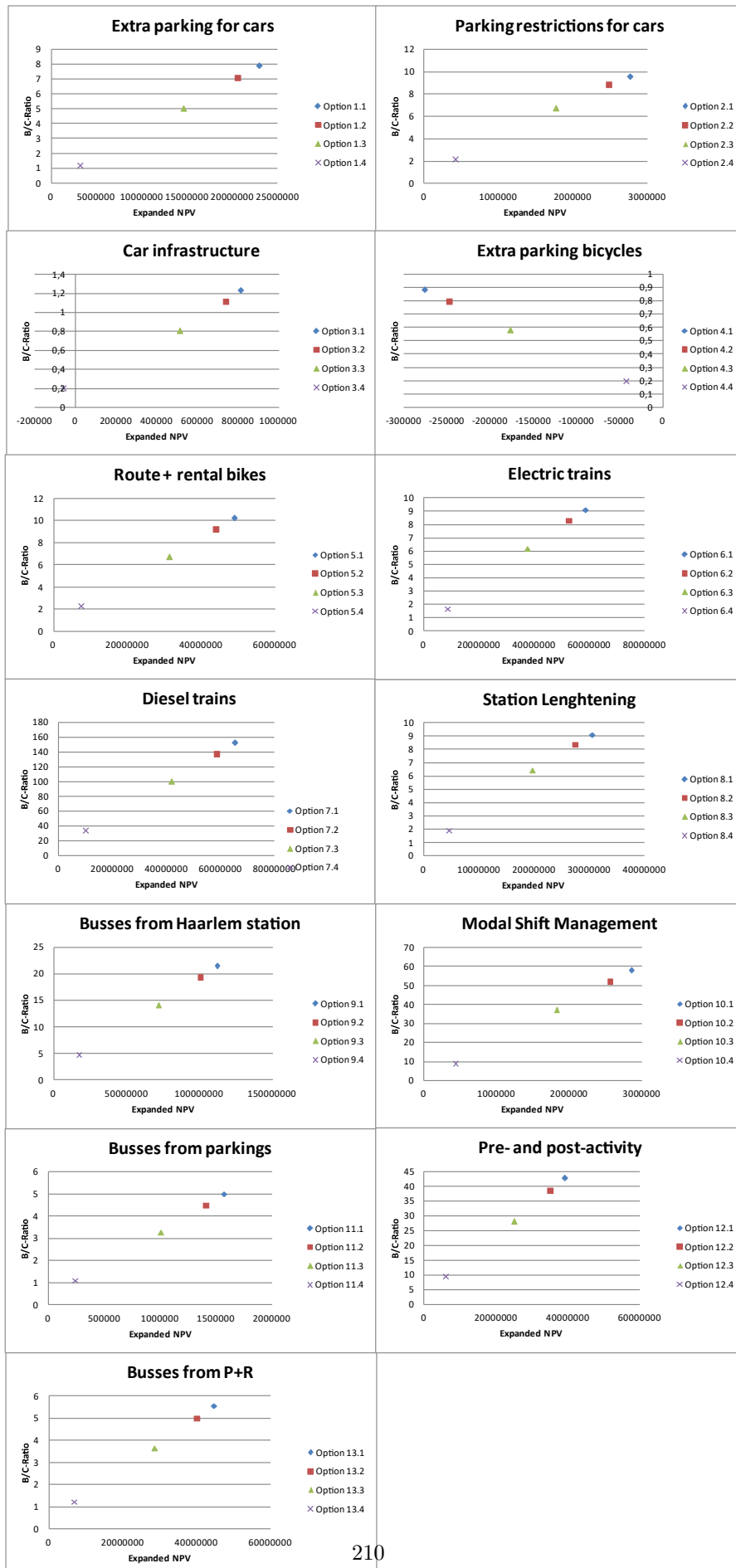
Option	Decision moment	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	1	Total NPV	B/C-Ratio	0,59 -	Total NPV	B/C-Ratio	0,71 -	Total NPV	B/C-Ratio	3,00 -	Total NPV	B/C-Ratio	3,00 -
Option zero	1	3,00	-													
Option 1	1	3,34		3,00	6,58		3,00	3,98		3,00	3,44		3,00	3,24		3,00
Option 1	2	3,28		3,00	3,76		3,00	3,45		3,00	3,30		3,00	3,21		3,00
Option 1	3	3,27		3,00	3,40		3,00	3,30		3,00	3,25		3,00	3,22		3,00
Option 1	4	3,49		3,00	4,12		3,00	3,55		3,00	3,49		3,00	3,47		3,00
Option 2	1	3,22		3,00	3,39		3,00	3,28		3,00	3,23		3,00	3,20		3,00
Option 2	2	3,21		3,00	3,26		3,00	3,23		3,00	3,21		3,00	3,20		3,00
Option 2	3	3,21		3,00	3,21		3,00	3,21		3,00	3,20		3,00	3,20		3,00
Option 2	4	3,23		3,00	3,23		3,00	3,23		3,00	3,23		3,00	3,23		3,00
Option 3	1	31,29		3,00	0,36		3,00	-0,79		3,00	-11,18		3,00	7,53		3,00
Option 3	2	10,58		3,00	-1,74		3,00	-12,04		3,00	11,89		3,00	6,07		3,00
Option 3	3	8,24		3,00	19,77		3,00	9,80		3,00	7,26		3,00	6,11		3,00
Option 3	4	-20,03		3,00	-20,03		3,00	-20,03		3,00	-20,03		3,00	-20,03		3,00
Option 4	1	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00
Option 4	2	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00
Option 4	3	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00
Option 4	4	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00	-15,80		3,00
Option 5	1	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42
Option 5	2	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42
Option 5	3	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42
Option 5	4	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42	3,19		2,42
Option 6	1	3,28		2,95	5,14		2,98	3,73		2,96	3,35		2,95	3,20		2,94
Option 6	2	3,23		2,95	3,56		2,97	3,35		2,96	3,24		2,95	3,18		2,94
Option 6	3	3,21		2,95	3,26		2,96	3,22		2,96	3,19		2,95	3,17		2,95
Option 6	4	3,30		2,97	3,30		2,97	3,30		2,97	3,30		2,97	3,30		2,97
Option 7	1	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68
Option 7	2	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68
Option 7	3	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68
Option 7	4	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68	3,01		2,68
Option 8	1	3,29		3,00	5,51		3,00	3,80		3,00	3,37		3,00	3,21		3,00
Option 8	2	3,23		3,00	3,59		3,00	3,36		3,00	3,24		3,00	3,17		3,00
Option 8	3	3,20		3,00	3,25		3,00	3,21		3,00	3,19		3,00	3,16		3,00
Option 8	4	3,26		3,00	3,26		3,00	3,26		3,00	3,26		3,00	3,26		3,00
Option 9	1	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21
Option 9	2	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21
Option 9	3	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21
Option 9	4	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21	3,02		1,21

Combination	Decision mome	Scenario Combination 1			Scenario Combination 2			Scenario Combination 3			Scenario Combination 4			Scenario Combination 5		
		Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV	Total NPV	B/C-Ratio	Total NPV
Option 10	1	3,04	3,00	3,19	3,00	3,09	3,00	3,09	3,00	3,00	3,05	3,00	3,00	3,03	3,00	3,00
Option 10	2	3,03	3,00	3,08	3,00	3,05	3,00	3,05	3,00	3,00	3,04	3,00	3,00	3,03	3,00	3,00
Option 10	3	3,03	3,00	3,04	3,00	3,03	3,00	3,03	3,00	3,00	3,03	3,00	3,00	3,03	3,00	3,00
Option 10	4	3,05	3,00	3,05	3,00	3,05	3,00	3,05	3,00	3,00	3,05	3,00	3,00	3,05	3,00	3,00
Option 11	1	3,35	1,92	3,35	1,92	3,35	1,92	3,35	1,92	1,92	3,35	1,92	1,92	3,35	1,92	1,92
Option 11	2	3,35	1,92	3,35	1,92	3,35	1,92	3,35	1,92	1,92	3,35	1,92	1,92	3,35	1,92	1,92
Option 11	3	3,35	1,92	3,35	1,92	3,35	1,92	3,35	1,92	1,92	3,35	1,92	1,92	3,35	1,92	1,92
Option 11	4	3,35	1,92	3,35	1,92	3,35	1,92	3,35	1,92	1,92	3,35	1,92	1,92	3,35	1,92	1,92
Option 12	1	3,05	3,00	3,05	3,00	3,05	3,00	3,05	3,00	3,00	3,05	3,00	3,00	3,05	3,00	3,00
Option 12	2	3,05	3,00	3,05	3,00	3,05	3,00	3,05	3,00	3,00	3,05	3,00	3,00	3,05	3,00	3,00
Option 12	3	3,05	3,00	3,05	3,00	3,05	3,00	3,05	3,00	3,00	3,05	3,00	3,00	3,05	3,00	3,00
Option 12	4	3,05	3,00	3,05	3,00	3,05	3,00	3,05	3,00	3,00	3,05	3,00	3,00	3,05	3,00	3,00
Option 13	1	3,10	1,19	3,10	1,19	3,10	1,19	3,10	1,19	1,19	3,10	1,19	1,19	3,10	1,19	1,19
Option 13	2	3,10	1,19	3,10	1,19	3,10	1,19	3,10	1,19	1,19	3,10	1,19	1,19	3,10	1,19	1,19
Option 13	3	3,10	1,19	3,10	1,19	3,10	1,19	3,10	1,19	1,19	3,10	1,19	1,19	3,10	1,19	1,19
Option 13	4	3,10	1,19	3,10	1,19	3,10	1,19	3,10	1,19	1,19	3,10	1,19	1,19	3,10	1,19	1,19
Combi 1	1	3,07	1,73	3,27	2,26	3,14	2,00	3,14	2,00	2,00	3,09	1,80	3,06	3,06	1,64	1,64
Combi 1	2	3,06	2,09	3,09	2,63	3,08	2,49	3,08	2,49	2,49	3,07	2,25	3,06	3,06	1,94	1,94
Combi 1	3	3,06	2,36	3,06	2,65	3,06	2,57	3,06	2,57	2,57	3,06	2,43	3,05	3,05	2,19	2,19
Combi 1	4	3,06	2,60	3,06	2,64	3,06	2,62	3,06	2,62	2,62	3,06	2,61	3,06	3,06	2,61	2,61
Combi 2	1	3,51	3,00	4,48	3,00	4,48	3,00	4,48	3,00	3,00	3,65	3,00	3,00	3,37	3,00	3,00
Combi 2	2	3,44	3,00	5,04	3,00	3,70	3,00	3,89	3,00	3,00	3,50	3,00	3,00	3,33	3,00	3,00
Combi 2	3	3,37	3,00	4,62	3,00	3,70	3,00	3,70	3,00	3,00	3,42	3,00	3,00	3,30	3,00	3,00
Combi 2	4	3,30	3,00	4,56	3,00	3,64	3,00	3,64	3,00	3,00	3,37	3,00	3,00	3,27	3,00	3,00
Combi 3	1	3,10	2,88	3,40	2,95	3,20	2,92	3,20	2,92	2,92	3,12	2,89	3,08	3,07	2,87	2,87
Combi 3	2	3,08	2,97	3,10	3,00	3,10	2,99	3,10	2,99	2,99	3,08	2,98	2,98	3,07	2,96	2,96
Combi 3	3	3,06	2,99	3,05	3,00	3,06	3,00	3,06	3,00	3,00	3,05	2,99	2,99	3,06	2,98	2,98
Combi 3	4	3,04	3,00	3,04	3,00	3,04	3,00	3,04	3,00	3,00	3,05	3,00	3,00	3,05	2,99	2,99
Combi 4	1	3,24	2,94	4,56	2,98	3,60	2,96	3,60	2,96	2,96	3,30	2,95	3,18	3,18	2,93	2,93
Combi 4	2	3,21	2,80	3,73	2,74	3,40	2,77	3,40	2,77	2,77	3,24	2,79	3,16	3,16	2,80	2,80
Combi 4	3	3,18	2,46	3,58	2,51	3,31	2,46	3,31	2,46	2,46	3,20	2,46	3,15	3,15	2,49	2,49
Combi 4	4	3,15	2,02	3,48	2,38	3,26	2,19	3,26	2,19	2,19	3,17	2,09	3,13	3,13	2,06	2,06
Combi 5	1	4,36	3,00	4,41	3,00	4,38	3,00	4,38	3,00	3,00	4,36	3,00	4,36	4,36	3,00	3,00
Combi 6	1	3,03	2,38	3,04	2,41	3,03	2,40	3,03	2,40	2,40	3,03	2,39	3,03	3,03	2,37	2,37
Combi 7	1	3,13	1,70	3,36	2,10	3,21	1,92	3,21	1,92	1,92	3,15	1,77	3,12	3,12	1,64	1,64
DGP	1	3,23	1,97	4,03	2,44	3,47	2,21	3,47	2,21	2,21	3,28	2,03	3,19	3,19	1,88	1,88

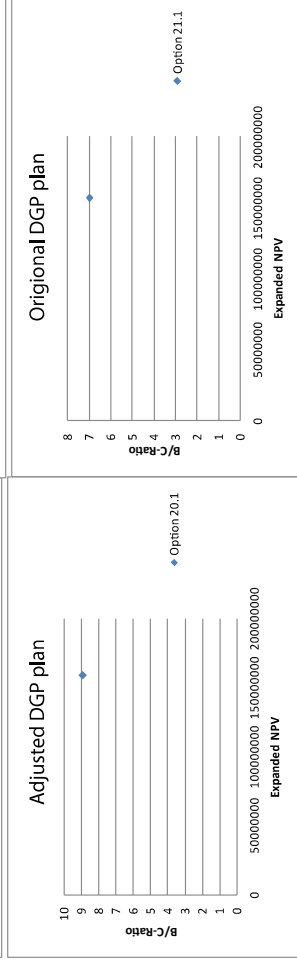
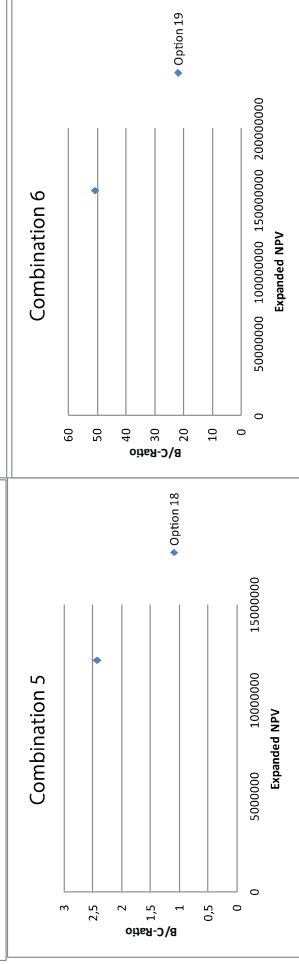
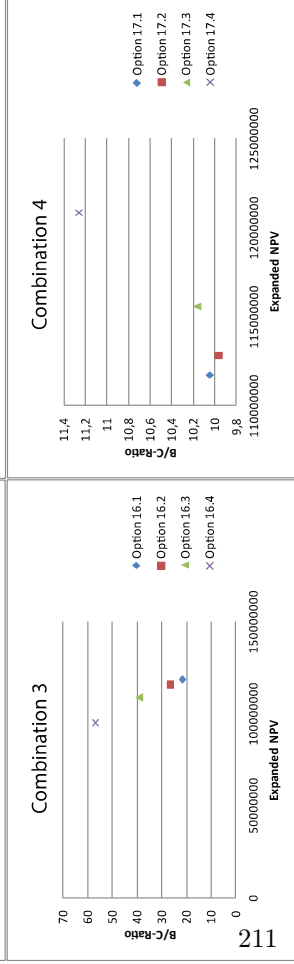
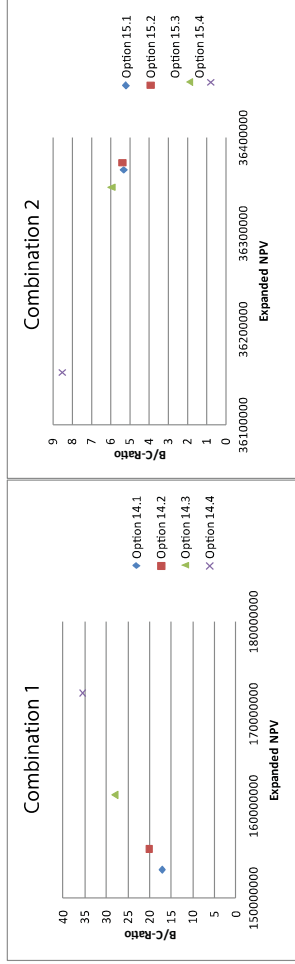
Scatter Plots for Sensitivity Analysis



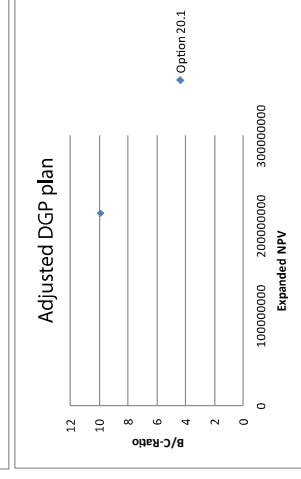
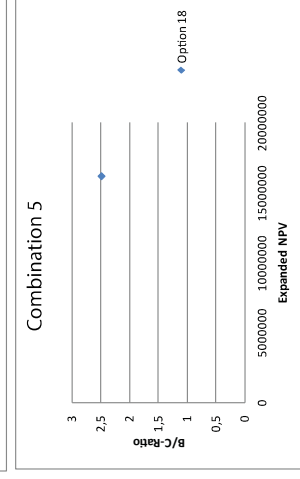
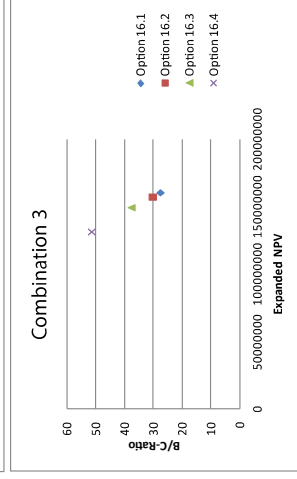
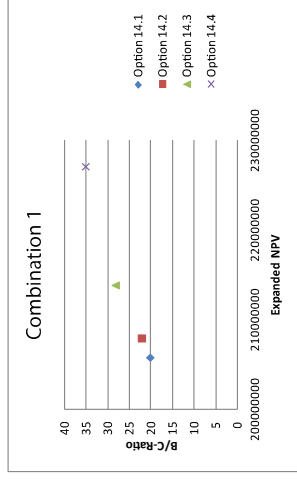
Probability p is set to 90%



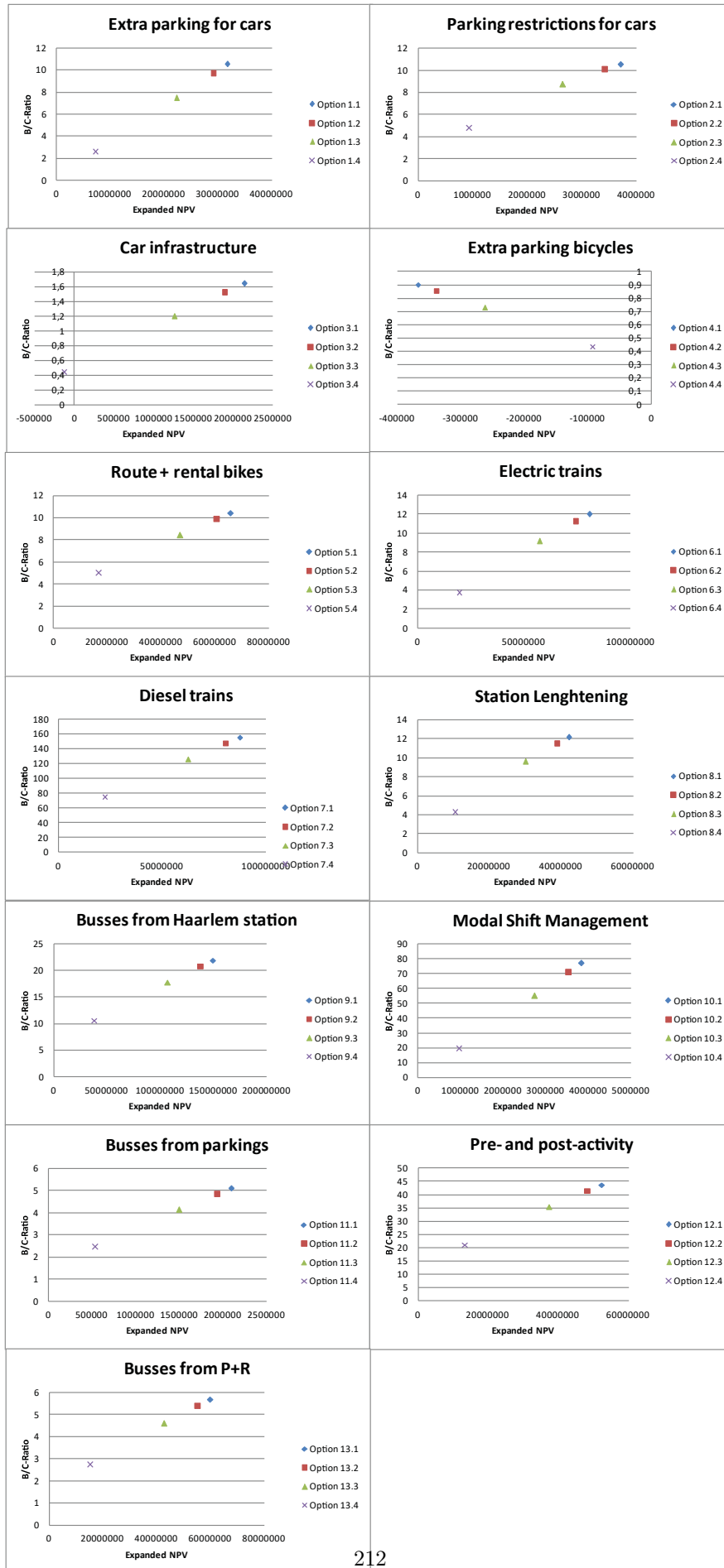
Probability p is set to 90%



Probability p is set to 95%



Probability p is set to 95%



Appendix I

Interview Presentation

Using the concepts of the real options approach for valuating infrastructural investments at Hallmark Events

Interview

Thesis
Rick Smits

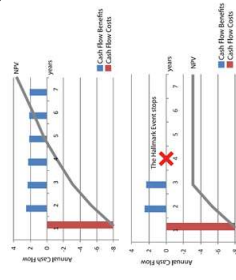
Inhoud

- Real Options in CBA
- Methodiek
- Case Study
- Uitkomsten
- Vragen gaan over de bruikbaarheid van de toepassing!

Hallmark Events

- Evenementen met vaak regionale functie (soms internationaal)
- Middel groot (tot miljoen bezoekers)
- Grote onzekerheid over het aantal herhalingen
- Case Study: Dutch Grand Prix in Zandvoort

Onzekerheid met aantal herhalingen



Vraag 1:

Hoe kan er worden omgegaan met de onzekerheid van het aantal herhalingen bij de valuering van investeringen??

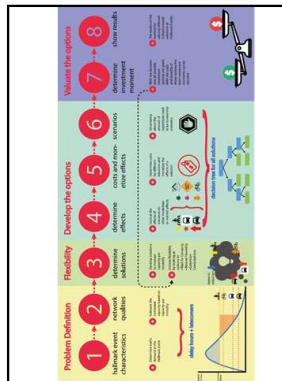
Traditionle Kostenbaten-analyse?

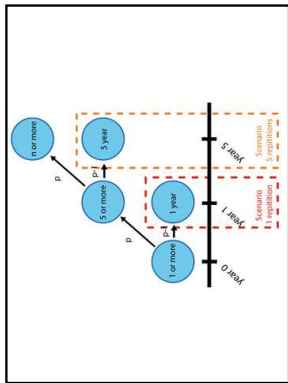
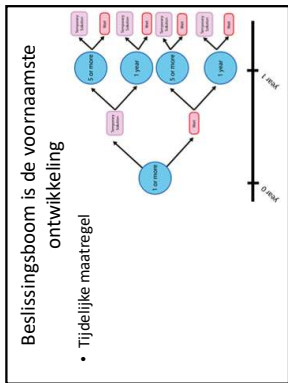
- Centraal Planbureau (2015) benoemd 3 problemen voor de CBA :
 - knowledge uncertainty
 - policy uncertainty
 - future uncertainty
- Daarnaast reistijd berekeningen lastig te begrijpen voor beleidsmakers (Rijdsberg, 2013)
- Uitkomsten en methoden lastig te begrijpen voor beleidsmakers (Mouter, 2012)

Real Options Approach

- Voordelen
 - ROA heet door de beslissingsboom alle mogelijkheden voor de toekomst ingebouwd. Daardoor kunnen beslissingen gemaakt worden met alle toekomst uitkomsten in het achterhoofd.
 - ROA heet door de beslissingsboom alle mogelijkheden voor de toekomst ingebouwd. Daardoor kunnen beslissingen gemaakt worden met alle toekomst uitkomsten in het achterhoofd.
 - ROA heet door de beslissingsboom alle mogelijkheden voor de toekomst ingebouwd. Daardoor kunnen beslissingen gemaakt worden met alle toekomst uitkomsten in het achterhoofd.
- Opties:
 - Opleg tot uitstellen
 - Opleg tot uitstellen
 - Opleg tot uitstellen
- Nadelen
 - Complexe methode om toe te passen en daarom beter om alleen de real options aanpak te gebruiken.

Daarom is er een nieuwe methodiek ontwikkeld om ROA te implementeren voor de validering van investeringen op Hallmark Events



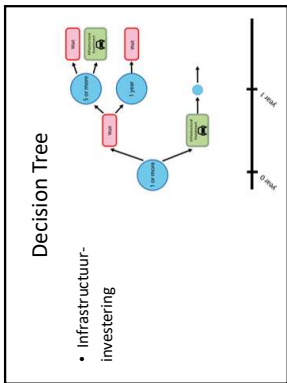


Zandvoort

Table 3.4: Travel Time Calculations

Modality	Peak hours	Cost	Extracosts
Car	27,509	292,629	18,540
Bicycle	528	5780	0
Public Transport	203,051	1,706,062	22,616
Footstrider	0	0	0

Infrastructuurle investeringen en tijdelijke maatregelen zijn getoetst om de problemen voor de DoP op te lossen.



Vraag 2

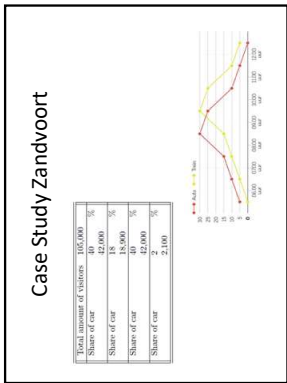
- Wat denkt u op voorhand van de bruikbaarheid van de beslissingsmomenten en het mogelijke uitstellen van investeringen?
- En wat verschilt dit van andere methodieken om investeringen te valideren?

Oplossingen

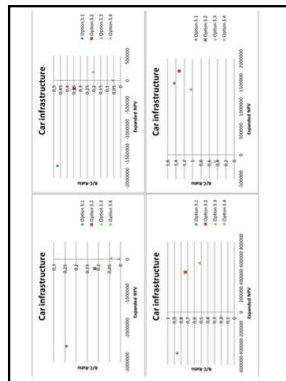
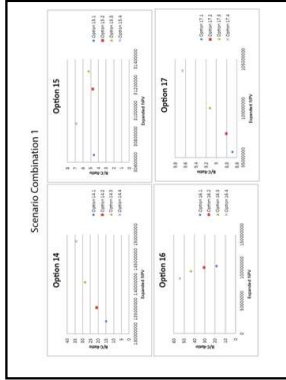
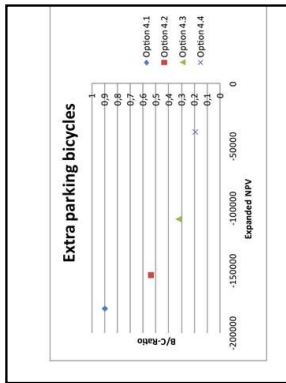
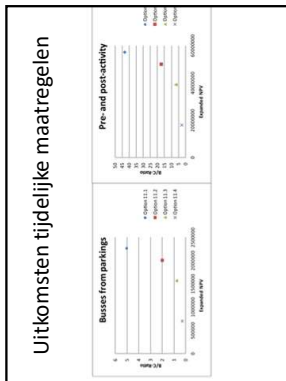
- Aantal voorbeelden
- Stationsverlenging, diesel treinen, bovenleiding
- Parkeerplaatsen bouwen, Kruispunten aanpassen
- Leenfietsen, fietsparkeren
- Extra activiteiten, bussen i.p.v auto of trein

Beslissingsmomenten moeten gekozen worden op basis van scenario

- Dit is waarschijnlijk de grootste onzekerheid omdat het lastig zal zijn om een inschatting te geven van de toekomst.

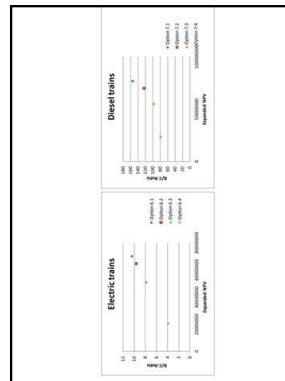
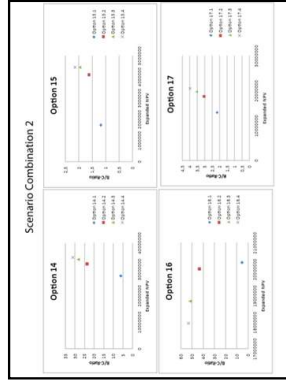


Modality	Peak hours	Cost	Extracosts
Car	27,509	292,629	18,540
Bicycle	528	5780	0
Public Transport	203,051	1,706,062	22,616
Footstrider	0	0	0



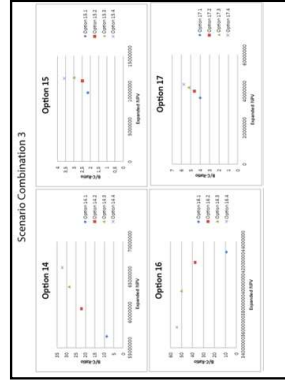
Vraag 3:

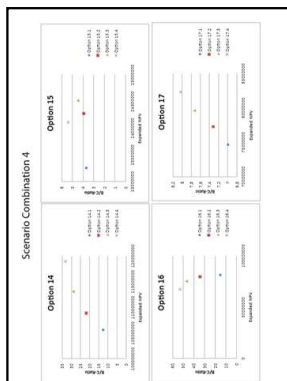
- Wat denkt u dat de meerwaarde van deze uitkomsten voor individuele oplossingen kunnen zijn ten opzichte van de traditionele waarderingsmethodieken?
- Daarnaast wat zijn de problemen die met deze methode komen?



Combinaties van oplossingen

- Uitgangspunten
- Combinaties van goed scorende individuele oplossingen
- Goedkoop
- Alleen auto
- Alleen OV
- Alleen Fiets
- DGP plan
- Aangepast DGP plan





Eigen conclusies tot nu toe

- Veel individuele oplossingen zijn het eerste moment vanwege het capaciteitstekort. Dit maakt de methodiek een beetje omslachtig.
- De uitkomsten zijn sterk afhankelijk van de scenario's, maar die zijn met grote onzekerheid ontwikkeld.
- Combinaties zorgen voor een optelling van NPV, maar een gemiddeld B/C-ratio

Vraag 4:

- Wat denkt u dat de meerwaarde van deze uitkomsten voor combinaties van oplossingen kunnen zijn ten opzichte van de traditionele waarderingsmethodieken?

Vraag 6:

- Bent u het eens met mijn conclusies?
- Heeft u nog opmerkingen?

Vraag 5:

- Wat ziet u als voornaamste problemen van de methodiek of redenen waardoor deze methodiek niet toepasbaar zal zijn?

Conclusies over combinaties

- Een aantal vormen zijn te identificeren.
- Investeren zo lang mogelijk uitstellen
- Investeren gelijk doen
- B/C is hoger bij late investering, maar NPV hoger bij directe investering
- Beslissingsmoment onduidelijk maar zeker niet het eerste jaar.

Eigen conclusies tot nu toe

- Data is onbeschikbaar voor zandvoort
- Daardoor is het voor het evenement zelf niet interessant, maar de soorten uitkomsten die te zien zijn, geven wel een nieuw inzicht
- Handig om te zien dat er investeringen zijn die misschien wel financieel aantrekkelijk zijn, maar niet in het eerste jaar.
- Sommige investeringen blijken niet aantrekkelijk te zijn in combinatie, die individueel wel positief bleken.