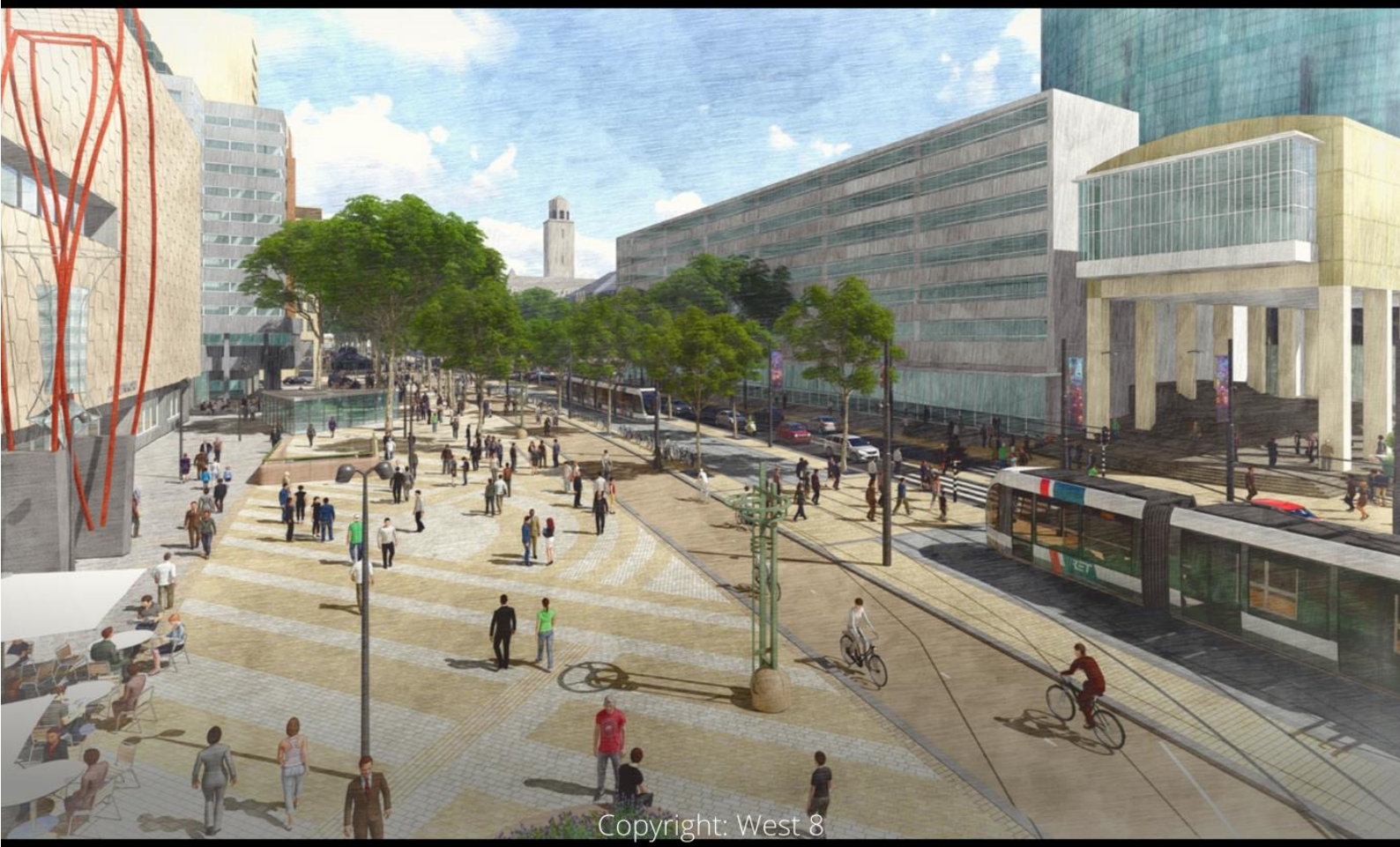
A societal beneficial car-free city centre in Rotterdam?

An explorative research into the lessons learned of societal cost-benefit results regarding a car-free city centre



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September 2020
Master Thesis
Complex Systems Engineering and Management

Sjoerd Keijzer
4366042

TU Delft

SWECO

A societal beneficial car-free city centre in Rotterdam?

An explorative research into the lessons learned of societal cost-benefit results regarding a car-free city centre

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Complex Systems Engineering and Management**

Faculty of Technology, Policy and Management

by

Sjoerd Keijzer

Student number: 4366042

To be defended in public on September 28th 2020

Graduation committee

Chairperson	: Prof.dr., G.P., van Wee, Transport and Logistics
First Supervisor:	: Dr., J.A., Annema, Transport and Logistics
Second Supervisor	: Dr.ir.,J.N., Quist, Energy and Industry
External Supervisor	: Dr., R, van Hout, Sweco

Preface

Hereby, I present you my master thesis. This thesis is written in order to conclude the Complex Systems Engineering and Management master. I have written a Bachelor thesis before but that is not challenging at all in comparison with a Master thesis. I was familiar with the saying that you either finish your thesis or your thesis will finish you and still I might have underestimated the challenges. The process of such a long project, can be unstructured and bumpy and hence very confronting.

Usually I am very structured and I was up for the challenges lying ahead of me. My internship at Sweco was already arranged months before I had to start writing my thesis. Hence, I was able to prepare my subject and research proposal in an early stage. February 2020 I started officially working on the thesis. After my first few weeks at Sweco the Covid-19 pandemic spread. The entire nation went into lockdown and my thesis kick-off day was the first day of a long period of time we had to work at home. After the kick-off, I officially started working on researching my thesis whereby I was forced to work at home. I had a difficult time adapting to the sudden changes in society, working at home and living up to expectations. My adaptation process took some time which was very confronting for me. In combination with writing a thesis I experienced a lot of self-criticism. Nevertheless, the situation taught me to let go since life cannot be controlled.

Luckily, I was not all by myself in this process. My supervisors and the people close to me have always been very comforting and stimulating towards me. It pushed me to break a vicious circle and step up my game. Overall, writing a master thesis has been an extensive and educational process. Despite, the feeling you are never done writing, I feel satisfied with the delivered work. A thorough analysis is carried out within my capabilities.

I would like to acknowledge some people in particular for their added value and support. First of all, I would like to thank Rob van Hout for giving me the opportunity to be an intern at Sweco. Despite, the majority of my internship I had to work at home, I felt welcome and part of the team. Moreover, Rob van Hout supervised me in collaboration with Stijn Altena. I would like to thank both of them for their guidance, feedback, critical view, unlimited patience and supportive attitude. Secondly, I would like to thank Jan Anne Annema in particular. As my first supervisor, he played a major role in guiding me through the process of writing a thesis. I appreciate the way of supervising. Jan Anne Annema always had time for me to answer either the most simple questions or discuss the most complex design principles. Hereby, I was able to keep the momentum going. Lastly, I would like to thank Bert van Wee and Jaco Quist for their critical view, constructive feedback and provision of new insights.

By finishing this thesis, my time as a student comes to an end. I have enjoyed both my Bachelor and Master study at TU Delft. It has been a fun, intensive and educational process forming me as a person as well. For now, new exiting challenges lie ahead!

Sjoerd Keijzer
Nieuwerkerk aan den IJssel, September 2020

Executive summary

In 2050 the Dutch government must reduce emissions by 95% compared to 1990. In order to reduce emissions, a couple of interventions are already taking place, such as the regulation of heavy emitting cars by so-called environment zones or the creation of traffic-calm areas. Another, more drastic intervention to reduce emissions, is the banning of cars by the introduction of a car-free area. The municipality of Rotterdam has a mission to achieve a sustainable, energy-efficient Rotterdam, with improved air quality. Already a couple of interventions and initiatives, to reduce emissions and live up to the Dutch climate goals, are taking place in the city of Rotterdam. Therefore, the city of Rotterdam offers a lot of potential, as a case study, to realise a car-free city centre.

Throughout the years, a couple of car-free initiatives have been implemented all over the world. Research into the effects of car-free interventions has been carried out, but it is unclear if a car-free intervention is beneficial for society. Therefore, it is attempted to carry out a societal Cost-Benefit Analysis (CBA). The CBA is a method wherein every incorporated effect is monetised. By providing an overview of all the costs and benefits the economic feasibility can be evaluated. This research elaborates on a gap in the literature regarding the relation between effects and the total impact on society, it is unclear if the benefits outweigh the costs and if a car-free intervention, in an economic sense, is a feasible alternative to make a positive change in society. Hence, the derived CBA results are assessed in greater detail to gain insights and learn lessons. To research this gap, the following research question is formulated:

Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam?

In order to fill the gap and answer the research question, three different steps have been undertaken to explore the potential of a car-free city centre. These steps form a chronological 'road' towards answering the research question. The following analysis's have been carried out:

1. Stakeholder analysis
2. Creation of project alternatives
3. Cost-benefit analysis

Results

As mentioned, the analysis's have been carried out in a chronological order towards answering the main research question. The stakeholder analysis focussed on retrieving the implications occurring due to a car-free city intervention. By focussing on users, transport suppliers and governmental bodies, multiple implications regarding these stakeholder groups could be summarised. This summary of implications is used as input the generate scenarios, these scenarios are used to create project alternatives. Based on the given input data, three rough project alternatives are sketched:

1. No additional investments
2. Invest in public transport
3. Invest in P+R & shared mobility
4. Rotterdam bicycle city

Here after, the project alternatives are incorporated in the CBA calculations. The alternatives were evaluated based on estimated effects. The following effects are valued and estimated in the CBA calculations:

- Emissions
- Noise
- Stink
- Traffic safety
- Public transport revenues
- Excise duty
- Spatial benefits
- Parking revenues
- Utility loss leisure car travellers (estimated via parking consumer surplus)
- Utility loss commuter car users (estimated via travel time losses)
- Health effects
- Crowdedness for public transport
- Crowdedness for cyclists
- Waiting time reduction public transport
- Bicycle network benefits

The CBA calculations represent, in each project alternative, a negative Net Present Value (NPV), indicating that it is not advisable, from an economic perspective, to ban cars out of the city. Instead of using the CBA as an assessor, the CBA is used as an improver. By doing so, the results can be used to anticipate and optimise project alternatives. In other words, the CBA can be used as a design instrument and lessons learned from the results of the formed project alternatives in this research, can be used to create an improved project alternative. Therefore, to assess the most important elements of the estimations, the effects are looked into in greater detail. Hence, configurations are created wherein the division of car substitutes over public transport and cycling is altered. Additionally, a configuration is created allowing a small amount of leisure travellers to park in the city centre. Hereby, disutility is reduced and parking benefits are earned by the government. This configuration is not entirely car-free but tends to be traffic-calm.

Based on this research and the incorporated effects, inherent their valuation, it can be noticed that travellers' car utility is valued highly. Major costs are related to car utility or the loss of it. By banning cars, commuters experience a big welfare loss because their travel time increases. Next to that, leisure travellers, whom are not able to park in the city centre anymore, experience a big consumer surplus loss. Additionally, the municipality is missing out on parking benefits since the majority of the parking benefits are generated in the city centre. These effects result in serious costs affecting the NPV massively. By allowing a small amount of cars to park in the city centre, and thereby reduce the utility loss, the NPV and benefit-cost ratio improve significantly.

By banning cars, noticeable benefits are generated as well. Society can benefit from spatial changes due to available space formerly allocated to cars. Next to that, positive effects such as a decrease in noise, emissions and stink are mentionable. Although, it must be noted that these effects have a minor impact on the NPV. The most important benefits are the public transport revenues and the health effects. Due to an increased amount of public transport travellers the public transport revenues increase. The health effects relate to an increased amount of cyclists. Commuters are more healthy if they travel by bicycle instead of car, resulting in a productivity gain for employers and thereby a benefit for society. By altering the division of travellers over the alternative modes of transportation in the configurations, it turns out that an increased amount of public transport users results in additional benefits. Additional cyclists do not result in a more beneficial benefit-cost ratio due to the decrease in travellers and thereby minimised public transport revenues.

Answering the main research question

The current created project alternatives are not economically feasible and thereby are not an advisable intervention. However, useful insights are derived to learn lessons for future car-free city centre designs or the transition towards a car-free application. In order to create a more feasible project alternative, it is important for researchers, developers and decision makers to focus on reducing the biggest cost effects and improving the most beneficial effects. The most important monetary effects are car utility related. More beneficial alternatives can be created by allowing cars to park in the city centre and thereby disutility is reduced and the loss of parking revenues is smaller. This implies that a car-free intervention might be to extreme and a traffic-calm intervention is more desirable.

By focussing on a car-free intervention itself researchers can learn from the development of effects. Based on this research, it is concluded that focussing on public transport is more beneficial than focusing on any other mode. However, it might be possible that in order to realise a more optimal car-free city design, the stimulation of bicycle usage is the key. Health effects generate significant benefits but it is likely this effect is underestimated. The estimated health effect solely focus on commuters but many more health effects can occur, such as reduced obesities or increased human life expectancy. If these effects can be valued in detail, health effects might out benefit public transport revenues.

Recommendations for further research

It is recommendable to create more robust scenarios in order to assess the potential of a car-free city centre in greater detail. More robust scenarios can be created by a more quantitative approach to predict, based on the given variables, the optimal scenario. Next to that, the valuation of effects can be more exact and comprehensive. Therefore, it is important to expand knowledge to limit the amount of assumptions and used proxies. Lastly, it is recommendable to look into the transition from traffic-calm towards car-free to research if experienced disutility is smaller compared to a sudden car-free intervention. Hypothetical, it is likely disutility is smaller since travellers already experience car limitations.

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1. Introduction

In Paris' climate agreement in 2015, the reduction of global warming was agreed upon. The Dutch national climate agreement centralised the goal to reduce emissions by 49% compared to 1990 in 2030 and by 95% in 2050 compared to 1990 (Rijksoverheid, 2019b). Last decade, among several big cities in the Netherlands, Rotterdam was regulating heavy emitting cars more strictly by so-called environment zones to reduce emissions. Moreover, the municipality is elaborating on initiatives for cleaner city logistics, intensifying electric car usage and incentivising bicycle utilisation (Gemeente Rotterdam, n.d.-c). Herewith, the range of interventions attempts to achieve cleaner air and a more attractive city for residents and businesses. One of the five area visions of Rotterdam, elaborates on a healthy city by centralising goals such as, life expectation, cleaner air and noise reduction (Gemeente Rotterdam, n.d.-b). Within this vision, the municipality has a mission to achieve a sustainable, energy-efficient Rotterdam, with improved air quality (Gemeente Rotterdam, n.d.-d).

Currently, to strengthen the goal, one of the main streets, the Coolsingel, is being renovated. This renovation will result in a more sustainable traffic-calmed street, wherein pedestrians and cyclists enjoy more space (Gemeente Rotterdam, n.d.-a). Reduced car usage results in cycling and walking becoming faster, safer and a preferred mode of transportation (Gundlach, Ehrlinspiel, Kirsch, Koschker, & Sagebiel, 2018). Furthermore, car usage affects land usage by traffic and parked vehicles, reducing the potential of other modes of transport and the optical quality of the environment (Nieuwenhuijsen, Bastiaanssen, Sersli, Waygood, & Khreis, 2019). Lowering the amount of cars, inherent their infrastructure and parking spaces, allows for opportunities to increase sustainable networks in a city and enlarge green areas, that can result into valuable health effects (Nieuwenhuijsen et al., 2019; Nieuwenhuijsen & Khreis, 2016).

Despite the Coolsingel will not be entirely car-free, at least car users will be discouraged to drive through the city centre. It is imaginable that in the future more streets or even the entire city will be car-free. An initiative of Rotterdam's residents is already pleading for more car-free or traffic-calmed streets in the city centre (De Roos, 2019). The idea of the initiative is focussed on a lively and safe city centre. Even though a car-free intervention might be a rigorous measure, it is not unthinkable that in the future the municipality will support such an initiative. Car transport contributes to an extensive amount of air pollution in urban areas but the extent differs depending on factors such as car density, traffic conditions and city lay-out (Nieuwenhuijsen & Khreis, 2016). Such factors will enlarge in the future, the city will grow by 55.000 inhabitants in 2035 and from this increase an expected 18.000 inhabitants are located in the city centre, resulting in increased pressure on the mobility network (Gemeente Rotterdam, 2019a; Hoppesteyn, Permentier, & van der Zanden, 2018). Hence, to expand opportunities and account for future challenges, a car-free intervention might be a suitable solution.

1.1 Scope

The aim of this research is to identify if a car-free city centre application is a societal feasible solution to intervene and reduce emissions in order to live up to the climate goals set by the government. Therefore, the goal of this research is to approach the elements that define an economic beneficial as possible car-free intervention. Already many cities are trying to reduce car usage and experiments, to become less car-dependent, are taking place, but yet no car-free cities, by regulation, exist (Urry, Leach, Dunn, & Coulton, 2017). Therefore, it is not known if a car-free intervention is an economically feasible alternative to reduce car usage and thus emissions. It can be concluded that the realisation of an entire car-free city is questionable since challenges, to be entirely car-free, still arise

(Nieuwenhuijsen et al., 2019). Since there is a gap in the literature on how to establish a car-free city, or in this case car-free city centre, the feasibility must be approached differently. Considering there is no reference, car-free scenarios are developed by an explorative scenario analysis in this research, in order to form a possible car-free vision. These scenarios are used as input for a societal Cost-Benefit Analysis (CBA).

The concept of a CBA is to ex-ante clarify and valuate all effects that affect the costs and benefits of a certain intervention or scenario (Mouter, 2012). As mentioned before, there are no case studies or examples yet and thereby a knowledge gap, regarding the impact of effects, exist. To be able to carry out the study in the limited research time of 17 weeks, there is focussed on certain effects. These effects are clarified later on, based on literature and stakeholder input. Thereby, the most important effects can be mapped and approached in greater detail in order to identify the feasibility of a car-free city approach, based on the most important factors. In other words, elements of the CBA method are used to approach the feasibility. Obviously, more effects might be affecting the costs and benefits but these effects will not be taken into account because stakeholders neglect these effects. That is why it is assumable that those neglected effects are not taken into account in the policy making process, or at least they are of minor importance.

1.2 Research questions

It is unclear if an entire car-free city will be realisable, that is why publications still enable services such as buses, taxies and emergency vehicles (Gundlach et al., 2018). The applicability of an entire car-free inner city is thereby questionable and a high level of stakeholder acceptability might be required. Therefore, the implementation is likely more successful in an urban environment where public transport users, pedestrians and cyclists are facilitated and inherent acceptability is higher. By the creation of acceptable scenarios, under the assumption the city is car-free, the economic feasibility and thus the interventions applicability, can be approached. Whether a car-free scenario is economically feasible, depends on the valuation of effects and thus the distribution of costs and benefits. Despite some effects are mentioned in the literature, the societal impact of effects is unknown or debatable, since there is no comparable case, and those effects must be carefully monetised. It is important to note that not all effects in the case of Rotterdam are specific for the city and that some effects might not be incorporated yet. Due to a lack in ability to quantify the selected literature, the intended effects must be reviewed with reflective nuance in order to ensure feasible input data.

In order to approach the elements that define a societal feasible car-free intervention, it is important to define the important monetary effects in order to identify how a feasible car-free application in the city centre of Rotterdam can be realised. The insights retrieved from these estimations can be used to learn how to create a more optimal car-free intervention. Therefore, the following main research question is formulated:

Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam?

To answer the research question, a few aspects have to be clarified. It is important to derive and distinguish reasonable scenarios. Therefore, it is of interest to determine on what to include in these scenarios and thus how to construct them. The scenario design might influence the costs and benefits due to different impacts of effects. By structuring these effects, the economic feasibility can be determined, hereafter the practicability of different scenarios can be accessed. To answer the main research question, the following sub-questions are formulated.

1. Which stakeholders have a stake?
2. What factors are important per stakeholder?
3. What are potential acceptable scenarios, from a stakeholder perspective, for a car-free implementation in the city centre of Rotterdam?
4. What are the costs and benefits per scenario?
5. Which monetary effects are important per scenario?
6. Which insights can be derived?

1.3 Research approach

The exploratory research approach is used to construct scenarios and for the identification and valuation of effects to get insight into a feasible car-free implementation in the city centre of Rotterdam. Exploratory research is used in the preliminary stage of a research process towards the actual design (Stebbins, 2001). Stebbins (2001) emphasises on the importance of explorative research by the fact that the exploration of different interests and topics result in the creation of useful, new, theory. The advantage is that from here on, the emergence of new theory leads to the understanding of new concepts. By applying this approach, the understanding of a car-free city concept can be identified.

Throughout the years, multiple experiments with car-free concepts have been carried out. Therefore, effects occurring in experiments, similar to a car-free city, are identified and measured. Next to that, cities closed for car traffic such as Venice and Fez already cope with problems which might occur in a car-free city (Borges & Goldner, 2015). By exploring this kind of input, assumptions regarding a car-free city scenario can be made. Hence, it is possible to approach the feasibility of the concept implementation. However, it must be approached with great nuance since the generalisation of effects can be highly uncertain. It is not an entirely equal application and thus the interpretation and thereby the impact of effects will differ inherently the valuation (Dudovskiy, 2016). Therefore, Stebbins (2001) acknowledges the importance of the validation of generalisations emerging from research. Additionally, he concludes that explorative research lacks a sense of finality. Or in other words, a definite concept lacks reasonability and thus validity. Many studies must be undertaken to generate validity (Stebbins, 2001).

The implementation of a car-free city affects multiple stakeholders. To account for changes, generalised input and to cope with conflicting stakes, it is to chosen to create different scenarios in order to research the impacts of multiple alterations. To construct scenarios, the explorative scenario typology by Börjeson et al., (2006) is used. It is a fitting tool to think of several possible futures and to adapt to different forms of outcomes (Börjeson et al., 2006). Usually quantitative methods will be used to make an optimal forecast based on multiple configurations. However, it must be noted that the scenario construction is limited since the amount of possible configurations is not doable in the given timeframe of 17 weeks. In the process of distinguishing different scenarios, multiple alternative sustainable futures are configured with inherent different impact of effects. Hence, it is likely that the impact of the intervention differs per scenario.

The construction of realisable scenarios is important to access the societal feasibility of a car-free intervention in the city centre of Rotterdam. In order to integrate scenarios it is required to generalise feasible input (Börjeson et al., 2006). Therefore, it is important to explore which factors have to be incorporated. Obviously, there is no data on what exact factors have to be included in the case of Rotterdam. Therefore, literature research is used to determine what implications occur in the case of Rotterdam and which factors can be included in the scenario analysis. To substantiate the

incorporation of factors, data extracted from expert interviews is used to support the literature. Constructed scenarios are used as a starting point to gather input data for the CBA.

It is attempted to use a CBA to approach the economic feasibility of a car-free application in the inner city centre of Rotterdam. The CBA method is chosen because it is seen as a method that strives to incorporate all relevant effects. These effects are inherently quantified and thus insights regarding the impact of effects can be determined (Mouter, 2012). The CBA is a mandatory technique to appraise the efficiency of a policy (Annema, Mouter, & Razaei, 2015). From a neoclassical perspective, the policy regulation, in this research a car-free city centre, is regarded efficient if the benefits outweigh the costs (Vining & Weimer, 2006). However, the downside of a CBA is that some impacts are hardly possible to monetise and results may be questionable (Annema et al., 2015). Nevertheless, this analysis method is applicable in an explorative study since monetised values are uncertain and calculations are only illustrative. Hence, the researcher can 'play' with the input data and thus the impact of perceived effects. As a researcher, you decide upon what to include in your analysis. Next to that, some values, mainly the monetised values of environmental effects, are based on the researcher's opinion (Koopmans, 2010). Therefore, there is a possibility the researcher plays with the value of factors whereby researched impacts can slightly differ based on the input. To minimise this limitation, this research strives to be as transparent as possible by critically reflecting on the results.

Obviously, all effects are unique in the case of Rotterdam but some effects might not differ in essence from other cases or applications and can thereby (partly) be generalised as input data for the CBA. Nevertheless, the interpretation requires great nuance. Dudovskiy (2016) concludes that nuance is necessary to interpret results in a situation where generalisation of effects and impacts is uncertain. Nevertheless, the outcome substantiates to the debate about the implementation of a car-free city because the effects level, affects the costs and benefits. All the obtained and validated data is inserted in excel. Excel is an easy tool to create a CBA and calculate the economic impact of a car-free city centre.

1.4 Relation between subject and master programme

The research into the field of the economic feasibility of car-free cities, fits the Complex Systems Engineering and Management (CoSEM) master program. The complex environment of different stakeholders, limited knowledge, a future aspect and the diversity of involved fields (such as regulations, law, economics, behavioural change and technical characteristics) requires a CoSEM approach in order to work towards the designing phase. The research attempts to explore the most important monetary effects to design, in further research, an optimal as possible car-free city intervention.

1.5 Report structure

In order to work towards answering the main research question, a broad overview of the literature is provided in chapter 2. Thereafter, the used methodologies are explained in chapter 3. Chapter 4 will analyse the involved stakeholders and their implications regarding a car-free city. The output of the stakeholder analysis is used to generate project alternatives by creating scenarios in chapter 5. The project alternatives are incorporated in a CBA analysis in chapter 6. Chapter 7 elaborates on lessons learned based on the derived results. The research and its outcome are discussed in chapter 8. Lastly, in chapter 9, conclusions are drawn and recommendations for further research are proposed.

2. Literature overview

In order to get a better hold on the system, the different elements of a car-free application regarding this research are clearly defined. During the analysis, literature is used to substantiate the exploration towards answering the main research question since the focus in this research is on exploring important effects and inherent the economic feasibility of a car-free regulation in order to learn lessons.

2.1 Literature overview

To get a first general overview of the literature, the most fitting keywords, "*Car-free"* and "City", were used to derive results. By using the operator AND search strings were inserted in different databases, such as ScienceDirect, Scopus and ResearchGate. To enlarge the search range, synonyms were used. Moreover, to further specify search strings, keywords were added. The addition of "*effects"* and "*impact"* further narrowed the scope down to a limited amount of publications. In total 40 publications were identified as possible eligibility.

To decrease the amount of fitting literature, the search string was limited to literature published after 2015. The car-free city phenomena are considered a recent development. The limitation resulted in the remaining of 23 publications. The further screening, to assess eligibility, was focussed on the content. From the content skimming, 5 publications (highlighted bold in Appendix B) were considered as core literature.

Lastly, by snowballing, the reference list of the core publications was consulted to identify publications to which their work is based upon. If a publication was mentioned in at least 2 reference lists of the core publications, the source was considered as eligible literature. A final content screening limited the amount of publications to 15 suitable sources that are centralised in this research (Appendix B). Despite only 15 sources are incorporated in Appendix B, more literature is used based on insights derived from the centralised literature. The literature overview in Appendix B divides the literature based on three main groups:

- Papers that address the core concept of car-free cities
- Papers that address effects occurring in a car-free environment
- Papers that address the acceptance of car-free concepts

This chapter will elaborate on the first main group as distinguished in Appendix B to get familiar with the topic. The other two groups are introduced later on in chapter 4. New literature is introduced there, to link the insights derived from literature, to stakeholder implications.

The literature overview will provide insights in the understanding of the chosen topic and the goal of this research. Firstly, the concept of a car-free city is discussed. Second, current knowledge about car-free applications is elaborated on. Thereafter, the reason to focus on car-free is clarified. Lastly, the knowledge gap, based on the given literature, is formed.

2.1.1 What is the concept of a car-free city?

The definition of a car-free city throughout the literature is pretty similar. The definition refers to a regulatory measure to limit car traffics by the establishment of a ban (Topp & Pharoah, 1994). However, the idea of car limitations or a car-free city implementation can be considered differently. Nieuwenhuijsen et al. (2019) view a car-free city as a city without private cars but wherein still,

among other things, buses, taxis and emergency vehicles are able to drive. Melia (2014) differently defines car-free as a development wherein designs are created to facilitate the movement by non-car means and thus thereby offer no car facilities such as parking or accessibility. Multiple articles such as, Gundlach et al. (2018) & Loo (2018), use the definition by Melia (2014) as their definition of a car-free city. Although, the identified 'limitation' by Nieuwenhuijsen et al. (2019) to a car-free city, must be considered, since it is imaginable an entire car-free city is not achievable. In this research, possible limitations to achieve an entire car-free city will be considered and either used or left out in the design.

Melia (2014) prefers to rephrase the concept of car-free in traffic-free. The concept of car-free offers too much space for misnomer. For example, Melia emphasises on the car-free housing developments wherein there are no parking spaces offered for residents while those car-free housing projects still might be developed to facilitate car movements. Solely, the parking element is removed. Therefore, traffic-free is a more complete definition of the exclusion of car movements and all its inherent activities. It is important to define the focus of traffic-free only regarding to cars. As already mentioned, Melia elaborated on the facilitation of non-car means or in other words non-car traffic. Nieuwenhuijsen et al., (2019) emphasize on the importance of making the remaining motor driven vehicles as sustainable and healthy as possible. Therefore, it can be concluded that if car traffic is substituted by a non-car means it is important to offer a sustainable mode in order to facilitate a substitution effect. Hence, car-free can be defined as a traffic-free intervention or regulation, focussing on the facilitation of sustainable non-car means.

In this research a combined vision, based on insights of both Melia (2014) and Nieuwenhuijsen et al., (2019) on car-free, are used. Based on these visions the following definition of a car-free city is formulated: '*car-free cities are developed to ban private and public car movements out of the city by traffic-free developments, focussing on the facilitation of sustainable non-car means, wherein still exceptions, such as emergency vehicles and disabled transportation, are facilitated.*' The author argues that this definition is more comprehensive to all related dimensions of car-free developments.

2.1.2 Car-free applications

In recent years multiple car-free developments have been made. These developments range in a wide spectrum of regulations. Wright (2005) clearly visualised the size difference of the impact of these regulations, figure 1. Those regulations vary from limited restrictions to long-term bans. Regarding the case of a car-free city centre in Rotterdam the focus should be on permanent largescale measures.

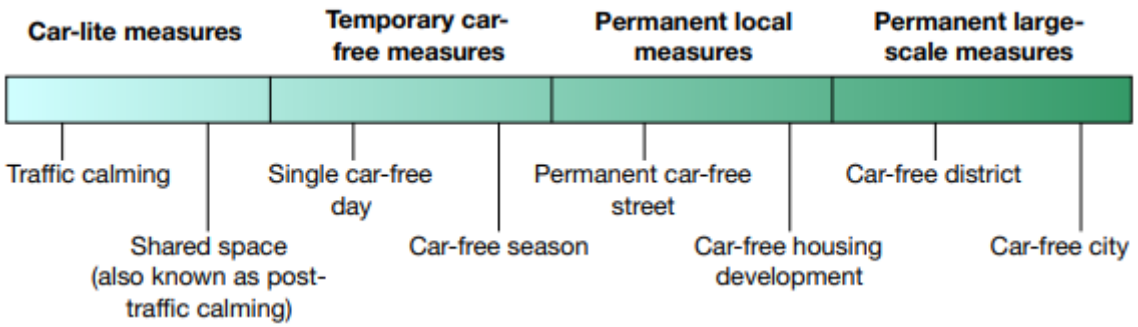

Figure 1 Car-free spectrum by Wright (2005)

Wright (2005) provides multiple examples of successful regulations or measures as depicted in his spectrum. Wright (2005) elaborated on examples of car-free cities such as Fez and Venice, but these

cities are car-free because of historical infrastructure. Currently, no entire car-free city, by regulation, exist (Urry et al., 2017). A car-free city centre can be framed as a permanent large-scale measure. The size is obviously smaller than an entire city but arguable bigger than a district. Despite no entire car-free city exist, some car-free developments, approaching the car-free city centre concept, are applied in the real world.

In the current developments there is no entire car-free realisation. Even in examples, which are almost entirely car-free, there are exceptions allowed, such as transport of disabled persons in Zermatt, Swiss (Wright, 2005). The city of Masdar was designed, as one of the first cities, to be entirely free of privately-owned cars (Alameri, 2011). Initially, the city was designed to be entirely car-free and to facilitate pedestrians and transportation by Personal Rapid Transit (PRT) but the emerging PRT technology, was not ready for implementation and the transportation concept within the city was re-evaluated and changed to shared electric cars (Manghnani & Bajaj, 2014). The project realisation was aimed at 2016 but the global financial crisis impacted this goal and pushed the date back to realising the project somewhere between 2020 and 2025 (Manghnani & Bajaj, 2014). The developments during the project changed the aim from a car-free city into a low carbon city. Hence, still no entire car-free city has been realised yet.

In 2017, the city of Oslo researched the possibilities to realise a car-free city centre. Based on a thorough stakeholder analysis and an in-depth case study analysis, regarding the cities of Strasbourg, Freiburg and Nuremberg, it could be concluded that there always should be exceptions for certain user groups and stakeholder (Rydningen, Høynes, & Kolltveit, 2017). Throughout the literature, the same challenge regarding car-free cities re-emerges on how to be entirely car-free and still be inclusive. Every attempt to be entirely car-free had it challenges and limitations and thereby compromises have been made to still partly facilitate (sustainable) car transport. Hence, it can be concluded it is not known what the optimal design of a car-free city centre looks like inherent its intended effects.

2.1.3 Why car-free?

The application of car-free interventions on a largescale still lacks solid examples. Therefore, there are still opportunities to research the feasibility of the intervention. Throughout the literature, multiple effects are mentioned but the exact impact lacks evidence. First of all, car-free interventions are intended to ban cars out of the city and thereby decreases congestion and inherent exhaust gases as for example in the case of Masdar city which is intended to be low carbon (Manghnani & Bajaj, 2014; Nobis, 2003). Additionally to the traffic related effects, valuable health effects can occur due to the absence of car traffic (Nieuwenhuijsen et al., 2019). In general, due to, amongst others, the decrease of carbon emissions, multiple environmental benefits occur (Ornetzeder, Hertwich, Hubacek, Korytarova, & Haas, 2008). In the extension of environmental benefits, the banning of cars offers significant spatial benefits, increasing the value of environmental effects due to improved liveability, safety and attractiveness (Loo, 2018; Ornetzeder et al., 2008; Szarata, Nosal, Duda-Wiertel, & Franek, 2017). Survey research by Szarata et al., (2017) in the city of Cracow, proved that a vast majority of the respondents were very satisfied with car-free areas in the city. Without cars, respondents valued tranquillity and appreciated the landscape and atmosphere even more. Szarata et al., (2017) drew another interesting conclusion. Based on their research, they concluded that 75% of the respondents would not want to restore back to the former situation with cars.

Car-free interventions are generally viewed as positive interventions for society. Multiple positive effects are mentioned in the literature. However, it must be noted that such a positive depicted intervention also has downsides. For example, Szarata et al., (2017) mentioned a, according to them,

negligible amount of respondents having problems with accessing certain facilities because these facilities were only accessible by foot or public transport. According to Litman (2003) physical accessibility is seen as an major factor in social inclusion and thereby an important issue in transport planning. In other words, besides numerous benefits, the removal of cars will have costs to facilitate accessible transport for everyone.

2.1.4 Knowledge gap

Car transportation has multiple effects on society. Those effects can be really diverse and literature is lacking strong evidence of the impact on society in a car-free environment. One of the problems regarding a lack of evidence is the different approach and meaning of car-free. Car-free interventions can be designed differently and in essence no design is entirely car-free yet. Bearing that in mind, it is unclear what the effects are and what the impact of those effects is. Certainly, the concept of being car-free has positive effects and scientific proof has been found for a support base but the allocation of costs and benefits is unclear. Positive effects have certain benefits but the removal of cars can result in discomfort and thereby costs.

The measurement of positive versus negative, or discomforting, effects in a car-free application is unclear. Studies proof the presence of certain effects and the significant changes compared to the former situation, but the relation in comparison with each other is missing. Thereby, it is unclear if the benefits outweigh the costs and if a car-free intervention, in an economic sense, is a societal feasible alternative to make a positive change in society. Besides that, the individual impact of effects on society is not studied yet. By researching the costs and benefits of individual effects and thereby the societal feasibility of a car-free interventions as an alternative, the decision-making process can be provided with valuable insights. Insights that might change the political view or approach regarding the implementation of a car-free application.

3. Methodologies

Based on the fact that it is unclear how the costs and benefits relate to each other, a chronological design road will be followed to stipulate the process. Different methodologies will be used in answering the sub and main research question. To get a hold on what costs and benefits are in play with respect to the city of Rotterdam, it enlightens to get insight in what factors and effects are at stake. Accordingly, these effects can be monetised and be used to approach the economic feasibility of a car-free city centre where after insights can be derived to learn lessons. Moreover, the division of the costs and benefits can be evaluated to add value to decision-making processes regarding the implementation of a car-free city centre. Since there is no blueprint on how to design a car-free city centre, possible designs are explored. To do so the following steps have been taken to approach the costs and benefits:

1. Stakeholder analysis
2. Creation of project alternatives
3. Cost-Benefit Analysis

3.1 Stakeholder analysis

Rydningen et al., (2017) used a stakeholder analysis to investigate the impact of proposed measures. By doing a stakeholder analysis they were able to determine in what way different users or stakeholder groups were affected by a car-free regulation. A stakeholder analysis is a logical step to get insight in different interests, problems and opportunities. The field of transport is profoundly embedded in society and there are multiple connections to different stakeholders such as countries, people, organisations and users that face different challenges regarding the cause, effect and solutions of problems (de Haan & de Heer, 2012). The analysis fits to shed some light on the complexity of the problem.

A stakeholder analysis is of great importance to provide insight into the range of stakeholders, including their networks, involved (Enserink et al., 2010). Gained insights can add value to policy analysis in multiple ways. Enserink et al., (2010) make use of the hexagon model by Mayer et al., (2004), as depicted in figure 2. A stakeholder analysis contributes to all activities but in this research the main focus is on the blue triangle between Design and recommend and Advise strategically. According to Enserink et al., (2010), these activities possibly contribute to the creation of strategies to satisfy particular stakeholders and by assessing the feasibility and potential to implement a certain policy intervention.

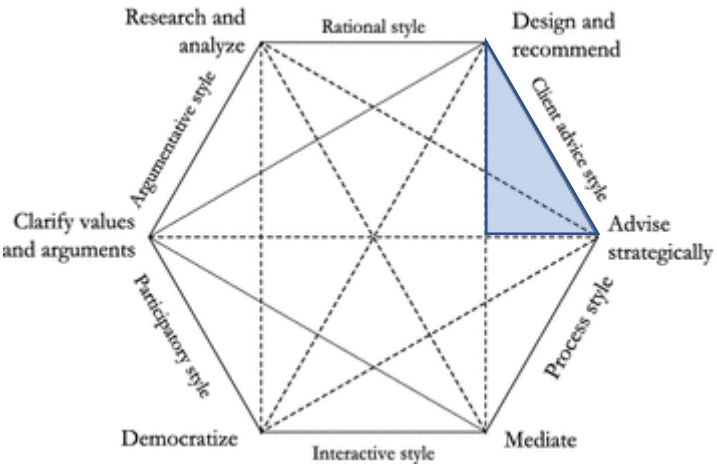

Figure 2 Policy activities hexagon by Mayer et al., (2004) derived from (Enserink et al., 2010)

To construct scenarios, or project alternatives, a conceptual design must be made. This conceptual design forms the dimensions of the car-free city centre system. With the identification of major stakeholders, inherent their needs and requirements, important context regarding system requirements or design constraints can be formalised (Faulconbridge & Ryan, 2018). By setting the right context, stakeholder implications regarding the intervention can be discussed. These implications mark the boundaries of the conceptual design.

In this research the method is applied by distinguishing important stakeholders. Thereafter, by assessing relations between those stakeholders and the power and interest per stakeholder the context is formalised. By setting the context, implications, affecting stakeholder groups by the implementation of a car-free city centre application, are elaborated on and discussed in detail.

3.2 Creation of project alternatives

By setting the context, rough project alternatives can be created. These project alternatives are rough sketches due to a lack of scientific evidence but will provide insights in costs and benefits. To create the project alternatives, a scenario analysis is carried out. To create scenarios different typologies can be used. Börjeson et al., (2006) distinguishes three different typologies as visualised in figure 3.

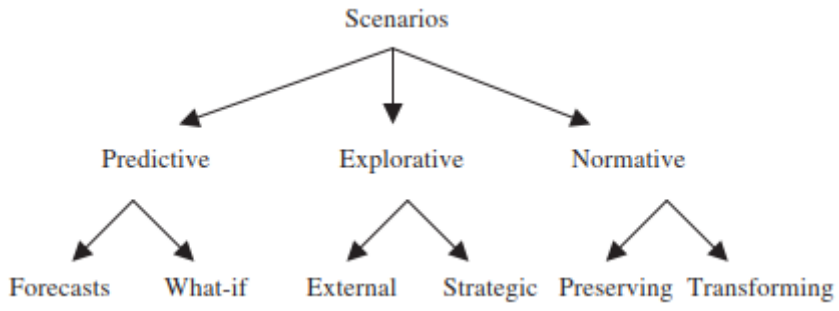

Figure 3 Different typologies distinguished by Börjeson et al., (2006)

To determine the fitting typology, Börjeson et al., (2006) formalised three different questions: *What will happen? What can happen?* and *How can a specific target be reached?* The what will happen question, responds to predictive scenarios. Predictive scenarios are usually created for situations that are expected to occur. Explorative scenarios are described by the what can happen question. These kind of scenarios are constructed to explore situation that are seen as possible to happen. Lastly, by

the how can a specific target be reached question, the normative scenarios are defined. In this typology there are already explicit normative starting points set. From here on, the focus is on how to establish or realise goals and depicted future situations.

In the case of a car-free city centre in Rotterdam, the explorative typology is most fitting to the concept. The explorative typology is used to create a wide scope of viable developments. The typology is commonly used for long time-horizon scenarios and it is more usually to create these scenarios in the far future. Hence, more structural changes can be allowed. Hereby, awareness for certain developments can be raised and taken into consideration. Moreover, the typology is very useful to explore consequences of certain developments. Therefore, Börjeson et al., (2006) argue that explorative scenarios come in handy regarding strategic issues.

Börjeson et al., (2006) further specify the explorative scenarios by external and strategic scenarios. The focus in the external scenarios is mainly on factors beyond the control of the involved stakeholders. Thereby, a rough sketch can be made to inform relevant strategic or planning departments. By assessing the policy, the external scenarios can contribute to further development of robust strategies. The generated external scenarios are usually quite general and thereby offer the possibility to derive flexible and adaptive solutions. Moreover, it creates common understanding between different stakeholders.

Strategic scenarios aim to illustrate a range of consequences due to strategic decisions. The scenarios incorporate policy measures in order to handle a specific issue. Börjeson et al., (2006) stipulate that these strategic scenarios focus on internal factors and external influences are considered. Target variables are defined and by varying future developments the consequences of a change or specific design can affect the impact on the target variables. The studied variables are relevant for decision makers and other interested stakeholders.

In this research, strategic scenarios fit the requirements regarding the creation of project alternatives. The project alternatives are created in order to study the development of certain variables and their share in the success of the economic feasibility of a car-free application. By studying the division of cost and benefits per project alternative individually and in comparison with each other, the main research question can be answered.

The creation of scenarios as presented by Börjeson et al., (2006) is followed as much as possible in this research. The method is not applied in great detail due to a limited period of time of 17 weeks. Börjeson et al., (2006) follow three different steps in the scenario creation process. Firstly, a generation phase wherein ideas and concepts are proposed. This generation step is carried out and input derived from the stakeholder analysis is used to substantiate the generated ideas. Secondly, the integration step, as suggested by Börjeson et al., (2006), is carried out wherein generated input is processed to create scenarios. This step is carried out more simplistic and not optimised by quantitative models due to high uncertain and unclear input variables. Lastly, a consistency check must be carried out but since no quantitative optimum is found this step is not carried out. Despite, a simplified analysis is carried, rough scenarios to evaluate in the CBA are constructed.

3.3 Cost-benefit analysis

The created project alternatives, in the previous step, help to identify which effects come in play regarding the city centre of Rotterdam. In order to approach the economic feasibility and the division of costs and benefits, the effects must be monetised and analysed. The cost-benefit analysis (CBA) is a tool to monetise effects and evaluate the economic feasibility. Van Wee & Roeser (2013) describe

the CBA as a method that provides an overview of on the one hand all the pros (benefits) and on the other hand all the cons (costs). Benefits can also be defined as harms a regulation will avoid (Driesen, 2006). These costs and benefits are monetised and thus quantified for a project or policy alternative. The costs and benefits are interpret by the change of utility or human welfare (Hwang, 2016). This change is usually monetised based on the willingness to pay (WTP) and willingness to accept (WTA) (Hwang, 2016; van Wee & Roeser, 2013).

All incorporated effects are monetised despite this might be difficult for some effects. The consequences of the project or policy intervention affect environmental effects which are commonly known as difficult to monetise. By expressing these effects, a broad view on the consequences of the intervention on society can be approached. However, the CBA methodology lacks to quantify the full set of environmental impacts (soft effects) (Dong, Manzo, & Hauschild, 2017). Although the CBA has its flaws and criticasters, it is arguably seen as a fair and neutral method. It is mainly regarded neutral because the methodology decides upon the appropriate stringency of safety, health and environmental regulations (Driesen, 2006). In other words, the method might not be perfect but it is a transparent methodology to approach the value of (soft) effects.

Under the assumptions that monetised values might lack the quantification of the full set of environmental impacts and some nuance is required, the methodology is used to elaborate on the welfare effects for the city of Rotterdam. These welfare effects are calculated over a period of time and discounted by a rate of 5,5% per year in order to accumulate the costs and benefits (Koopmans & Lieshout, 2014). The sum of the accumulated outcome is defined as the Net Present Value (NPV). Additionally, next to the NPV, the benefit-cost ratio can be determined, indicating the difference between the costs and benefits (van Wee & Roeser, 2013). Basically, if the benefit-cost ratio exceeds 1, it implies that the benefits are bigger than the costs and vice versa if the costs outweigh the benefits, the benefit-cost ratio indicates a negative investment. However, point of view is important regarding the interpretation of results. Often, politicians act strategically to implement a certain project or regulation, despite CBA results indicate a negative investment, for political gain (Mouter, 2013). Moreover, sometimes a positive decision is made despite a negative CBA, it has to be noted that most of the time this is the case for smaller investments (Koopmans & Lieshout, 2014; Rienstra, 2008).

The explorative nature of the study regarding a car-free city centre in Rotterdam, offers potential to get insights in the individual costs and benefits per identified effect. The NPV or benefit-cost ratio might be sensible for the political debate, but the CBA offers much more than just a review for political purposes. Rienstra (2008) argues that the CBA can also be used as ‘improver’ instead of ‘assessor’. If outcomes are different than expected or intended, the results can be used to anticipate to optimise alternatives.

In this research, process steps are carefully outlined in order to work towards answering the main research question. Firstly, a 0-alternative, or business-as-usual, alternative is created. Thereafter, the project alternatives in relation to a car-free city centre are explained. Hereafter, detailed effect valuations are given. By explaining all the alternatives and effects, the CBA estimations can be made. The CBA estimates a delta difference of a project alternative in comparison with the 0-alternative to estimate the effect impact relative to a business-as-usual situation. The obtained results provide an indication of all the gained benefits and made costs due to a car-free city intervention. Since the results are rough estimations the sensitivity is tested accordingly. The method is in the first place used to assess the societal feasibility of a car-free city centre. Based on the obtained results the method is used as an improvement tool for decision makers. Thereby, the intention to shine a light on the development of a car-free city centre comes in play and lessons can be learned.

4. Stakeholder analysis

Intervening in a complex system is difficult due to, amongst other things, multiple stakes. In order to implement a working and feasible intervention it is important to distinguish the playing-field. Therefore, it is suitable to map the stakeholders involved, regarding a car-free implementation in the city centre of Rotterdam. From here on, a broad perspective of involved stakeholders will be mapped. By analysing the stakeholders in greater detail, implications can be formulated. These implications are used to identify important factors regarding the intended policy intervention. This chapter will focus on answering sub-question 1 and 2.

4.1 Stakeholder identification

Research by Rydningen et al., (2017) emphasised on the importance of involving stakeholders in the planning process of the realisation of a car-free city centre in Oslo. According to their research, it is essential to incorporate stakeholders in the process with their view and demands in order to facilitate exceptions. A car-free city application will affect car users since they are not able to drive through the city centre anymore. Such a policy measure affects way more stakeholders and thereby implications for society occur. To assess the impact on society it is valuable to identify the stakeholders and their interest. Therefore, stakeholder groups as distinguished by Rydningen et al., (2017) and other important stakeholders are assessed in greater detail. Table 1 elaborates on multiple stakeholders regarding the possible intervention of a car-free city centre in Rotterdam and thereby answers sub-question 1. Hereby, the stakeholders are described and their interest in the intervention and their power to affect the decision-making process is distinguished. Table 1 roughly distinguishes three main stakeholders groups: users, transport suppliers and governmental bodies. This distinguish is made to elaborate on the implications later on.

Table 1 Stakeholder identification

Stakeholder	Description	Interest	Power
Municipality of Rotterdam	The governmental body and decision maker in the city of Rotterdam.	The municipality is aiming for a greener and more healthy city with clean air (Gemeente Rotterdam, n.d.-c). On the one hand there Is a need to be more sustainable because Rotterdam does not live up to the legal norms regarding nitrogen dioxide emissions and on the other hand the municipality focusses on being a more interesting city for businesses and residents (Gemeente Rotterdam, n.d.-c). Therefore, the municipality is intervening to reach this goal. A car-free city might be an	The municipality is the policy maker in the city of Rotterdam. Next to that they are responsible for governing designed solutions and interventions in an appropriate manner.

		interesting intervention to do so according to Kristiaan Leurs (personal communication, March 13, 2020)	
Metropole Region Rotterdam The Hague (MRDH)	The MRDH is a collaboration of 23 different municipalities to boost the economy and improve accessibility (MRDH, n.d.-a).	The MRDH want to boost the economy by for example the creation of new employment opportunities. This done from a sustainable accessibility point of view (MRDH, n.d.-c). The MRDH emphasises on a mobility transition to create a sustainable, clean, silent and energy efficient region (MRDH, n.d.-b).	MRDH is able to share knowledge with the municipality of Rotterdam. Next to that it finances the realisation of projects.
MKB Rotterdam/ Urban Department Store (UDS) Rotterdam	Both MKB Rotterdam and UDS Rotterdam represent the interests of both retailers, shops, restaurants and other food facilitators in the city centre of Rotterdam.	For an entrepreneur it should be easy to do business and one of the main criteria is good accessibility for both customers and suppliers (MKB Rotterdam Rijnmond, n.d.; UDS Rotterdam, n.d.). The interest representor UDS, was already against an initiative to close off the city centre during the Christmas period in 2019 (Kreunen, 2019).	Representors such as MKB Rotterdam Rijnmond and UDS are able to lobby for regulations affecting their businesses and interest.
RET	The RET facilitates the bus, metro and tram services in Rotterdam and The Hague and they maintain the infrastructure (RET, n.d.-a).	The RET strives to deliver perfect organized, high quality transport (RET, n.d.-b). It is in their interest to deliver this service at all time.	The RET can lobby to restructure the transport network in order to live up to their goals and the traveller's needs.
Shared mobility providers (such as JUMP & Felyx)	Multiple shared mobility services are active in Rotterdam and diverse transport means are available such as bicycles and scooters. These shared mobility providers care about the future and the current mobility system and are trying	Shared mobility providers view their services as an addition to the sustainability transition. By stimulating this transition, they want more users to make use of their alternative forms of mobility (Felyx, n.d.) .	Shared mobility is seen as a potential mode of transport to decrease car usage. The municipality of Rotterdam offers possibilities for new innovations to facilitate up to 500 vehicles (Gemeente Rotterdam, 2020a). Successful

	to improve sustainable city transportation (Felyx, n.d.; JUMP, n.d.).		innovation can push the municipality to intensify the usage of shared mobility services.
ANWB	The ANWB represents the car users in the Netherlands.	At the moment, the ANWB has no specific opinion on car-free measures (Roxy Tacq personal communication, May, 13, 2020) The ANWB focusses on different topics such as smart mobility, sustainable mobility, traffic safety, accessibility and affordability (ANWB, n.d.-b). They are aiming for clear and consistent rules throughout the Netherlands. In 2018 the ANWB was unhappy with the environment zone in Rotterdam since different rules applied compared to other cities (ANWB, 2018). The municipality of Rotterdam can count on a strong lobby by the ANWB if rules aren't centralised.	The ANWB has lobby power in the Dutch and European politics (ANWB, n.d.-b).
Ruimte voor Lopen	Ruimte voor lopen is a platform created by over 30 different stakeholders consisting of governmental bodies, knowledge institutes and societal organizations to stimulate and facilitate walking (Ruimte voor lopen, n.d.).	They have an interest in the improvement and stimulation of walking. Thereby, they aim to improve the image of walking , create a safe and accessible walking environment and they try to obtain an integral spot in the policy making process (Ruimte voor lopen, n.d.).	Ruimte voor lopen consists partly out of governmental bodies and is able to lobby for their interests.
Fietsfan010; Fietsersbond	The Fietsersbond represents the interest of cyclist in the Netherlands and Fietsfan010 specific in Rotterdam (Fietsersbond, n.d.; Fietsfan010, n.d.)	Both organizations have an incentive to support cyclists. They are mainly aiming to improve facilities regarding cycling infrastructure, safety and new innovations such as shared bicycles (Fietsersbond, n.d.). Both stakeholders want to	Both stakeholders unite cyclists. They have lobby power and are often asked for advice regarding cycling.

		increase bicycle utilization in the city of Rotterdam.	
Citizens	The citizens living in the city centre of Rotterdam. They are represented by Wijkorgaan Stadsdriehoek.	The citizens are interested in a reduction of congestion (Kreunen, 2019). It is not necessarily required to create more walking space since Rotterdam has wide sidewalks (Kreunen, 2019).	Wijkorgaan Stadsdriehoek links the citizens to the municipality by organizing lobby events (Hoogkwartier, n.d.). Hence, citizens will be heard during the possible launch of new initiatives.
Visitors	Travellers to and from the city of Rotterdam.	For a visitor it must be easy to access the city via multiple modalities.	-
Commuters	Commuters who are travelling on a daily base to and from the city.	Dutch commuters are not very concerned about their travel time (de Jong, 2019). Other factors play an more important role in their travel behaviour, such as comfort in public transport and the possibility to relieve stress (de Jong, 2019). The exclusion of cars does not have to be a problem if a good alternative can be provided.	Commuters are represented by multiple interest groups such as the ANWB (car users), Fietsersbond (cyclists) and Rover (public transport users). These interest groups are able to lobby.
City council commission: Construction, Housing & outside	Each council is responsible for the preparation of the decision making process of the municipality. This council is responsible for, amongst other things, the following domains: land policy, living and building.	Residents from all layers in society must be able to find a suitable house. Therefore, enough and affordable houses must be available on the market.	They are able to realise new residents in Rotterdam. If there is pressure on the housing market they are able to step in and regulate.
City council commission: Energy transition, sustainability, economics & mobility	This council focusses on the following policy areas: MRDH, economics, catering industry, tourism, events, mobility, parking, traffic safety, energy transition and sustainability.	Since amongst other things mobility and sustainability is part of their portfolio, this council should carefully explore the possibilities of a car-free city centre in order to seamlessly transition towards a smooth regulation.	The expertise of this council is required to implement adequately a new policy. By making use of their expertise, the transition towards a car-free city might generate more support amongst the other councils.

City council commission: Major projects, organisation & finance council	This commission focusses on the financial aspects in the city of Rotterdam. More over the Coolsingel street is part of their domain.	The implementation of a car-free city centre in Rotterdam requires major investments in infrastructure, landscape and the rearrangement of public space. These investments must be transparent and responsible.	This councils manages the budget of the municipality and can decide upon and reflect on investments.
City council commission: Safety & governance	The council of safety & governance focusses on multiple domains such as safety, public order, nuisance and enforcement.	By excluding cars out of the daily street life, the change in travel behaviour might have implications for the current activities. This council must organise a safe environment for all travellers.	The council is able to emphasise on (socio) technical systems to guarantee the safety of travellers in a changing environment and inherent infrastructure.
City council commission: Employment, income, integration, debt & poverty reduction	This commission focusses on providing employment and inherent income and thereby reduce debts and poverty amongst citizens in Rotterdam.	A car-free application affects multiple stakeholders and thereby the provision of jobs. They need to guarantee that implications not affect people's jobs.	They are able to lobby for the creation of employment.
City council commission: Health, education, culture and sports council	This council focusses on welfare and public health.	Public health can be enhanced by emitting less emissions. Nevertheless there must be accounted for implications such as the effects on emergency services. By safeguarding certain criteria people welfare can be guaranteed.	Their expertise can be used to support the intervention and increase its potential by elaborating on flaws.

4.2 Relationships between stakeholders

After exploring the stakeholders interests and power, it is useful to look into the relationships between stakeholders. It is essential to understand actors and gather knowledge about their environment (Enserink et al., 2010). In order to determine the relationships between stakeholders, a formal chart is created (figure 4). The formal chart gives an overview of the interactions by the use of two different arrows. A two-headed arrow represents an equivalent relation while a one-sided arrow represents a hierarchical relationship. Stakeholders with a similar interests are grouped because they have similar relationships with the other stakeholders. The MRDH, as a governmental body, provides contracts and tenders to public transport providers and as long as the RET is responsible for providing public transport services in Rotterdam they should cope with a change in travel behaviour. The municipality of Rotterdam, in cooperation with the MRDH, creates a mobility roadmap to vision the mobility in the future. Travellers and thus inherent transport service providers are affected by this roadmap. If the municipality is aiming in their roadmap to exclude cars in the city centre, then

are other transport users affected inherently. The municipality regulates the amount of shared vehicles in the city in order to maintain safe transport and prevent nuisance. It is likely when there is a change in policy that the amount of shared vehicles will be revised.

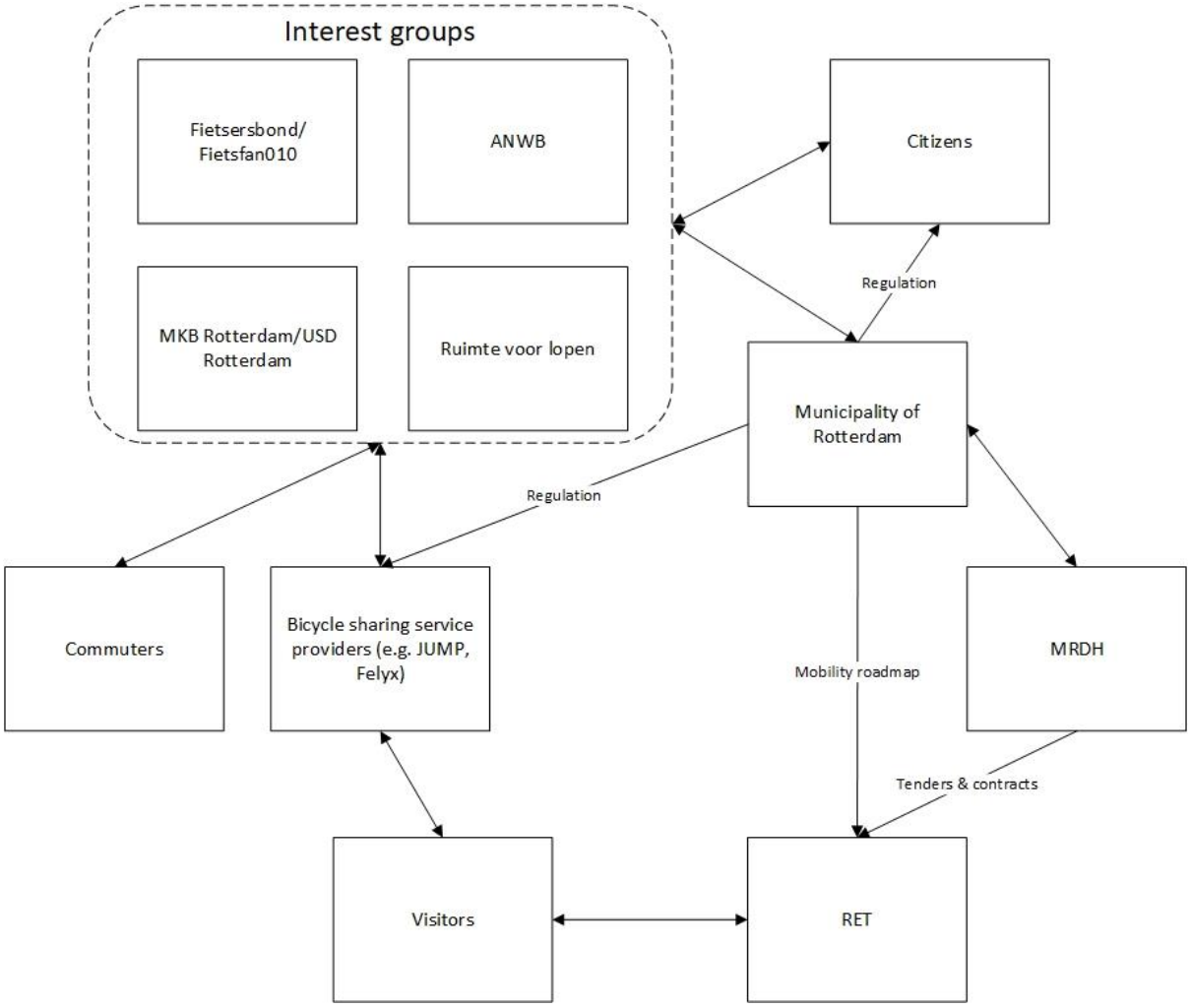

Figure 4 Formal chart

4.3 Mapping actor dependencies

After mapping the relations, it is useful to identify the position per stakeholders regarding a car-free city application. Therefore, a power-interest grid is created in figure 5. In the grid, four quadrants are distinguished based on either a high or low level of interest and a high or low power. The grid provides insight in critical and dedicated actors (Enserink et al., 2010). It provides insights in the feasibility of the intervention by assessing the key stakeholders.

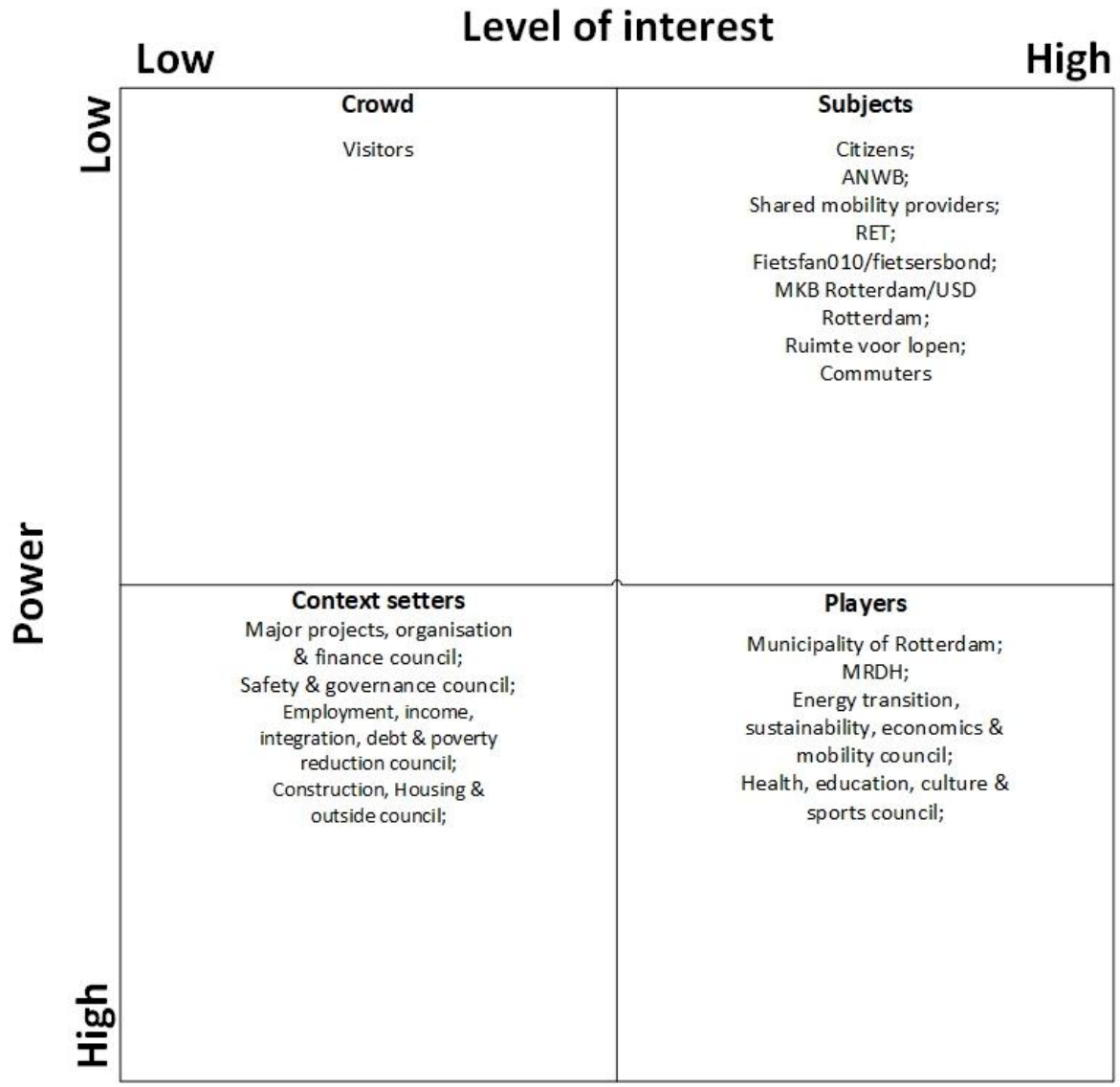

Figure 5 Power-Interest grid

The 'players' are the most important stakeholders because they have a major stake since they have both high power and a high level of interest. These stakeholders can have a big influence on the success or failure of the policy or intervention. The stakeholders that are placed in the other quadrants will have a different role in the process towards a possible intervention. The 'context setters' are (currently) not interested in the project but can have a major influence on the outcome. This group can be really important to make the project a success. The 'subjects' have a high interest but barely power to intervene. From their perspective, it is very likely the policy or intervention will affect their welfare and therefore they would like to direct the effects in their best interest. Lastly, the 'crowd' is acknowledged. The crowd has barely interest and power and play therefore a minor role. Overall, the analysis provides insight in which stakeholders can direct a car-free city intervention to success or failure.

In the context of this research, the players are governmental bodies. These governmental bodies need to align in order to be able to implement a successful regulation. Considerations regarding the completion of a solid policy need to be weighted.

4.4 Actor implications

The distinguished actors will be affected by the intervention. The current analysis provides an overview in their interest, power and their relation towards each other. As mentioned before, roughly three different actor groups will be elaborated on: users, transport suppliers and governmental bodies. Implications for this groups occur and are reviewed accordingly with additional literature as mentioned before in chapter 2 and as distinguished in Appendix B. By providing insights in the implications, important factors for the realisation of a feasible car-free city centre design can be determined. By researching the implications, sub-question 2 can be answered.

4.4.1 Users

The users of the system are direct affected people by a car-free intervention. They are defined as the daily travellers, both commuters and leisure, throughout the city, such as car users, pedestrians, cyclists and public transport users. Moreover, residents are seen as users since the city layout will be affected by a car-free city centre application. The exclusion of cars, affects car users directly since they need to switch to another modality in order to perform the same journey. Hence, alternative transport modes will be affected by an increased amount of travellers. The increase of travellers can result in crowdy transport means, what might result into less comfort and longer travel times and thus resistance towards a car-free application. Therefore, for the users, it is important to facilitate alternative transport means in order to accommodate the increasing amount of travellers on the different networks. An enhancement of the public transport network must be reviewed carefully. Borgers et al. (2008) observed a tension field regarding travel time and distances. The addition of many stops to a transport network will slow down the speed and increases the overall travel time. Contrarily, cyclist and pedestrians might profit from the exclusion of cars since they have to share the road with one less modality. Moreover, cyclists are more likely to accept car-free initiatives (Borges & Goldner, 2015; Gundlach et al., 2018; Melia, Barton, & Parkhurst, 2013). By taking these effects into account, transport planners should carefully consider the aftermath of a car-free application.

The exclusion of cars, offers opportunities for an alteration to the city centre design. The available space can be used for more green or other recreation forms. Residents should benefit from the land gained by banning cars (Morris, Enoch, Pitfield, & Ison, 2009). Moreover, nuisance and congestion will decrease. In other words, the liveability will be affected and that alteration might push the willingness to visit the city. Next to that, local businesses profit from an increased volume of pedestrians (Pojani, 2007). In the city centre of Den Bosch it turned out that pedestrians and cyclists spend much more money to shops and restaurants compared to car drivers (Bart Eigenman, personal communication, April, 6, 2020). The difference lies within the fact that car drivers often come with a specific goal to visit and thereby only spend money on their needs.

It is likely a lot of users will change their behaviour regarding their choice of transport mode and their motive to visit the city. However, this might not be certain at all. Luiu et al., (2018) acknowledges that autonomy, flexibility and independence are fundamentals in the travel needs. Moreover, the car is the most used transportation mean by the older population (Luiu et al., 2018). The older population might not be able to make use of other modes of transportation due to further distances towards a starting point for their journey. Thereby, implications regarding their independence come at stake.

4.4.2 Transport supplier

The users of the system make use of a transport modality to, from and in the city centre. The exclusion of cars as a transport mean affects all the users and transport suppliers. Some users need to switch from one mode to another and the current network, of alternative modalities to cars, will be pressured. The interest groups, representing the concerned modality users, will try to influence the impacts for their respective network. It is very likely investments regarding the increase of capacity have to be made. Next to that, these interest groups will try to guarantee a certain amount of quality while traveling. For example, the RET is already investing in new capital in order to prevent that the occupancy rate will go over 100% according to Halmer Kranenburg (Personal communication, April, 7, 2020). In other words, transport suppliers need to account in their service level and capacity in order to live up to the increased amount of travellers and the required standards to facilitate new and existing travellers.

The impact on the current network will have consequences on the city landscape. It might be possible that suppliers need to expand in both capital and infrastructure. Considerations regarding the placement of new infrastructure must be weighted in order to prevent a movement of negative externalities such as view and noise. For example, if a new tram line is built on the current car infrastructure, the reducement of noise may be neglected. Therefore, implications might occur in order to live up to intended improvements of a car-free intervention.

Shared mobility providers are dependent of regulations by the municipality. Since they are bounded to a certain amount of vehicles it is not possible to increase their fleet. Therefore, to keep up with a rising demand it is important that suppliers are granted the needs to live up to expectations. Next to that, there might be additional implications. For example, their vehicles must be maintained and stored or they need to provide their service in unregistered areas what affects their offered mobile application. Therefore, companies might need to reorganise and have to expand and grow in multiple domains.

4.4.2.1 Logistics reallocation

Transport suppliers might be affected by a reallocation of logistic supplies. Since trucks are not able or limited to enter the city, local businesses need supplies via a different way of transportation. Crawford (2012) claims that moving freight is the biggest challenge in the creation of a feasible car-free city. He reasons that only a dedicated system, to facilitate a 24-hour-a-day freight service in big cities without hindering passenger services, will be sufficient. Crawford proposes ‘metro-freight’ as a dedicated system. This transportation mean is automated on the current rails infrastructure and is transporting standard shipping containers. According to Halmar Kranenburg (Personal communication, April, 7, 2020) there is still space to deploy more metro movements in the current metro network but this capacity is required to fulfil the needs of an increasing amount of passenger transport. Hence a tension field will occur if the metro network will be used to transport both freight and passengers. A new metro line might be required but this is a very expensive investment. Despite it is an expensive investment it might be a solution since the operating costs are cheap and externalised costs are minimal (Crawford, 2012).

Crawford (2012) centralises the proposal of freight transportation by metro in car-free areas because no alternative achieves all the benefits of metro-freight. An alternative to metro-freight is the transportation of freight via trams. In the case of Rotterdam this might be a more suitable solution. According to Halmar Kranenburg (Personal communication, April, 7, 2020) there is sufficient capacity on the tram network. Therefore, the RET is aiming to intensify the usage of this network. It is possible

to mix freight and passenger transport via the same tracks. However, a drawback is that the additional freight transportation movements may delay passenger transport (Crawford, 2012). On the one hand the transportation of freight offers the possibility to more sustainable freight transport in the city while on the other hand it might have implications for passenger transport.

Assuming it is possible to move freight via the public transport infrastructure still some challenges lie ahead. For example so called utility areas are required to handle freight, stock freight and distribute freight (Crawford, 2012). The utility areas are out of scope in this specific research. However, considerations regarding last-mile transportation must be made since this transport movements must be offered by a service provider making use of a specific infrastructure. Crawford (2012) proposes to make a distinguish between lightweight deliveries via pedal-powered vehicles such as bikes or handcarts and battery-powered deliveries for bulky loads. Recently, in Amsterdam an initiative for sustainable last-mile deliveries is launched. By the use of strategic located hubs and smart software the company TringTring delivers local entrepreneurs via special cargo bikes way more efficient than truck freight deliveries (Gemeente Amsterdam, 2020). An increased amount of these cargo bikes might influence the cycling traffic flow due to their unwieldy design. To guarantee an excellent biking network it is important for transport planners to account for multiple implications regarding different network users. In order to be as bike-friendly as possible the infrastructure is seen as the 'key' feature in its success (Tight, Rajé, & Timms, 2016). Therefore, infrastructure must facilitate both passenger cyclists, inherently to make shared mobility providers successful, and cargo cyclists and still be able to guarantee a smooth traffic flow.

Obviously, not all goods can be transported by bicycle or small carts such as bulk materials. That is why Crawford (2012) argues that it might still be important to tolerate some types of street traffic for special cases. Amongst others, Crawford includes the movement of cranes, construction equipment, maintenance vehicles and emergency vehicles. In order to prevent unnecessary car movements, this advocacy must be strictly regulated. This can be done by for example so-called limitation zones as is done in for example Den Bosch. In Den Bosch this regulated limitation works perfectly and is mainly being used for supplying or special transport (Bart Eigenman, personal communication, April, 6, 2020).

4.4.3 Governmental bodies

The governmental bodies, and especially the municipality of Rotterdam, will be the game chancers in the success or failure of this intervention. Hence, most of these bodies are 'players' in the power-interest grid. These bodies will encounter multiple implications dependent of their intended policy. Next to that, in the political field, governmental bodies might collide in their interest. The design of a car-free city centre application is not prefabricated. Every design varies from city to city and thereby implications differ per case. Rotterdam has different needs and thus, different councils, within the municipality of Rotterdam, will try to elaborate on their best interest. The decentralised organisation structure might hinder the development of the policy due to the colliding interests and inefficient decision-making. The decision-making process cannot be slow since it is important to facilitate travellers with an alternative as soon as possible to prevent hinderance.

4.4.3.1 Acceptability to create a support base

It is likely the policy or intervention will encounter resistance. Therefore, the municipality need to create a support base or certain level of acceptability. The nature of a policy influences the acceptability . Two characteristics are distinguished to approach the influence on the acceptability

regarding a policy measure. The level of coerciveness of a policy has to perceive and the behavioural target of the intended policy or intervention must be assumed (de Groot & Schuitema, 2012).

The level of coerciveness focusses on the extent to which a policy measures affects or applies to behavioural change. The level of coerciveness is distinguished by pull and push measures (de Groot & Schuitema, 2012). Multiple studies implied that pull measures are regarded more acceptable than push measures (Eriksson, Garvill, & Nordlund, 2008). However, Eriksson et al., (2008) acknowledges that if revenues generated from a push measure are used in the same domain, the measure is more acceptable. Pull measures stimulate the desired behaviour while pull measures focus on the discouragement of undesired behaviour (de Groot & Schuitema, 2012). The stimulation of desired behaviour is often regarded unfair and unacceptable and therefore lacks public support and thus acceptability because pull measures are expected to restrict one's freedom (de Groot & Schuitema, 2012; Eriksson et al., 2008). The restriction of cars affects the freedom of travellers and can thereby be considered unacceptable. The policy can be more acceptable if revenues gained from the measure are used in the same domain and thus it is important to facilitate travellers with alternative modes of transport.

The behavioural target of the environmental policy is assumed by de Groot & Schuitema (2012) as the effort it takes to change behaviour. Hereby, they refer to behavioural costs which consists of financial costs, convenience costs and effort costs to adapt to the specific behaviour intended by the policy. A distinguish between low- and high cost behaviour policies is made. Policies with low cost behaviour will barely affect one's interest, and is thereby considered more acceptable, while high cost behavioural policies are assumed the opposite since they change individuals well-being or level of comfort (de Groot & Schuitema, 2012). Policies to change (private) car use behaviour are classically viewed and placed in the high cost domain because personal advantages are declined (Bamberg & Schmidt, 2003). Therefore, a car-free implementation can be regarded in the high cost domain declining the acceptability of the policy. To increase acceptability, it is important to create a low cost as possible policy by creating an effortless as possible transition towards the use of alternative modalities.

In order to provide an acceptable intervention it is important to elaborate on factors respecting the acceptability. A strong political lobby and public participation process could provide understanding and cooperation amongst stakeholders according to Bart Eigenman (Personal communication, April, 6, 2020). Another important factor is inclusiveness since the municipality is representing the interest of all layers in society. It might be possible certain groups in society lose one or more fundamentals, as described by Luiu et al., (2018), in their travel needs. A lost fundamental is not a problem per definition, since transport users are able to adapt to new circumstances. It will be a problem if an individual or group is not able to adapt and thereby will be excluded of the possibility to travel. Rotterdam's decentralised organisation has as a potential disadvantage that "extreme" preferences by dominant groups may be prioritised and implemented that harm minorities their well-being (Bjorvatn & Cappelen, 2003). It does not have to be a problem per definition since in general, increased mobility supports decentralisation (Bjorvatn & Cappelen, 2003). The paradox is in the establishment of multiple policies or interventions. The decentralised nature of an organisation offers possibilities for rather extreme interventions but by an increased variety in public policies, minorities will relocate to their preferred mobility policy. Nevertheless, implications regarding inclusiveness will be a challenge for governmental bodies in order to safeguard the well-being of minorities.

4.4.3.2 Effects due to Governmental interventions

Implications occur due to valuable effects inherent to the intervention. These effects can be very diverse from health effects to economic effects to societal effects. Economic effects are a consequence of health and societal effects. For the governmental bodies it is important to prevent negative implications or at least minimise them. Therefore, it is important to research the impact of certain effects in greater detail in order to access the impact. By doing so, governmental bodies might be able to redirect impacts and maximise benefits.

An entire car-free city, by regulation, has not been realised yet. Therefore, the exact effects of a car-free application cannot be interpreted related to the case for Rotterdam. However, throughout the years, (partly) car-free experiments have been carried out and can be used to obtain useful insights. In the past, car-free days have been held and later on, an initiative for car-free housing has been developed (Loo, 2018). Car-free housing projects are seen as a way to develop more liveable, pedestrian cities with a major role for public recreation with no space for frequent car use (Ornetzeder et al., 2008). Research by Nobis (2003), into the effects of car-free housing, emphasised on the importance of the availability of different modes of transport to account for the missing car transport movements. Ornetzeder et al. (2008) claim that car ownership influences the way people organise their lives for routines such as work, shopping or leisure. This relates to Nobis' research wherein a significant increase in bicycle usage is observed, resulting in the bicycle becoming the dominant means of transport for car-free house residents. Since, different modes of transport will become more dominant, and especially the bicycle, it is important that transport planners consider physical constraints to account for a relatively large group of car-less travellers (Brown, 2017). To make a car-free environment eligible, infrastructure must be able to account for a modal shift. Therefore, implications regarding the current infrastructure must be considered and weighted in order to explore the possibility of a car-free city centre.

If a car-free environment can be realised, more green space can be created. In addition, car-related negative effects are neglected (Loo, 2018; Nieuwenhuijsen & Khreis, 2016). Environmental harm is reduced by the reduction of emissions, pollution and noise (Loo, 2018). Nieuwenhuijsen et al. (2017) literature review indicates certain positive health effects, such as reduced obesity, increased birth weight and cleaner air resulting in reduced morbidity and thereby mortality. Next to that, Loo (2018) recognises the disappearance of road traffic risk and thereby its impact on mortality. In an earlier research, Nieuwenhuijsen & Khreis (2016) linked the effects in a framework in order to get greater understanding of the relation between certain health effects. Figure 6, visualises the relations as framed by (Nieuwenhuijsen & Khreis, 2016).

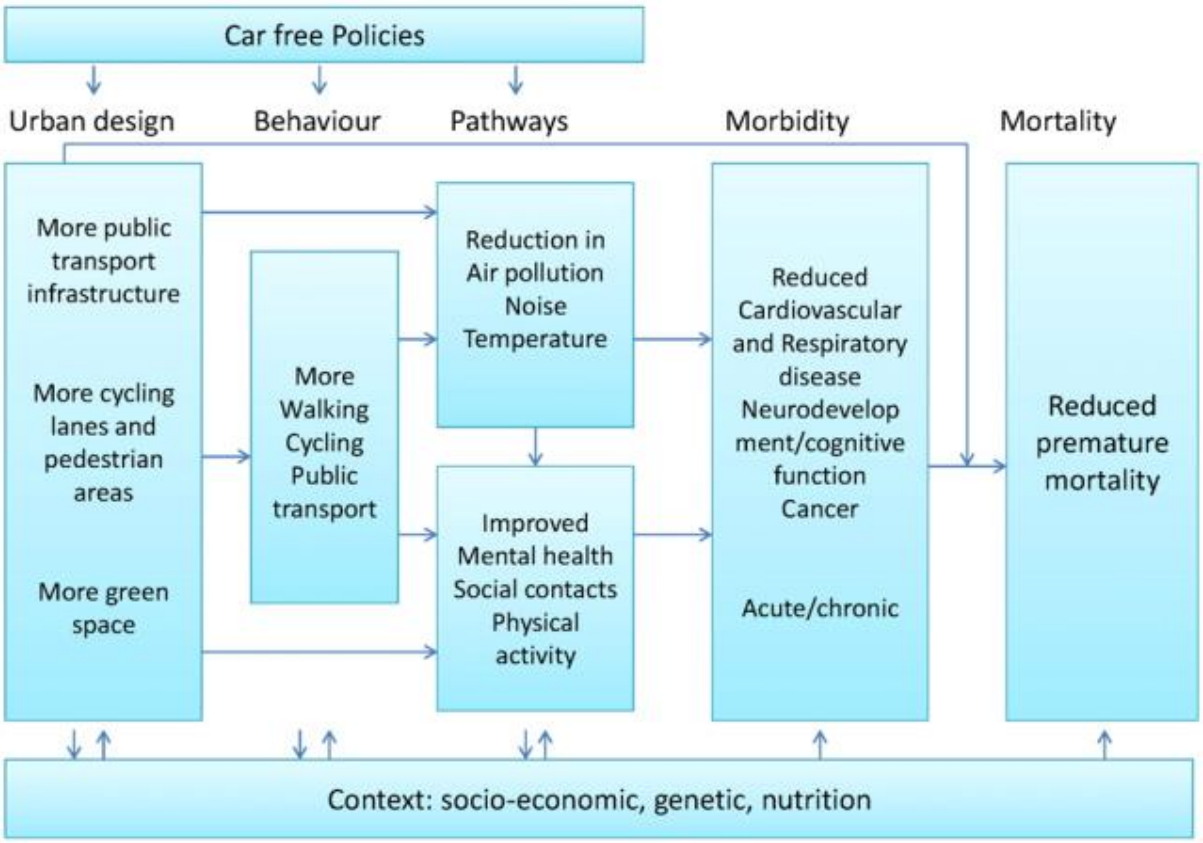

Figure 6 Linkage between urban and transport planning, environmental exposure, physical activity and health (Nieuwenhuijsen & Khreis, 2016)

The framework by Nieuwenhuijsen & Khreis (2016) provides a positive view on the health effects due to car-free policies. It is important to note that it is too simple to draw a positive conclusion based on this framework. Obviously, the reduction of car usage results in less emissions and the switch to cycling or walking has other positive effects. One of the most important effects is that the aspect of walkability creates social cohesion and thereby creates liveable placemaking that affects and improves the regenerating of the urban environment (Cheshmehzangi, 2015). Although, the framework is limited by excluding the economic aspect. Implications might occurs due to a rebound effect. For example, if the money saved by not owning a car is spent on other activities such as air transport, emissions and noise might be even bigger than by making use of the car (Ornetzeder et al., 2008). However, the rebound effect might not apply to the emissions in the case of Rotterdam since it might 'rebound' in a different place. Since it is not known how this rebound effect will develop related to the city centre of Rotterdam, it will be left out of scope. Such effects can be monitored after the implementation of a policy. Ornetzeder et al., (2008) research identified significantly lower CO_2 emissions in car-free households in Austria. Assuming this conclusion applies to Rotterdam, valuable health effects can be obtained as visualised in figure 6. This positive implication is very important since the air quality in the city is bad. Residents in the city centre of Rotterdam approximately live 1 year less than the average Dutch citizen (Kristiaan Leurs, personal communication, March 13, 2020).

Next to health effect due to the use of alternative, more sustainable, transportation modes other effects occur. Social effects occur such as the reduction of crime, increased social cohesion, increased physical activities and a reduction in stress (Nieuwenhuijsen et al., 2017). Increased physical activities and stress relief are interrelated with increased green space. Research by Sauter & Huettenmoser (2008) in the city of Basel, proved a significant increase in social contacts if the speed limit of cars

decreased. Moreover, if cars disappeared out of the street view and sidewalks become wider, activities increased even more. Overall, Sauter & Huettenmoser (2008) discovered a relation between streets with slow moving traffic, including a minimal amount of parking spots and improved environmental qualities, with a large potential for individual development, satisfaction and social inclusion.

Social inclusion is an important factor for governmental bodies. The city belongs to each individual resident and thus it should be as inclusive as possible for every individual. Governmental bodies need to consider the implications of a car-free regulation regarding the social exclusion of individuals. Typically, disabled and older people are considered likely to be excluded since they have to be able to participate in society and to do so journeys need to be seamless. It is important that there is no obstacle in access from origin to destination (Maynard, Journal, Use, & Spring, 2009). Maynard et al., (2009) makes use of a "social model for disability" wherein she defines disability as follows (p.22): "disability is the lack of opportunity to participate in mainstream activities". Usually this lack of opportunity finds its origin in physical and social barriers. For example, the design or lay-out of buildings and streets can form physical barriers for certain people such as disable people who are dependent of their wheelchair. Social barriers are often related to organisational barriers such as information provision. People who need assistance at train stations need to arrange this in advance and thereby it is even more difficult to travel with the train (Maynard et al., 2009). Therefore, governmental bodies need to review their facilities carefully to make sure alternative transport modalities are both accessible physically and socially. Although, governmental bodies might consider improving their facilities, in order to make it inclusive for everyone, they should consider special transport as well. Maynard et al., (2009) concludes in earlier research that a significant amount of disabled people believes that it would be better to come up with special transport than to make public transport more accessible. The municipality of Den Bosch accounted for inclusion by providing access to special transport in the city centre including destinated parking spots (Bart Eigenman, personal communication, April, 6, 2020). By doing so, the concept of an entire car-free city cannot be guaranteed.

4.4.3 Conclusion

Multiple implications affect the stakeholders in the playing-field. Multiple positive implications arise by the regulation of a car-free city centre. Current used car space can be redeveloped in more green areas or offers opportunities for the improvement of alternative modalities. The redevelopment of used space must be considered carefully since multiple factors come at stake. Current transport networks might not live up to a sudden increase in travellers. Moreover, logistic suppliers potentially have to make use of these transport networks as well. Next to that, social inclusion might be a challenge by banning the car. Some negative implications can be accounted for by creating a balanced city and by the prevention of certain aspects such as resistance and inherently social exclusion.

5. Project alternatives

In order to answer sub-question 3, scenarios are created to realise project alternatives. To create project alternatives the scenario methodology by Börjeson et al., (2006) is used. In their methodology they distinguish three elements or techniques towards the creation of scenarios. The first step mentioned, is the concept of generating ideas and gathering data. Secondly, these generated ideas must be integrated to combine segments into complete concepts. And lastly, the created scenarios must be verified by a consistency check. Börjeson et al., (2006) use the same methods in the consistency technique as for the previous two steps and thereby consistency is assumed in all scenarios. Before the creation of scenarios via the methodology of Börjeson et al., some general assumptions and dimensions regarding a car-free city centre in Rotterdam are given to define and limit the design.

5.1 General boundaries

In advance, some dimensions are set to facilitate on the one hand governmental control and on the other hand to guarantee a certain level of embeddedness in society. Governmental control relates to the instrumental possibilities within the government's power. The project alternatives will be realised in 2030 and thus are highly uncertain. Therefore, scenarios are based on current knowledge in order to guarantee feasible outcomes. Future changes can thereby only improve the scenarios. The created scenarios will result in car-free project alternatives within the dimensions of the formed definition of a car-free city. This research defined a car-free city as follows, by recapping to chapter 2, '*car-free cities are developed to ban private and public car movements out of the city by traffic-free developments, focussing on the facilitation of sustainable non-car means, wherein still exceptions, such as emergency vehicles and disabled transportation, are facilitated.*'

Based on the given definition, it is assumed that in each scenario private and public cars are banned. However, exceptions are allowed such as the facilitation of emergency vehicles and disabled transit. Moreover, it is assumed that, just as in the city of Den Bosch as described by Bart Eigenman (Bart Eigenman, personal communication, April, 6, 2020), logistic suppliers are regulated to enter the city. The exact design of the logistic supply is assumed out of scope in this research because it is assumed logistic suppliers will develop their processes to facilitate the most optimal delivery based on infrastructure, opportunities, regulations and customer needs. These effects can therefore be neglected in the CBA.

The exact design of the regulations regarding a car-free city centre are left a bit in the blue. This study attempts to get insights in costs and benefits and not in the optimal design of a car-free city centre. However, gained insights might be valuable for the creation of an optimal design. The main focus is on banning ordinary car traffic. These car users are pushed out of the car and need to change their travel behaviour. Hence, travellers either switch mode or quit travelling to their destination. Based on generated ideas, project alternatives are created to facilitate these travellers in their travel needs by creating an alternative travel option. These project alternatives are explorative and intended to get rough insights in the divisions of costs and benefits and the importance of certain effects towards the realisation of a feasible design in a later stage.

To get a feeling for the size of the project, the city centre of Rotterdam is visualised in the red zone in figure 7. This depiction is based on googlemaps but is also used by the municipality and therefore it is assumed to be a correct representation of the city centre. The created scenarios are focused to facilitate travellers travelling from and to this specific area of town.



Figure 7 City centre of Rotterdam

5.2 Generating ideas

The generation technique focusses on generating and collecting knowledge, future views and concept ideas (Börjeson et al., 2006). Multiple techniques are distinguished to gather this information in order to create a scenario. In this research, a stakeholder analysis is carried out to generate ideas, gather knowledge and get a hold on some parts in the future. Amongst other techniques, the interview method can be used as an element to retrieve (additional) information. Interviews, Appendix C, are used to substantiate the stakeholder analysis and inherent its implications. The stakeholder analysis tends to provide design requirements for the construction of scenarios.

The implications are used as input for the scenarios in order to answer sub-question 3. To summarize the distinguished implications, table 2 is created to provide an overview of the factors related to the implications per stakeholder group. These factors are important per stakeholder category and will be considered in the creation of the scenarios.

Table 2 Stakeholder implications

Users	Transport suppliers	Governmental bodies
Travel time	Travel quality	Acceptability
Comfort	Travel capacity	Inclusiveness
Liveability	Investments	Infrastructure adequacy
Revenue increase	Traffic flow	Health
	Exception accessibility	Social cohesion

Based on the given factors several transport modalities, to facilitate travellers in their travel needs due to the removal of cars, can be thought of. As mentioned before, the scenarios will be based on current knowledge, and futuristic or pilot alternatives, such as the PRT in Masdar City, will not be considered. Such uncertain alternatives are also left out of scope in order to create an acceptable as possible scenarios, thereby it is assumed the transition towards known, conventional, transport alternatives is more easy than unknown innovations. Therefore, solely conventional alternatives will be used in the creation of alternatives.

Rotterdam hold in esteem a high quality public transport system. Mainly the bus and tram have some capacity to facilitate more travellers. The metro on the other hand is reaching its capacity. Currently, the RET is able to increase their amount of trips in the metro network one more time according to Halmer Kranenburg (Personal communication, April, 7, 2020). Therefore, if a significant amount of travellers must be accommodated to make use of the public transport network, investments must be made.

Another conventional mode of transportation is the bicycle. The bicycle is already getting a more central position in the street scene. By 2025, the municipality of Rotterdam is aiming to be the bicycle city of the Netherlands (Gemeente Rotterdam, 2019a). Therefore, investments will be made in infrastructure but also in the facilitation of users. Thereby, the municipality aims to attract users to make use of the bicycle.

In the past years, the municipality has been facilitating shared mobility. Shared mobility alternatives are an upcoming mode of transportation, mainly focussed on the city centre and thus, it might be a very good solution to facilitate travellers in their last mile transportation. These shared vehicles are limited to a certain area but can certainly be used in the entire city centre. At the moment, the amount of shared vehicles is regulated. If demand increases, due to the substitution from car to a shared bicycle, electric vehicle or electric scooter, the government should re-evaluate the regulated amount of shared vehicles. Shared mobility providers, such as Felyx, aim to provide sustainable transport. Hence, shared mobility might be a suitable solution to the replacement of cars. Shared mobility vehicles are facilitated and maintained by the suppliers and usually distributed at or nearby transport hubs such as P+R stations. These P+R stations are located out of the city and offer the possibility to park the car and switch to another mode of transport, such as public transport or a shared mobility vehicle.

Based on the generated conventional alternatives for car transport, three different modes can be distinguished. To facilitate travellers in the city centre, the municipality could aim to invest in public transport, bicycles and/or shared mobility.

5.3 Integrating ideas

The creation of rough scenarios, in order to provide possible project alternatives to a car-free regulation, are all based on some basic principles. Because the exact blueprint of a car-free city is not the aim of this research, some assumptions, regarding all created alternatives, are made.

First of all, social inclusion is a repeating problem in literature and no fair solution to guarantee inclusion is found yet. Next to that, users of the system and governmental bodies value the importance of social inclusion. Social inclusion is seen as one of the pillars of acceptability and thereby and important factor in the realisation of feasible scenarios. Given there is no acceptable solution, car traffic to facilitate minorities such as disabled persons, will be allowed. The exact measure to regulate these exceptions is not given and assumed out of scope.

Second, a real-world design is likely a combination of multiple alternatives. A kind of all-inclusive scenario so to say. Since a preferred design is a gap in the literature, this research tries to shine light on different aspects of facilitating travellers in a car-free city. Therefore, rather robust scenarios will be created to approach the impact of an alternative.

Lastly, the scenarios are mainly focussed on the provision of a transport alternative. Many effects occur due to the ban of cars. The effects on the city design are left out of scope. However, some rough assumptions are made. It is assumed that in each scenario, space comes available for more recreation and green. Yet again, it will not be specified since it is not the aim of the research. Next to that, it is assumed all alternatives are equally sustainable and thereby have an equal footprint. Thus, internalised emissions are left out of scope.

The integration of generated ideas is usually done by a range of modelling techniques (Börjeson et al., 2006). Given the limited timeframe, a limited amount of scenarios is constructed by hand. Therefore, the scenarios might not be quantitative optimal based on the given input variables. Based on the explorative nature of this study this limitation is not regarded as an obstacle to approach the impact on society. Börjeson et al., (2006) define exploratory models based on causal links. A new system or structure can be developed by changing causal links. It is also noted by Börjeson et al., (2006) that forecasts can be used in the provision of additional information for a qualitative analysis. The created scenarios are mainly qualitative and are approached quantitatively in the CBA. Based on the generation technique, the following four scenarios are constructed and explained in greater detail: no additional investments, invest in public transport, invest in P+R & shared mobility, Rotterdam bicycle city.

5.3.1 Scenario 1: No additional investments

The current infrastructure in Rotterdam is able to facilitate many travellers but by a big increase it will not be able to safeguard certain values such as quality and reliability. If car travellers have to substitute to either public transport or the bicycle, the concerned networks will be exploited. In this scenario no additional investments are made to relieve the pressure on certain networks.

Since no investments will be made, expensive costs will be saved. The disadvantage of not investing is that it is likely negative effects occur. The stakeholder analysis indicated users of the system value comfort, it is likely the increase of travellers will result in crowded transport networks and thereby discomfort. This scenario aims to provide insights in the impact of not investing and thereby if investment savings outweigh negative effects. Inherently, the true valuation of effects can be assessed if effects are not prevented or limited by an investment. In this scenario the car substitutes are equally divided over the alternative modes public transport and the bicycle and thereby both modes attract 50% of the travellers.

5.3.2 Scenario 2: Invest in public transport

The city of Rotterdam has an intensive and high quality public transport network throughout the city. The city centre is fairly good accessible from the outer city and surrounding establishments. The city centre will be a highly concentrated destination for travellers. In this scenario it is assumed that the majority of car users, 75%, switches to public transport and the remaining 25% to the bicycle. The exact division of travellers in this scenario is determined in the CBA. The instrumental nature of the CBA offers the possibility to play with this division of travellers.

In order to still facilitate high quality public transport, the different public transport modalities are evaluated. At the moment, the bus and tram network have more than enough capacity to facilitate a big amount of travellers. The metro network on the other hand has barely space to facilitate a big amount of additional travellers. Therefore, it is assumed solely investments in the metro network will be made to account for the travellers increase.

According to Halmer Kranenburg (Personal communication, April, 7, 2020) an additional metro line will be required to facilitate all additional travellers. The investments in the metro infrastructure are focussed on solely the city centre. The exact origin and destination of the line is therefore not specified. The investments will be made in rail infrastructure. However, it is likely investments must be made in additional infrastructure such as stations, waiting areas or check-in systems, these investments are left out of scope. It is unknown how the current infrastructure is able to facilitate more travellers and thereby if the facilities are sufficient. The additional metro line travels by the stations Beurs, Centraal station and Blaak. These are the busiest stations in Rotterdam (Treinreiziger, 2019). Figure 8 visualises the placement of the proposed metro line by an purple L symbol.



Figure 8 Additional metro line

Due to the high concentration of stations in the city centre, it is assumed no additional station can be realised. Therefore, travellers will only benefits from additional metro trips in the network, travel distance and time will stay unchanged, although the increased intensity of metros could improve the travel time by a decrease in waiting time. In other words, the capacity will be improved and assumed to be appropriate to facilitate the additional amount of travellers.

The public transport supplier of Rotterdam, RET, highly values the traffic flow and the additional capacity should live up to the expectations and guarantee a sufficient flow of travellers. Halmer Kranenburg (Personal communication, April, 7, 2020) elaborated on the goals of the RET and their investments in the quality of a travellers trip. They already invest in new and additional vehicles to

facilitate travellers in their future needs and this should continue in order to live up to the additional depicted increase of travellers. Therefore, exploitation costs in new metros are made to live up to the set standards.

5.3.3 Scenario 2: Invest in P+R & shared mobility

Shared mobility is an approachable alternative for travellers to accomplish their journey. This alternative consists of multiple possibilities such as the bicycle (e-bike), e-scooter and small electric cars. The range of different shared mobility vehicles offer a suitable alternative for a lot of individual travellers. In this scenario it is assumed the amount of shared mobility vehicles, allowed in the city, are re-evaluated in order to safeguard a sufficient amount of vehicles regarding the increasing demand due to the ban of cars. The downside of shared mobility is that the vehicles are limited to certain zones. These zones cover the entire city centre but travellers from outside the city will not be able to make their entire trip via shared mobility vehicles.

A significant amount of shared mobility vehicles are stored at transport hubs. A lot of travellers travel from and to these hubs via those shared vehicles. Therefore, in this scenario, the municipality invest in hubs in order to facilitate a greater amount of travellers to utilise shared mobility. Cars are not allowed in the city centre but they are allowed outside the centre. Therefore, car users will still be facilitated to make use of the car by offering a P+R hub outside the centre. These P+R hubs offer the possibility to make almost the entire trip by car and just travel the last mile by a different modality. Therefore, if a travel time loss would occur due the ban of cars, this loss is minimised. This might result in interesting insights for governmental bodies since the stakeholder analysis elaborated on the importance of acceptability and thereby inherent limited disutility. The P+R hubs are connected to public transport networks and the possibility to make use of shared mobility is facilitated. Car travellers are thereby offered a wide range of alternatives to finish their trip into the car-free city centre.

Currently, some P+R facilities are almost at the maximum of their capacity. Figure 9, shows an overview of all the P+R facilities in the area of Rotterdam. For example, the P+R facility Kralingse Zoom, nearby the city centre, has an average occupancy rate of 94%. All the parking places in the city centre are not accessible anymore and the P+R facilities are not able to facilitate much more cars in the current situation. Therefore, there must be invested in either new P+R facilities or in the expansion of current facilities. Figure 10, visualises potential locations, by blue ovals, for these facilities. All these locations are strategically chosen nearby highway exits and public transport modalities and within cycling distance of the city centre. The exact location and realisation of these facilities are left out of scope. This scenario assumes the investment in P+R will be sufficient to facilitate all new users of the system. Accordingly, users will be able to switch to their preferred mode for last mile travel.

	Parkeervakken	Gem. bezettingspercentage
Meijersplein	491	90%
Alexander	474	92%
Kralingse Zoom	1873	94%
Slinge	853	98%
Hoogvliet	229	96%
Hoogvliet Zalmplaat	24	46%
Hoogvliet Tussenwater	62	97%
Pernis	33	94%
Noorderhelling	320	90%
Nesselande	61	97%
Schenkel	100	101%
Capelsebrug	384	101%
Melanchtonweg	82	100%
Beverwaard	508	13%

Figure 9 Average occupancy rate P+R facilities (Gemeente Rotterdam, 2020c)

As mentioned above, the P+R facilities are located near the exits of a highway and are connected to the public transport network. Moreover, these locations offers the possibility to make use of shared mobility services. Thereby, travellers are able to make use of public transport, a stored bicycle or a shared mobility service such as a bicycle or scooter for their last mile transport. It is assumed the traveller division over the 3 distinguished modes is equal. Since the majority of the people will have the city centre as their destination, it is assumed the walking distance is too big and walking is not an option. Moreover, it is assumed that the regulation of the amount of shared mobility vehicles is conform the required output and since the provision of the vehicles is provided by a private company, there are always enough shared mobility vehicles available. Currently, half of the allowed shared mobility vehicles are bicycles (Gemeente Rotterdam, 2020a).

In this mode 50% of the car substitutes travels by car to the P+R facility and the remaining 50% of travellers is equally divided over public transport and the bicycle. At the P+R facility, the travellers are equally divided over public transport, a personally owned bicycle and over shared mobility vehicles to travel their last mile.



Figure 10 Potential locations for P+R facilities

5.3.4 Scenario 3: Rotterdam bicycle city

The Netherlands is a bicycle nation and Rotterdam wants to expand that feeling in the city centre. In this scenario the bicycle is centralised and most of the car switchers will be attracted to make use of the bicycle. The vision of being the bicycle city of the Netherlands in 2025 will be extended to 2030 and onwards.

To realise this vision, investments regarding the facilitation of bicycles must be made. These investments are quite diverse. It is important to invest in bicycle infrastructure by facilitating safe bicycle parking spots or bicycle storages. Next to that, the quality of the bicycle network must be maintained and improved. It is likely that because of the increased amount of cyclists, the travel safety might be in jeopardy. Hence, to prevent this from happening, it is important to facilitate a qualitative high bicycle network. The facilitation of a qualitative good transport network and safe bicycle storage facility, eases the travel comfort. Thereby, the bicycle alternative can be an inviting solution for users of the system. Moreover, health effects are usually linked to cycling and this might be an interesting benefit for governmental bodies.

Cyclists can be attracted to the bicycle by great infrastructure benefits but cycling must be an accessible alternative too. It must be inclusive for as many people as possible. Therefore, stimulation programs to attract people to cycle are part of the investments. Moreover, the facilitation of bicycles is part of this stimulation concept. This is done by subsidies and by making shared bicycles more accessible. The accessibility of shared bicycles is limited to certain areas and these areas must be expanded to be more inclusive.

In summary, this scenario invests in the facilitation all around the bicycle. Those investments will be used to realise and improve infrastructure such as roads and park & bike facilities and thereby making cycling a far more attractive mode of transportation. Moreover, it will be used to stimulate bicycle usage and make it affordable to everyone. The bicycle is a natural choice since it is superior to alternatives due to the great facilities, the affordability and the accessibility. The investments in cycling result in 75% of all car substitutes switching to the bicycle. The remaining 25% of travellers makes use of public transport.

6. Cost-Benefit Analysis results

In this chapter the CBA results for the city centre of Rotterdam are calculated in order to answer sub-question 4 and 5. In order to do so, a 0-alternative is created to compare with the created project alternatives. After the identification of the 0-alternative, the specific effects per project alternative compared to the 0-alternative will be discussed. Hereafter, the valuations per effects are given. Based on the incorporated valuation in excel the results are presented. Lastly, the most important effects are analysed in a sensitivity analysis.

6.1 0-alternative and effects taken into account

In order to estimate the societal impact of an intervention, a base case is required. This base case, or 0-alternative, represents a situation of the future without intervening. Or in other words, how would the world look like in business-as-usual, or in 'do minimal', circumstances if the government just continues in the current system. Therefore, by determining the impacts of the intervention compared to 0-alternative(s), the benefits (positive impacts) and costs (negative impacts) can be estimated. The net present value of the calculated difference implies the economic feasibility of a scenario. Obviously, multiple business-as-usual scenarios are plausible since costs and benefits are dependent of factors such as demography and economy for which it is impossible to know their future developments. Therefore, a 0-alternative is created for the expected costs and benefits based on the current future expectations. These future expectations are based on current knowledge regarding the development of effects. Obviously, given data regarding the future is an approximation and thereby uncertain. Despite future data is uncertain, it is assumed a correct or at least good enough depiction to create a sufficient image of the future. This assumption is made given the explorative nature of this study and its intention to shine a light on future developments. In addition, a sensitivity analysis of 10% higher/lower costs and benefits is carried out to account for shifts in the uncertain data.

Within the current future expectations it is assumed that car trips still will be made. Currently, 156.000 car trips are made in the city centre of Rotterdam per day (Gemeente Rotterdam, 2020b). These car trips consist out of 70% commuting trips and 30% out of a leisure purpose. Without intervening, the Municipality calculated a decrease of approximately 900 car trips on a daily base per year in the coming 10 years, the car trips developments are visualised in figure 11. This decrease of almost 0,6% per year is relatively small and the effect on traffic safety and parking benefits will be almost neglectable. However, next to a decrease of car trips, emissions will decrease, due to predicted technological innovations, by approximately 30% in 2030 (Rijksoverheid, 2019a).

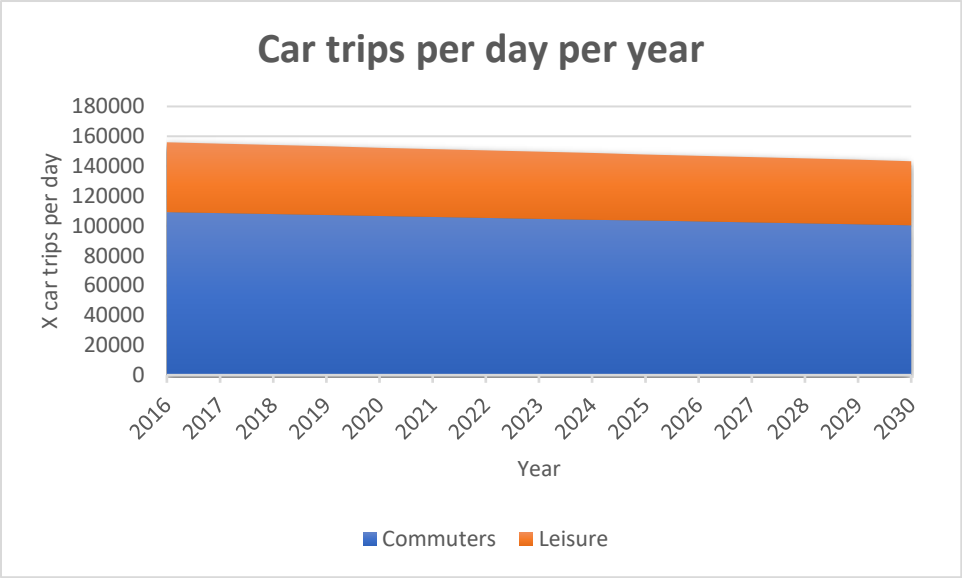

Figure 11 Car trips per day per year in the 0-alternative

If the municipality intervenes and creates a car-free city centre, no car trips are made anymore. There will be an exception for special cases such as emergency vehicles as distinguished by Crawford (2012), but it is assumed this amount of transport movements is so small that the effects are neglected. The decrease of 900 car trips on a daily base per year is mainly accounted for by a switch to bicycle trips. The public transport share will only increase by 3% the coming years. In 2019, the RET, the public transport provider in Rotterdam, made 921.000.000 traveller kilometres (RET, 2019). The amount of traveller kilometres has been quite constant over the past years. It is expected that, under the assumptions no radical changes occur, this amount of traveller kilometres stays constant besides the 3% grow in 10 years.

The city centre is heavily congested and due to the congestion, mainly during rush hours, travellers in Rotterdam have 25% more travel time resulting in 115 hours travel time loss over the year per traveller (TomTom Traffic Index, 2020). Moreover, the congestion and huge amount of cars in the city centre result in negative effects on society. Emissions, noise, stink and traffic accidents affect humans well-being. Next to that, society is missing out on certain positive health effects. Travelling by bicycle has significant health effects. Cyclists are 1,3 days per year less sick than not cyclists, resulting in a yearly productivity profit of € 364 (Van Ommeren, Lelieveld, De Pater, & Goedhart, 2012). In all car-free scenario's bicycle usage will increase by a certain percentage and thus a productivity profit will be made in those scenarios in comparison to the 0-alternative.

The presence of cars generates financial costs and income for the municipality. The municipality provides and maintains almost 12.000 parking spots in the city centre of Rotterdam. At all parking spots an hourly fee has to be paid and these earnings minus the costs for maintaining the parking spots, result in huge net income. In the city of Rotterdam, the net parking income was almost € 35.000.000 in 2018 (Gemeente Rotterdam, 2018). The costs and earnings are made in the entire city of Rotterdam. Since most of the parking facilities and paid parking spots are in the city centre it is assumed most of the benefits are gained in the city centre. Therefore, it is assumed that 75% of the parking benefits are derived from the city centre. Therefore, the municipality of Rotterdam earns every year € 26.000.000 on car parking. Moreover, governmental bodies earn money on excises since cars need fuel to drive. Next to that, the competition of cars eases the public transport network. For bus, tram and metro the government subsidies public transport suppliers with € 0,31 per kilometre (Van Ommeren et al., 2012). It is expected that the more travellers make use of the

public transport services that the occupancy rate and ticket sales increases and thus revenues increase. In Amsterdam exploitation benefits are made due to an efficient and occupied network. It is assumed Rotterdam has an exploitation benefit as well and thereby the government does not have subsidy costs. Travellers spent € 0,11 per each individual public transport kilometre (Bakker & Zwaneveld, 2009). Therefore, the public transport provider, RET, earns € 0,11 per each individual public transport kilometre. Thus, every additional kilometre will result in additional public transport revenues and since it is already prognosed the public transport share will increase by 3%, it can be assumed these revenues will increase.

Different effects are mentioned in the 0-alternative. In order to calculate the net present value in the CBA, all the effects have to be valued. The delta difference between the effects in the 0-alternative and scenario are taken into account in the CBA. The following effects are valued in this research:

- Emissions
- Noise
- Stink
- Traffic safety
- Public transport revenues
- Excise duty
- Spatial benefits
- Parking revenues
- Utility loss leisure car travellers (estimated via parking consumer surplus)
- Utility loss commuter car users (estimated via travel time losses)

Liveability is not mentioned in the effect valuation list while it is seen as a common effect in the CBA. It is chosen to value liveability in a classical way by the valuation of different effects defining liveability. Effects such as emissions, noise, stink, traffic safety and health typically define liveability. The explorative nature of this study requires a more detailed valuation of effects in order to learn lessons. Moreover, some alternative specific costs and benefits are distinguished. This distinguish is elaborated on per project alternative. The following effects are alternative specific valued:

- Health effects
- Crowdedness for public transport
- Crowdedness for cyclists
- Waiting time reduction public transport
- Bicycle network benefits

6.2 Project alternative 1: No additional investments

The first alternative focusses on the regulation itself in the current system to assess the costs and benefits if no investment, to accommodate the car-free regulation, is undertaken. Therefore, travellers changing from the car to either public transport or bicycle, have to make use of the same infrastructure as the current users of the system. Currently, the public transport and bicycle share are equal. Therefore, by banning cars the amount of car travellers are equally divided over the other two modes. Since no investments in alternative infrastructures are made, crowdedness on both transport networks occur.

Crowdedness in public transport

The effect of crowdedness solely applies to metro transportation since the tram and bus network have enough capacity to facilitate additional travellers. The metro capacity is already at its maximum. Therefore, it is assumed that additional travellers result in crowdedness and thereby a disutility for travellers. Research by Batarce et al., (2016) found a significant effect on the marginal utility of travel time. Their research found discomfort multipliers for every minute travelling in high density conditions per passenger/m^2 up till 6 passengers/m^2. The disutility in a public transport vehicle is 2.5 times bigger if 6 passenger/m^2 are standing in a vehicle compared to a vehicle with no standing passengers. Inherently, for every additional traveller the value of travel time increases. In other words, the costs for disutility increase for every additional traveller/m^2. It is assumed that the metro capacity is perfectly fitting for the current demand but every additional traveller will result in crowdedness.

Amount of passengers

On a regular day 308.000 passengers make use of the metro in Rotterdam (van Velzen, 2019). If 50% of the 156.000 car trips are substituted by metro, another 78.000 trips have to facilitated by the current metro network. On average, the occupancy rate per car is 1.5 persons in Rotterdam (De Vries, 2010). Therefore, by substituting those 78.000 car trips, another 117.000 travellers have to facilitated by the current public transport network. The metro facilitates 70% of all the public transport users in the city of Rotterdam (van Velzen, 2019). Thus, 82.000 additional travellers make use of the metro network. The total amount of travellers rise to 390.000 resulting in a 26% increase. This increase results in crowdedness.

Costs for crowdedness

The average travel time in a public transport vehicle in the Randstad is 22 minutes (Hilbers, Coevering, & van Hoorn, 2009). For every minute a traveller travels in high density there is an utility loss and thereby costs for discomfort. It is not known how the additional amount of travellers affect the amount of passengers/m^2. A proxy of 3 passengers/m^2 is chosen to assess the impact of crowdedness in the public transport network. If there is no passenger density (0 passengers/m^2), the value of travel time is estimated at €/hour 3,1. By an increase to 3 passengers/m^2, the value of travel time increases to €/hour 5,53. Thereby, a delta increase of €/hour 2,43 per passenger, affects the costs for a loss in utility. It is assumed there is only crowdedness during rush hours on working days and hence weekend days are excluded. The rush hours in public transport are between 7.00 – 9.00 o'clock and between 16.00 – 18.00 o'clock. On a daily base, travellers experience crowdedness for 4 hours. Therefore, on an annual base, travellers have an utility loss of approximately € 14.750.000.

Crowdedness by bicycle

By banning cars, 50% of the car trips are substituted by bicycle resulting in an increase of 117.000 cyclist trips. Thereby, the amount of cyclist trips on a daily base more than doubles to 231.000 cyclist trips per day. The value of time for bicycles is more difficult to determine and a range of values is given, based on literature research, by Van Ommeren et al., (2012). In the most pessimistic scenario, the value of time by bicycle is equal to the value of time for public transport. Given this fact, the same proxy estimates for public transport by Batarce et al., (2016) are used to determine the utility loss for cyclists.

An average cyclists, cycles 861 kilometres per year or 2,35 kilometre per day (RAI vereniging, 2018). The average cycling speed is 12 kilometres per hour (Molnar, 2002). Hence, it can be calculated that

the average cycling time per traveller per day is 12 minutes. By using equal input data for crowdedness as is used in the calculations for public transport, the annual costs for bicycle crowdedness are estimated around € 4.760.000.

Division over modes & health effects

It is assumed the current amount of car trips are equally substituted over both public transport and bicycle. Hence, 50% more traveller kilometres will be travelled compared to the 0-alternative. The other 50% of the car trips will be substituted by cycling.

Travelling by bicycle has significant health effects. Cyclists are 1,3 days per year less sick than not cyclists, resulting in a yearly productivity profit of € 364 (Van Ommeren et al., 2012). The health effects of pedestrians are assumed out of scope since it is assumed the only walking activity is the trip from a public transport stop to a destination. The current public transport network in Rotterdam covers the entire city centre very well and thus walking distances can be neglected. Moreover, the health effects of walking are neglected since not the entire trip is made by foot. The average occupancy rate of a car in the city centre of Rotterdam is 1,10 persons per car (De Vries, 2010). The substitution of 50% of the car trips by bicycle, results in 86.000 additional cyclist trips per day. The gained profits due to health effects only applies to working cyclists. The Dutch central statistical office indicates 7 out of 10 people are working. By multiplying the target group with the productivity profit, the health benefits results in a gain of € 22.000.000 per year.

6.3 Project alternative 2: Improve public transport

Investment

In this policy the current transport network is improved to facilitate additional travellers. The impact of a car-free city will affect the transport network massively since the amount of travellers can almost double. According to Halmer Kranenburg (Personal communication, April, 7, 2020). the current network will certainly not be able to facilitate this amount of travellers and investments in the metro network must be made. The costs per kilometre metro infrastructure are estimated at € 75.000.000 (Koolen & Stoelinga, 2005). The distance in the city centre of Rotterdam is, as the crow flies, 3 kilometres. Therefore, it is assumed at least 3 kilometre of new metro infrastructure is required to accommodate for the new travellers, the total investments costs are estimated at € 225.000.000. The new metro infrastructure offers the opportunity to increase the frequency of the metro on the most busy nodes. Therefore, exploitation costs to facilitate the increased frequency are made. The exploitation costs are € 640.000 per additional vehicle (Koolen & Stoelinga, 2005). On average every 5 minutes a metro departs in the city centre of Rotterdam. It is assumed the frequency increases to a metro departure every 3 minutes. Therefore, the amount of trips, and thus amount of required vehicles per hour, rises from 12 to 20. The additional required vehicles result in an exploitation costs of € 7.680.000 per year. Moreover, the infrastructure requires maintenance. The maintenance costs are estimated by Koolen & Stoelinga (2005) at € 815.000 per kilometre and thus the total maintenance costs are estimated at a total of € 2.500.000 per year.

The cost estimations are assumed sufficient since an earlier project in Rotterdam, the Hoekse lijn connection, was estimated at € 318.000.000. These costs were estimated for a 1,2 kilometre extension of the metro track, the realisation of a new station and the modernisation of a few other stations (Stroecken, 2017). For the realisation of this project 4 years were allocated. Therefore, it is assumed that for the realisation of new metro infrastructure in the city centre of Rotterdam at least 4 years are required to realise the project.

Division over modes & health effects

It is assumed the majority of the current car trips, 75%, will be substituted by the new high quality public transport accommodation. Therefore, 75% more traveller kilometres will be made in relation to the 0-alternative. The remaining 25% of the car trips will be substituted by cycling.

The 25% car trips substituted by bicycle, result in 43.000 additional cyclist trips per day. By applying the health effects solely to commuters as the target group, a productivity profit gain and thus health benefits gain of € 11.000.000 per year is made.

Crowdedness

The investments in the metro infrastructure result in a frequency increase. It is assumed these investments are sufficient to prevent crowdedness from happening in the public transport network. However, still 25% of the car trip substitutes change to bicycle and thereby affect the crowdedness of the bicycle network. The increased amount of cyclists result in a total of € 3.570.000 costs for society per year.

Waiting time reduction

The increased frequency in the metro network results in a waiting time reduction for all public transport travellers. The average waiting time in the city centre of Rotterdam is between 3 to 7 minutes. It is assumed the average waiting time is 5 minutes and that the frequency increase reduces the waiting time by 2 minutes. Research by Li & Hensher (2011) indicated a value of time for public transport waiting time during rush hours of €/hour 16,14. Both current users and new users benefit of the waiting time reduction. Since the waiting time reduction only applies to rush hours it is assumed that travellers benefit of the waiting time reduction for 4 hours a day. If both the current public transport users and the new travellers benefit from a 2 minute waiting time reduction for 4 hours a day, society benefits from a total waiting time reduction of € 12.000.000 per year. It must be noted that the rule of half applies as determined in the general CBA guidelines pages 49 -52 (Romijn & Renes, 2013).

6.4 Project alternative 3: Invest in P+R facilities & shared mobility

Investment

In the city centre of Rotterdam, 12000 cars can be parked. This amount of parking spots is sufficient for the city since the occupancy rate is 51% (data retrieved by an advisor mobility data of the municipality Rotterdam). By the realisation a car-free city centre these parking spots vanish. The occupancy rate in current P+R (park and ride) facilities is very high, some facilities even have too little capacity. To divide the pressure to other P+R facilities in Rotterdam and accommodate for the vanished parking spots in the city centre, it is assumed in this project alternative that at least 10.000 parking spots are realised in new P+R facility(ies) at the edge of the city centre.

To estimate the costs for a new parking facility the costs are estimated based on comparable cases. Recently, in the city of Breukelen, the municipality of Utrecht appraised € 5.000.000 to realise 200 new parking spots in a P+R facility (RTV Utrecht, 2020). A report by Grontmij (nowadays known as Sweco) for the municipality of Arnhem, appraised the costs for 1100 parking spots in a parking facility at € 24.000.000 (Cobouw, 2017). Proportionally the estimated costs approach each other closely. Since the realisation of a P+R facility in Breukelen was more recent, the € 5.000.000 per 200 parking spots seems more comprehensive. Hence, the costs for the realisation of 10.000 new parking spots are estimated at € 250.000.000. The operation costs are estimated at 1% of the investment costs.

Division over modes & health effects

In this scenario it is assumed the amount of car trips in the city centre is substituted by all alternative modes of transportation. Since a fairly good car alternative, to park just outside the city centre, is offered, it is assumed still 50% of the car trips will be made by car to the P+R facilities. The remaining 50% of the car trips are equally substituted by bicycle and public transport transportation. Out of all the substituted car trips 25% is made by bicycle, or in other words 43.000 travellers substitute to the bicycle. As calculated in scenario 1, the additional cyclists gain € 11.000.000 in productivity profits. On top of this amount there are several cyclists making use of a shared bicycle. Out of the 156.000 car trips, still 78.000 trips are made by car to the P+R. It is assumed the travellers travel their last mile by either public transport, an own bicycle or shared mobility. The division over this modes is assumed to be equal. Therefore, out of this 78.000 trips, 26.000 are made by bicycle and another 26.000 are made by shared services and half of those trips are made by shared bicycles. This relates to 13.000 substituted car trips and 14.000 travellers. Out of this 14.000 travellers, 10.000 of them are work related and can thereby be used to calculate productivity profit. However, since not the entire trip is made by bicycle it is assumed the effect has only a 50% impact, resulting in an additional productivity gain of € 1.800.000. The 26.000 trips that are made by self-owned bicycles have a comparable effect. This amount of bicycle trips relate to 28.600 travellers. Out of all these travellers, 20.000 are work related. By again reducing the impact of the effect, these cyclist gain € 3.600.000 benefit of gained productivity. Therefore, in addition to the € 11.000.000, another € 5.400.000 productivity profit is gained.

Crowdedness

In this alternative the amount of travellers using both public transport and bicycles increases. Solely investments in parking infrastructure is made and thereby crowdedness occurs in both alternatives. Out of all travellers, 25% switches to public transport (making the full journey by public transport) and another 25% switches to public transport for their last mile transportation from a P+R facility towards their destination. It is assumed the last mile travel time, from a P+R facility by public transport towards any destination in the city centre, is 5 minutes. The crowdedness experienced by travellers making use of public transport, results in an utility loss for society of € 14.500.000.

Next to crowdedness in public transport, the bicycle network is affected by an increased amount of cyclists. The amount of cyclists increases by a 25% share of the car trips that have to be substituted. Next to that, another 39.000 car trips are substituted by both shared bicycles and self-owned bicycles. As for public transport, it is assumed the last mile cycling time from a P+R facility to the final destination has an average travel time of 5 minutes. The intensified bicycle network results in a loss for society of € 4.080.000.

Parking revenues

The P+R facilities still facilitate car users to make a significant part of their trip by car and thereby the municipality is still able to generate parking income. As mentioned before, it is assumed still 50% of the current car trips are made by car. This does not imply a 50% gain on parking revenues since the prices in the city centre are higher than outside the city centre. Moreover, the municipality has an obligation to maintain the P+R facilities. In a no parking scenario there would be a loss of € 26.000.000 since these are the earning in the 0-alternative. In this P+R scenario, this loss is smaller since still some cars make trips towards the city centre and park just outside. It is assumed that the losses on parking revenues are 25% smaller compared to an alternative with no parking. This value is determined based on the fact that only 50% of the car trips are made and that prices outside the city centre are lower than inside the city centre.

Implications for utility loss

Since car users still are partly facilitated in their journey, the utility loss is expected to be smaller. Instead of an entire trip via a different modality only the last part of the trip has to be substituted. The additional travel time for a single trip, due to switching mode, is assumed to be a maximum of 10 minutes. This assumption is made, based on the fact that car travelling in the city centre is often slower than other modalities due to congestion. However, switching mode increases the travel time and it is possible that additional distance has to be covered. Based on the determined assumptions the utility loss, of 20 minutes per day per commuter, is estimated at € 7.300.000 per year.

6.5 Project alternative 4: Rotterdam bicycle city

Investment

Rotterdam has a vision to become the bicycle city of the Netherlands. In this scenario it is assumed almost all the car trips are substituted by bicycle trips. To realise this vision, 15 to 20 million euros per year are required to invest (Gemeente Rotterdam, 2019a). These investments are budgeted for the entire city of Rotterdam in a normal situation. Since it is assumed the city is car-free, more investments will be made in the centre specifically. Therefore, in this policy alternative it is assumed the entire budget of € 20.000.000 is required to realise a bicycle city in the city centre of Rotterdam. Yearly, 1,5% of the investment costs are required to maintain the infrastructure (Gemeente Rotterdam, 2019a).

Division over modes & health effects

As a result of the bicycle stimulation it is expected the majority of the car travellers substitute the car for the bicycle. It is assumed 75% of the current car travellers are replaced by making use of the bicycle and the remaining 25% of the travellers will substitute to public transport. It is assumed the public transport network is able to accommodate this increase of travellers since the tram and bus have enough capacity and the metro network is able to increase their performance one more time. Thus, no additional investments in public transport are required.

If 156.000 car trips are substituted by mainly bicycles an increase of approximately 130.000 travellers are going to use the bicycle on a daily base. This amount of travellers is approached by multiplying the amount of car trips with the average occupancy rate of 1,10 persons per car in the city centre of Rotterdam as derived by De Vries (2010). Since not all travellers are working, it is assumed 70% of the 130.000 cyclists (90.000 travellers) are the target group. These 90.000 travellers will have a total productivity profit, due to boosted health effects, of € 33.000.000.

Crowdedness

The investments in amongst other things infrastructure prevents crowdedness in the bicycle network from happening. Thereby, in this alternative, there is no utility loss on crowdedness due to an increased amount of cyclists. The public transport network on the other hand, has to facilitate more travellers in the current infrastructure since 25% of the car trips are substituted to this alternative mode of transportation. The increase of travellers results in € 13.800.000 crowdedness costs in public transport for society per year.

Network benefits

Congestion and travel time affect the reliability of the network. Whether capacity decreases or capacity is exceeded, the network is more unreliable and thereby increases the possibility of a delay.

Out of the total travel time benefits, 25% is the standard key figure allocated to the reliability of the bicycle network (Van Ommeren et al., 2012). Expressed in costs, this 25% refers to 1 – 8 euro cents per cycled kilometre. Assuming that the bicycle network, in this rough estimated project alternative, is not optimal yet, 4 cents per cycled kilometre is used to calculate the travel time benefits allocated to the reliability of the network. In this project alternative, the network is improved and thereby reliability benefits are gained.

Out of the 156.000 car trips, 75%, or 117.000 car trips, are substituted to the bicycle. These trips are 70% commuter related and 30% has a different purpose. The average commuting car has 1,1 passengers and by multiplying this factor with the amount of commuter trips, it can be estimated that the amount of cyclists increases by 90.000. All car trips with an other purpose have 1,5 passengers per car on average. Given this factor, it can be calculated the amount of cyclists with a different purpose is equal to 52.600. The sum of the cyclist, including the 114.000 cyclists in the 0-alternative, gives a total of 256.600 cyclists profiting of an improved, more reliable, network. It is assumed the average cycling distance per cyclist per day in the city centre of Rotterdam is 3 kilometres. Given the amount of cyclists, distance and benefits per cyclist per cycled kilometre, it can be calculated that society benefits for € 8.100.000 due to a more reliable network. In these calculations, the rule of half is applied for all new cyclists in order to prevent an overestimation of the benefits.

6.6 Valuation of effects

First, all general effects are valued. These effects, play a role in each scenario. In this elaboration the given valuation might be affected by the scenarios infrastructure implementation. A wide range of effects is elaborated on, some effects are left out of this research to prevent for a double count as formalised in the CBA guidelines. These effects are discussed later on in the discussion chapter. The exact calculation per effect is provided in Appendix D.

6.6.1 Emissions

By banning cars, society benefits of prevented emissions by all those cars. According to the ANWB, car emissions consist of CO_2, NO_X and both PM_{10} and $PM_{2,5}$ (ANWB, n.d.-a). The costs sum of those emissions can be used to define the total emissions costs. The Dutch government uses a study by CE Delft to determine the costs for emissions in the Netherlands. Next to that, the government has specified in a study the amount of emissions in gram per kilometre for all motorised road users. This study distinguishes the traffic category, vehicle type, road type, highway (yes/no) and traffic flow. Table 3, specifies the costs and emissions per emission factor to provide an overview for the emission calculations.

Table 3 Emission factors car

Emission factor	**Costs (from (CE Delft, 2017))**	**Emission (from (Rijksoverheid, 2019a))**
CO_2	0,057 €/kg	59,375 g/km
NO_x	34,70 €/kg	0,137 g/km
PM_{10}	44,60 €/kg	0,029 g/km
$PM_{2,5}$	79,50 €/kg	0,008 g/km

The values used in the emissions column are extracted from the table tab non-highway. In this tab, the row light traffic, including cars, vans and motorcycles is used. And within this row, the values determined for normal city traffic are used. The values are given from 2014 up till 2030. Car

emissions reduce on a yearly base due to technical innovations, therefore the most positive scenario is chosen to calculate the costs by using the expected emissions in 2030.

In the calculations, it is assumed, a single trip in the city centre of Rotterdam is 3 kilometre. With the amount of car trips per day, the average trip length, the amount of emissions per kilometre and the price per kilogram, the costs for car emissions can be calculated. The total emission costs by car in the city centre of Rotterdam are approximately € 10.000.000 per year.

6.6.2 Noise

Car traffic produces noise and too much noise harms people. In the city centre of Rotterdam there are so many cars that a lot of noise is produced during the day, it is seen as the biggest noise source in the city (Gemeente Rotterdam, 2019b). In 2017, there was a lot of noise in the city centre with a minimum of 55 decibel at the most quiet areas. Since 2019, Rotterdam has set a threshold to reduce road traffic to a maximum of 53 dB in the city (Gemeente Rotterdam, 2019b). This threshold must be met in the entire city centre. Currently there is a lot of noise in the city centre of Rotterdam. As can be seen in figure 12, the noise limit of 53 dB is exceeded through the entire city centre.



Figure 12 Noise in dB per street in the city centre of Rotterdam (Gemeente Rotterdam, 2019b)

It is assumed the average noise throughout the city is 65 dB. By eliminating cars out of the city and thereby reducing the noise to the threshold of 53 dB, an average total of 12 dB is reduced. Society benefits of this reduction and to calculate the benefits of this reduction the contingent valuation (CV) is used. The CV makes use of the willingness to pay (WTP) for a decibel reduction per person. The WTP for a 1 dB reduction per person per year is set on € 16 (CE Delft, 2017). Currently, 35.000 civilians are living in the city centre of Rotterdam (Hoppesteyn et al., 2018). Obviously, during the day, more people are in the city centre than just the civilians. However, these additional people will not be included in the calculations since these people are not exposed to the city centre noise

continuously. Civilians in the city centre of Rotterdam benefit from a noise reduction for € 6.700.000 per year.

6.6.3 Traffic safety

Most serious traffic accidents happen with cars. In the city centre of Rotterdam there are 4 black spots (Gemeente Rotterdam, 2020c). Such a black spot has at least 6 serious accidents in the past 3 years. Obviously more serious accidents happen in the city centre but those are not registered in a black spot. It is assumed 20 serious accidents happen per year in the city centre of Rotterdam. The costs for serious injuries due to an accident are estimated by Decisio at € 332.905 per person (Van Ommeren et al., 2012). Moreover, yearly 12 persons die due to car accidents in the city of Rotterdam. In total 20 black spots are defined in the city of Rotterdam, whereof 4 of those black spots are located in the city centre. Out of all the serious accidents in the entire city 20% of them occur in the city centre. This implies that the city centre is very dangerous in terms of traffic safety. It is thereby assumed that each year 20% of all traffic deaths occur in the centre. Decisio estimates the costs for a traffic death at € 3.082.361 per case (Van Ommeren et al., 2012). Yearly, car accidents result in costs around € 14.000.000.

6.6.4 Stink

The city centre of Rotterdam is very car crowded and traffic is often congested resulting in a lot exhaust gases. Exhaust gases by cars usually have a bad smell. These exhaust gases can damage residents living pleasure. The loss of living pleasure due to stink is valued at a price of € 185,42 per household (Witteveen+Bos, 2011). In the city of Rotterdam there are 20970 registered households (Allecijfers, 2020). These households are yearly damaged for € 4.000.000 due to exhaust gases.

6.6.5 Public transport revenues

Currently, 921.000.000 traveller kilometres are made by public transport travellers in Rotterdam. The amount of kilometres is for the entire city of Rotterdam. The public transport services in the city centre are more busy compared to the outer city. However, the majority of travellers travel from outside the city centre towards the city centre. Therefore, it is assumed 50% of the transport kilometres are made within the city centre of Rotterdam. Based on the amount of traveller kilometres in the city centre and the public transport revenues of € 0,11 per travellers kilometre, it is estimated the RET earns € 50.600.000 per year.

6.6.6 Excise duty

Cars need fuel and the government levy excise duty on fuel. The government earns money on excises. For every kilometre driven by a car they earn € 0,03 (Van Ommeren et al., 2012). If 156.000 car trips a day are made in the city centre covering a 3 kilometres distance, the government earns € 5.000.000 per year. Per project alternative, all car trips are either substituted by an alternative or cars are parked in the P+R facilities (project alternative 2). Therefore, it is assumed cars cover no additional distance compared to the 0-alternative. Because all kilometres driven in the city centre are substituted and no additional distance is covered, the governments misses out on € 5.000.000 per year.

6.6.7 Spatial change

In the case of a car-free regulation it is assumed that the current road infrastructure will be

restructured for amongst other things new recreation possibilities. In the 0-alternative this is obviously not the case, so there will be missed out on certain profits regarding improved recreation due to improved quality or an increased amount of nature in the city. Yearly, Rotterdam has 1.3 million visitors (Beek & van Heel, 2019). The willingness to pay for additional recreation possibilities is valued at € 1,14 (Buck Consultants International, 2016). If the municipality does not intervene and thus increased recreation cannot be realised, they are missing out on € 1.500.000 additional recreation benefits.

In addition to roads, parking spots are part of car infrastructure. In urban areas, parking spots have a substantial share in the car infrastructure costs. The total car infrastructure costs in urban areas are estimated around € 94,90 per 1000 vehicle kilometres and approximately 60% of these costs are due to the impact of parking spots (Schroten, Van Essen, Aarnink, Verhoef, & Knockaert, 2014). Hence, the parking spot infrastructure costs per 1000 vehicle kilometres are estimated around € 57. On a daily base 156.000 car trips are made thus on a yearly base almost 57.000.000 car trips are made. Since it is assumed the distance travelled by car in the city centre is 3 kilometres, the total vehicle kilometres on a yearly base can be calculated by multiplying this distance of 3 kilometres with the total amount of 57.000.000 car trips on a yearly base. Based on the given numbers the total parking spot costs per year are estimated around € 10.000.000. These costs in infrastructure can be spared in a car-free environment. Therefore, in a car-free scenario, society benefits due to spatial changes for € 11.250.000 per year.

6.6.8 Parking

The government plays a major role regarding the transport movements in the city. The municipality facilitates and regulates the parking spots in the city centre of Rotterdam. By facilitating there is also a maintaining obligation for the municipality. As mentioned before the parking benefits were estimated around € 35.000.000 in 2018. Based on the parking share of the city centre as specified in the 0-alternative, the total societal utility loss is estimated at € 26.000.000. This loss is seen as an utility loss since the municipality derives and roams utility from travellers parking their car in the city centre. Those travellers are not able to park their car in the city centre anymore and experience a utility loss and thereby the municipality is not able to roam this utility.

6.6.9 Loss consumer surplus leisure car users

Many travellers visit the city for leisure purposes such as recreation, sightseeing or tourism. These travellers derive utility and value the importance of parking in the city because they make their trip by car, despite the high parking fee in the city centre. Figure 13 represent the parking fees per area in Rotterdam. The red area, the city centre, has an hourly fee of € 4,14 with a maximum of € 21 per day.

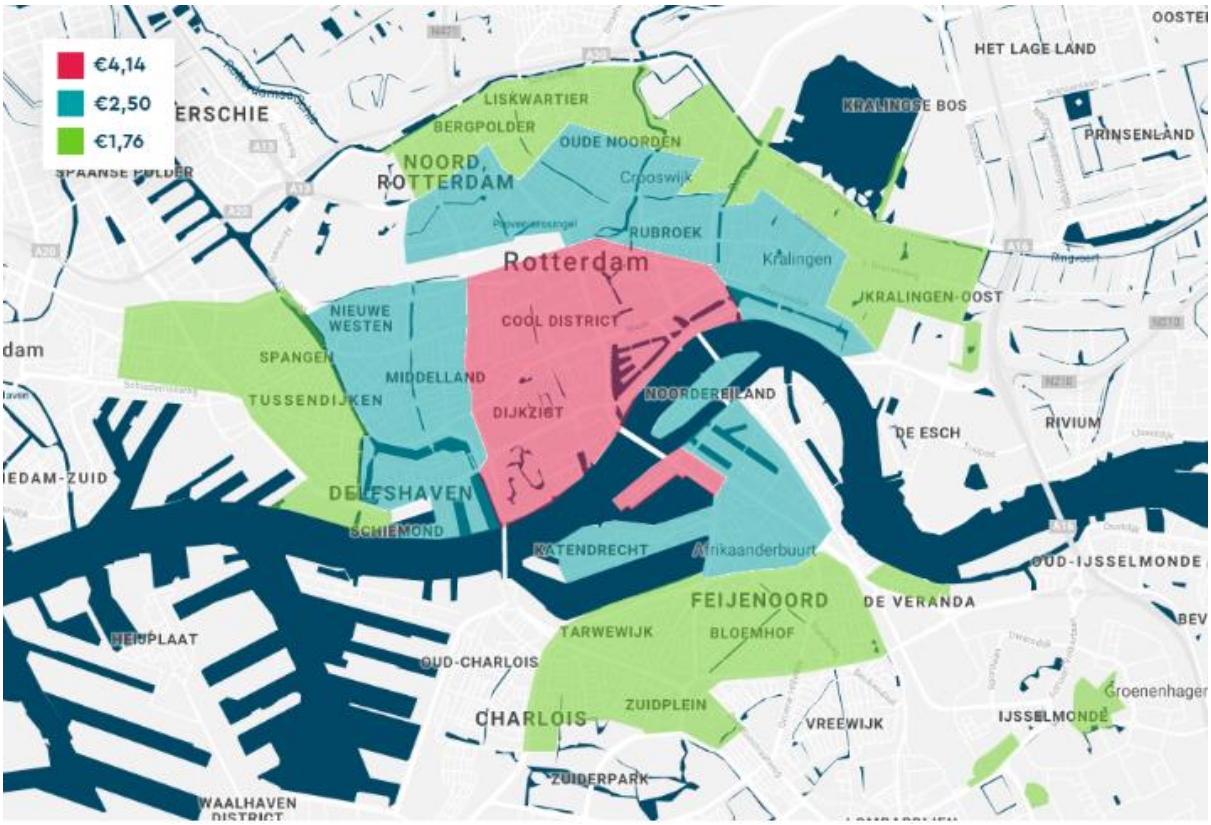

Figure 13 Parking fees Rotterdam

In the current circumstances 12000 cars can be parked in the city centre with an average occupancy rate of 51% (data retrieved by an advisor mobility data of the municipality Rotterdam). In a car-free city, travellers will not have the possibility to park the car anymore and thereby will experience a negative consumer surplus. Obviously, not all cars are parked the entire day, but all day long the total amount of parking spots will be occupied by 51% and thus it is assumed 6120 cars (travellers) experience a negative consumer surplus per day.

Lehner & Peer (2019) researched the impact of parking fees on demand. In the case of a car-free city the demand must be zero, or in other words the price must be so high that no traveller wants to park its car anymore. The loss of surplus, because of the price change, result in a loss for society. Lehner & Peer (2019) elaborated on the elasticity of parking dwell time (EPD), this EPD moderates the effect of an increased parking price on parking demand. In their research Lehner & Peer (2019) found a proxy value of -0,3 for EPD, meaning that a 1% price increase results in -0,3% demand decrease. Hence, to realise a 100% reduction a 333% price increase is required. Accordingly, the daily price in the city centre must rise to € 70 per day.

Currently, as visualised in figure 14, a balanced situation between supply and demand is achieved by 6120 used parking spots and a price of € 21 per day. As mentioned before, in a car-free situation there are no parking spots available and thus the demand must be zero. This is achieved by a daily price of € 70. To calculate the loss of consumer surplus, the price difference between the current situation and the new situation must be used. There is no surplus left if the price increases by € 49. By multiplying this value with the amount of travellers losing out on parking provides the daily consumer surplus loss. In these calculations the rule of half applies as determined in the general CBA guidelines pages 49 -52 (Romijn & Renes, 2013). On a yearly base, travellers experience a negative parking consumer surplus of € 55.000.000.

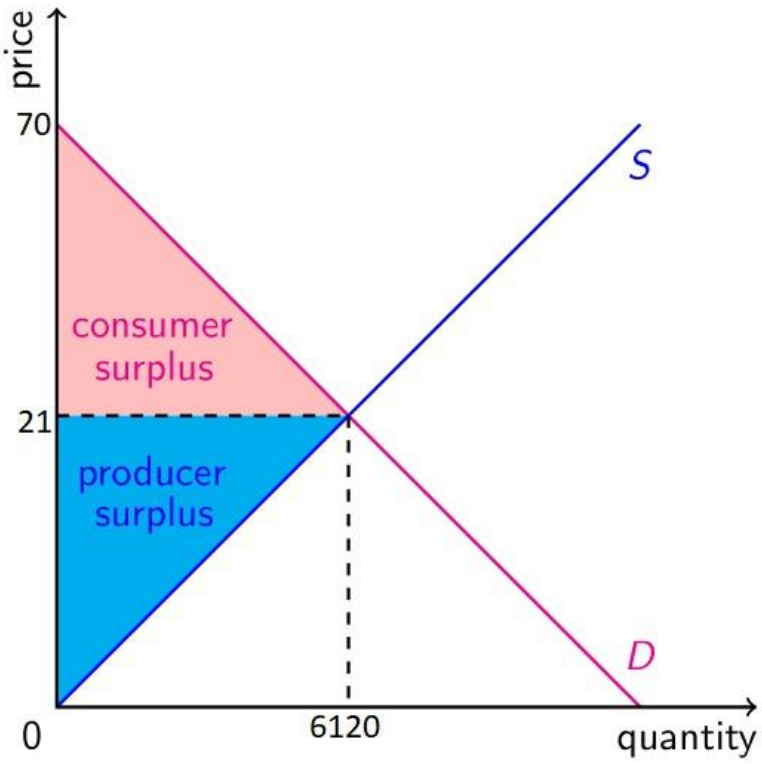

Figure 14 Parking surplus

6.6.10 Utility loss commuter car users

The utility loss for commuters, who travel by car to the city centre in the 0-alternative, is different form leisure travellers. Commuter travellers have to make their trip regardless the mode. To determine their utility loss, their additional travel time is estimated. To determine the group size and calculate the utility loss, some incremental steps are taken to approach the group size. Firstly, as mentioned earlier, it is assumed that only commuters will have a utility loss. Out of the 156.000 daily car trips, 7 out of 10 trips are made by commuters as determined by the Dutch central statistical office, decreasing the group size to 110.000 trips. Secondly, it is assumed that commuters living inside the township have sufficient alternatives and thereby no utility loss since Rotterdam is good accessible by public transport and bicycle. According to the Dutch central statistical office 4 out 10 commuters live inside the town (Verkeerskunde, 2017). Hereby, the group is limited to 65.000 car trips. Out of all remaining car trips, 36% of the car trips are made by commuters dependent of the car due to a bad connection via an alternative modality (Hollenberg, 2013). Hereby the group, experiencing a utility loss, is limited to 23.500 car trips.

To calculate the utility loss, the additional travel time by switching to another mode of transportation is determined. It is unknown what the exact origin and destination is of all travellers. Therefore, the utility loss is approached by reviewing the additional travel time out of regions known as poorly accessible. The regions of Voorne Putten and the Haaglanden, consisting out of Hoek van Holland, Westland and Midden Delftland, distinguish themselves by the huge amount of commuters by car towards, amongst others, the city of Rotterdam (Verkeersonderneming, 2017). These regions are poorly accessible by public transport and the cycling distance is often regarded too big. By consulting google maps, the distance, travel time by car, public transport and bicycle are collected in table 4.

Table 4 Travel time per alternative

Origin	**Distance**	**Travel time by car**	**Travel time public transport**	**Travel time bicycle**	**Additional travel time in best alternative**
Voorne Putten	30 km	40 minutes	90 minutes	100 minutes	50 minutes
Hoek van Holland	31,5 km	28 minutes	39 minutes	98 minutes	11 minutes
Westland	27 km	24 minutes	60 minutes	97 minutes	36 minutes
Midden Delftland	21 km	22 minutes	60 minutes	69 minutes	38 minutes

From table 4 it can be concluded that the additional travel time is substantial. Travelling by public transport is the best alternative from each origin towards the city centre of Rotterdam. The average additional travel time for a one-way trip is 34 minutes. The value of time by car is valued at 9,25 €/hour (Van Ommeren et al., 2012). Based on the given information, a single commuter has on a daily base 68 minutes additional travel by the best alternative transportation mode, or in other words, travelling by car saves € 10,50 per commuter per day. As determined, 23.500 car trips per day are made by commuters experiencing a utility loss in a car-free situation. The cost savings in the current environment will result in a utility loss per traveller in a car-free situation. By assuming that a single commuter makes a two-way trip, the determined amount of car trips (23.500) is divided by two to calculate the amount of unique commuters. Research by De Vries (2010), determined an average occupancy rate of 1,10 persons per car in the city centre of Rotterdam. Hence, an estimated amount of 13.000 commuters per day experience a utility loss due to the ban of a car in the city centre. Since the choices for individuals are affected and limited, volumes of mode use will chance and thus, the rule of half has to be incorporated in the calculations as determined in the general CBA guidelines pages 49 -52 (Romijn & Renes, 2013).

In the current situation, travellers out of poorly accessible regions save an estimated € 25.000.000 per year by car travelling. In a car-free situation, these commuters have to switch to an alternative mode of transportation and will thereby experience a utility loss equal to the estimated savings.

6.7 Results

The effect valuations, based on the given variables, are incorporated in excel and specified per project alternative in order to answer sub-question 4. The excel calculations per alternative are given in Appendix E. For each project alternative, the net present value is calculated and the benefit-cost ratio is determined. If the benefits outweigh the costs, the benefits-cost ratio is > 1, vice versa the benefit-cost ratio is < 1. Table 5 summarises the total costs and benefits per effect after a period of 20 years, including the net present value and the benefit-cost ratio.

Table 5 CBA results

Effects * 1.000.000	Project alternative 1	Project alternative 2	Project alternative 3	Project alternative 4
Investment	-	€ -225	€ -250	€ -252
Operating costs	-	€ -22	€ -29	€ -3
Consumer surplus loss (leisure)	€ -638	€ -490	€ -638	€ -638
Utility loss (commuters)	€ -290	€ -223	€ -85	€ -290
Parking revenues loss	€ -302	€ -232	€ -226	€ -302
Public transport revenues	€ 294	€ 338	€ 176	€ 147
Health effects	€ 255	€ 98	€ 190	€ 383
Crowdedness public transport	€ -171	-	€ -168	€ -160
Prevented car accidents	€ 163	€ 125	€ 163	€ 163
Reduction car emissions	€ 116	€ 89	€ 116	€ 116
Spatial benefits	€ 131	€ 100	€ 131	€ 131
Network benefits (bicycle)	-	-	-	€ 94
Waiting time reduction	-	€ 107	-	-
Reduction of traffic noise	€ 78	€ 60	€ 78	€ 78
Exploitation costs	-	€ -68	-	-
Excise income loss	€ -58	€ -45	€ -58	€ -58
Crowdedness cyclists	€ -55	€ -32	€ -47	-
Stink reduction	€ 46	€ 36	€ 46	€ 46
Net present value	€ -433	€ -384	€ -602	€ -547
Benefit-cost ratio	**0,71**	**0,71**	**0,60**	**0,68**

Based on the results given in table 5, it can be concluded that the exclusion of cars in the city centre of Rotterdam has serious costs. The CBA has a negative net present value in all given scenarios. In the worst scenario, every earned euro costs almost double the benefit. Given the used valuations and incorporated effects, it is not advisable, from an economic perspective, to implement a car-free city centre in Rotterdam. However, the benefit-cost ratio is not even that negative. This can indicate that a relatively small increase in benefits, or alteration in the division of costs and benefits, could result in a more economically advisable scenario.

6.7.1 Impact of effects

The costs and benefits are ranked, in table 5, by their value and thereby their impact. By taking a closer look to the specific costs and benefits, it can be noticed some costs have serious impact on the net present value. It turns out that travellers, value car utility very high since major costs are car related. On the one hand, governmental bodies miss out on parking earnings. On the other hand, car users, who prioritise car travelling over other modes due to a lack of sufficient alternatives, experience a big utility loss because they are not able to travel their journey by car anymore. Moreover, car users, preferring the car as a transportation mode to the city centre over any other transportation mode, experience a major consumer surplus loss. This ‘car bullying’ policy affects travel behaviour and thereby has a major effect on individuals travel time, mode choice and inherent utility loss. It can be noted that network systems of alternative modes of transportation are affected by an increased amount of travellers. Public transport users and cyclists experience an utility loss due

to an increased amount of travellers in their respective networks. Crowdedness can be prevented by investing in infrastructure.

Despite the utility loss, and inherent costs to this loss, outweigh the benefits, still some remarkable benefits are made. Society benefits from prevented negative effects related to cars, such as emissions, noise and car accidents. A consequence of banning cars in the city centre is that the car infrastructure can be replaced for another purpose. The vacant space can be used for recreation purposes and the municipality saves infrastructure maintaining costs, resulting in spatial benefits. Out of all benefits, the most interesting benefits are the health effects and the increased public transport revenues. Significant benefits occur by the substitution from cars to bicycle. The more people switch to bicycle, the more benefits are generated. These health benefits have such an impact that it seems the switch from car to bicycle will be crucial in the transition towards a car-free city centre. Next to that, if the occupancy rate of the metro increases and more traveller kilometres are travelled, the public transport supplier makes significant benefits. The only disadvantage of this benefits is the impact of crowdedness which neglects the benefits earned. Therefore, investments to prevent crowdedness from happening are required.

The difference in net present value and benefit-cost ratio between the scenarios is mainly determined by either the loss of consumer surplus, the utility loss, public transport revenues or the health effects. It can be concluded that an increased amount of public transport users generate significant benefits for society. Next to that it can be concluded that (partly) facilitating the car, reduces the utility loss and thereby costs can be reduced massively. However, to realise this cost reduction, investments must be made neglecting the impact of the reduction of utility loss. It is noticeable that the more people make use of the bicycle, the higher the health effects, the bigger the benefits and thus the better the benefit-cost ratio. Based on the given assessment of the most important costs and benefits, sub-question 5 can be answered. Project alternative 1, no intervention, and 2, focussing on mainly public transport, are in economic terms the best scenarios since a lot of public transport earnings are gained. Project alternative 3 facilitates cars partly, resulting in a smaller utility loss and the effort to increase shared mobility, contributes to more bicycle movements and thereby bigger health effects. However, big benefits are limited and crowdedness still occurs resulting in the worst benefit-cost ratio of the four depicted project alternatives. Project alternative 4 focusses on Rotterdam as a bicycle city and significant greater health benefits are made compared to the other scenarios. Nevertheless, the impact of public transport crowdedness has a major impact on the cost-benefit ratio.

6.7.2 Stakeholder consequences

By taking a closer look at individual effects, the implications for stakeholders can be assessed. It is of importance to understand the division of costs and benefits amongst stakeholders in order to elaborate in the political debate on achieving the desired and intended result. The municipality of Rotterdam has multiple goals related to improved liveability. Therefore, it can be assumed governmental bodies, especially the municipality of Rotterdam, are aiming to allocate main benefits to residents and users of the system by a car-free intervention.

By taking a look at the costs and benefits, as depicted in table 5, it can be concluded a car-free intervention results in multiple liveability benefits which the municipality is aiming to achieve. These benefits are improvements for residents and users of the system and might be very desirable for society. The most remarkable benefit is the increase in public transport revenues. This benefit has an important share in achieving a more societal beneficial CBA. The benefits earned by this effect, are gained by public transport providers. However, the results indicate that if car substitutes mainly

switch to the bicycle, the public transport revenue increase is limited and health effects are more beneficial. Therefore, in order to live up to goals set by the municipality of Rotterdam, it might be advisable to create an as big as possible share for cyclists in the division of travellers over the different modes of transportation. The downside of this division is that an increase in public transport users generate greater benefits.

A car-free intervention also has huge costs for users since car users lose utility. The utility loss for both commuters and leisure travellers outweigh every other benefit. Decision makers seriously need to consider the impact of a car-free intervention since the main costs for society affect the users. Hence, the great benefits the municipality is aiming to retrieve for users have a counterpart to consider.

If no investment in specific infrastructure is made, crowdedness occurs which is disliked by users of the system. The results indicate crowdedness for public transport users have bigger costs than cyclists crowdedness. Moreover, cyclists are more likely to accept a car-free intervention indicating crowdedness might be of less importance for cyclists. Hence, users of the system might prefer more cyclists over additional public transport users.

6.8 Sensible results

The current results are based on a predefined business-as-usual, or do-minimal, alternative. The project alternatives can score differently on other business-as-usual alternatives and thus it is valuable to get insight in the development of the NPV and benefit-cost ratio when changes occur. Moreover, it is possible that effects are wrongly estimated. By carrying out a sensitivity analysis it is possible to get insight in the impact of a change on the calculations and to determine whether results are sensible. Firstly, the possible underestimation of liveability is elaborated on. Thereafter, a sensitivity analysis as defined by Vrijland (2003) is carried out.

6.8.1 Liveability underestimated?

In this research, liveability is defined within several effects such as emission, noise, stink, safety and the quality of public areas. Benefits earned on those effects improve the overall liveability of the city centre of Rotterdam. The valuations of these effects are estimated by making use of key figures commonly used in CBA calculations. A project evaluation by Centraal Planbureau (2018) concluded that the valuation of liveability benefits, in urban infrastructure projects, with key figures might result in underestimation. In this evaluation the used CBA, for a tunnel in the city of Maastricht, estimated the costs for urban quality at € 12.000.000. Researchers found, by the valuation of increased house prices due to the new tunnel, an actual liveability benefit of € 220.000.000. Although this specific substantial increase in benefits and the results cannot be generalised, the researchers emphasise on the importance of accounting for the underestimation of liveability effects by key figures.

It is important to be aware if a sensible result is obtained. Hence, to get insight in the development of the costs and benefits it is assumed that it might be possible that liveability benefits are underestimated in this research. In order to assess the impact of bigger liveability benefits the effects are assumed twice as big in project alternative 1. This project alternative is chosen since no investments are made yet. Hereby, the impact of solely a car-free intervention in combination with bigger benefits can be assessed.

This research make use of a classic sum of effects to interpret liveability. Therefore, the following effects are used to define liveability: reduction car emissions, reduction of traffic noise, prevented

car accidents, stink reduction and spatial benefits. The liveability effect estimations in project alternative 1 are multiplied by two. In case the benefits are twice as big as expected, the benefit-cost ratio represents a value of 1,07 as can be seen in Appendix E. This indicates that the investment in a car-free city is beneficial for society given the circumstances and incorporated effects. If the liveability benefit multiplier is even bigger, many more benefits are generated.

6.8.2 Sensitivity analysis

It is likely that economic changes, such as the impact of covid-19, affect the development of costs and benefits. Therefore, to account for sudden changes, a sensitivity analysis is carried out to get insight in the impact of +10/-10% higher costs or benefits. The piece-by-piece approach, as defined by Vrijland (2003), is used to perform the analysis. Vrijland (2003) argues that altering the effect value is not suitable to calculate the final outcome. Vrijland asserts that variables, defining the effect, must be varied by keeping the remaining variables constant. In this way, margins between variables within an effect can be varied. The variables are altered by +/- 10% because it is the most common alteration.

From the results, the effects affecting the net present value the most could be distinguished. Because these costs and benefits have a major impact on the outcome, variables, defining the concerning effects, are altered to approach the sensitivity. Table 6 visualises the variables that are being altered per effect, its initial value and the initial effect value per project alternative. Vrijland (2003) approach is used by changing solely one variable per effect and keeping the remaining variables, defining the effect, constant.

Table 6 Base case

			Scenario 1	Scenario 2	Scenario 3	Scenario 4
Variable	Initial value	Effect	Initial value	Initial value	Initial value	Initial value
Parking benefits city centre	75%	Parking revenues	€ 26.000.000	€ 26.000.000	€ 26.000.000	€ 26.000.000
Parking infrastucture costs	€ 57,00	Spatial benefits	€ 11.250.000	€ 11.250.000	€ 11.250.000	€ 11.250.000
Yearly producitivity profit	€ 364,00	Health effects	€ 22.000.000	€ 11.000.000	€ 16.400.000	€ 33.000.000
Value of time by car	€ 9,25	Utility loss	€ 25.000.000	€ 25.000.000	€ 7.300.000	€ 25.000.000
Income per traveller kilometre	€ 0,11	Public transport revenues	€ 25.300.000	€ 37.950.000	€ 15.180.000	€ 12.650.000
Daily parking price	€ 21,00	Consumer surplus	€ 55.000.000	€ 55.000.000	€ 55.000.000	€ 55.000.000
		Benefit-cost Ratio	**0,71**	**0,71**	**0,60**	**0,68**

The +/- 10% alteration per variable is adjusted in table 7 and 8. The impact of the alteration per effect and thus per cost or benefit changes the Benefit-cost ratio. Based on the given alterations, a value decrease, increases the benefit-cost-ratio. Or in other words, if variable values increase the costs are increasing more rapidly than the benefits. Overall, it can be concluded the benefit-cost ratio only has a minor change due to the impact of a +/- 10% alteration. Therefore, if a business-as-usual situation slightly differs from the base case, almost the same conclusions can be drawn.

Table 7 +10% alteration

10%			Scenario 1	Scenario 2	Scenario 3	Scenario 4
Variable	New value	Effect	New value	New value	New value	New value
Parking benefits city centre	85%	Parking revenues	€ 29.750.000	€ 29.750.000	€ 29.750.000	€ 29.750.000
Parking infrastucture costs	€ 62,70	Spatial benefits	€ 12.200.000	€ 12.200.000	€ 12.200.000	€ 12.200.000
Yearly producitivity profit	€ 400,40	Health effects	€ 24.000.000	€ 12.000.000	€ 18.000.000	€ 36.000.000
Value of time by car	€ 10,18	Utility loss	€ 27.400.000	€ 27.400.000	€ 8.000.000	€ 27.400.000
Income per traveller kilometre	€ 0,12	Public transport revenues	€ 27.650.000	€ 41.475.000	€ 16.590.000	€ 13.825.000
Daily parking price	€ 23,10	Consumer surplus	€ 60.000.000	€ 60.000.000	€ 60.000.000	€ 60.000.000
		Benefit-cost Ratio	**0,70**	**0,68**	**0,59**	**0,66**

Table 8 -10% alteration

-10%			Scenario 1	Scenario 2	Scenario 3	Scenario 4
Variable	New value	Effect	New value	New value	New value	New value
Parking benefits city centre	65%	Parking revenues	€ 22.750.000	€ 22.750.000	€ 22.750.000	€ 22.750.000
Parking infrastucture costs	€ 51,30	Spatial benefits	€ 10.300.000	€ 10.300.000	€ 10.300.000	€ 10.300.000
Yearly producitivity profit	€ 327,60	Health effects	€ 20.000.000	€ 10.000.000	€ 14.800.000	€ 29.500.000
Value of time by car	€ 8,33	Utility loss	€ 22.400.000	€ 22.400.000	€ 6.600.000	€ 22.400.000
Income per traveller kilometre	€ 0,10	Public transport revenues	€ 23.000.000	€ 34.500.000	€ 13.800.000	€ 11.500.000
Daily parking price	€ 18,90	Consumer surplus	€ 49.000.000	€ 49.000.000	€ 49.000.000	€ 49.000.000
		Benefit-cost Ratio	**0,74**	**0,73**	**0,61**	**0,71**

To visualise the impact of a +/- 10% alteration in comparison to the base case, a tornado chart per Project alternative is created (figure 15,16,17,18). In all alternatives it can be seen that the parking revenues and the consumer surplus effects have a major impact on the delta net present value. Both effects are costs in the CBA and thereby it can be noted that a decreased variable will results in lower costs and thereby a better benefit-cost ratio.

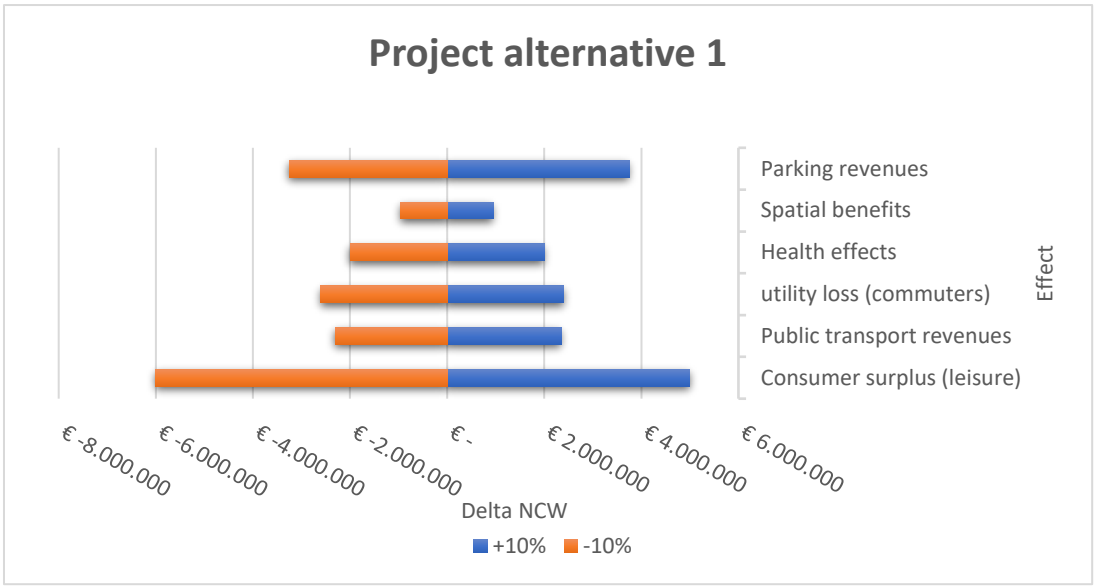

Figure 15 Impact selected effects on net present value project alternative 1

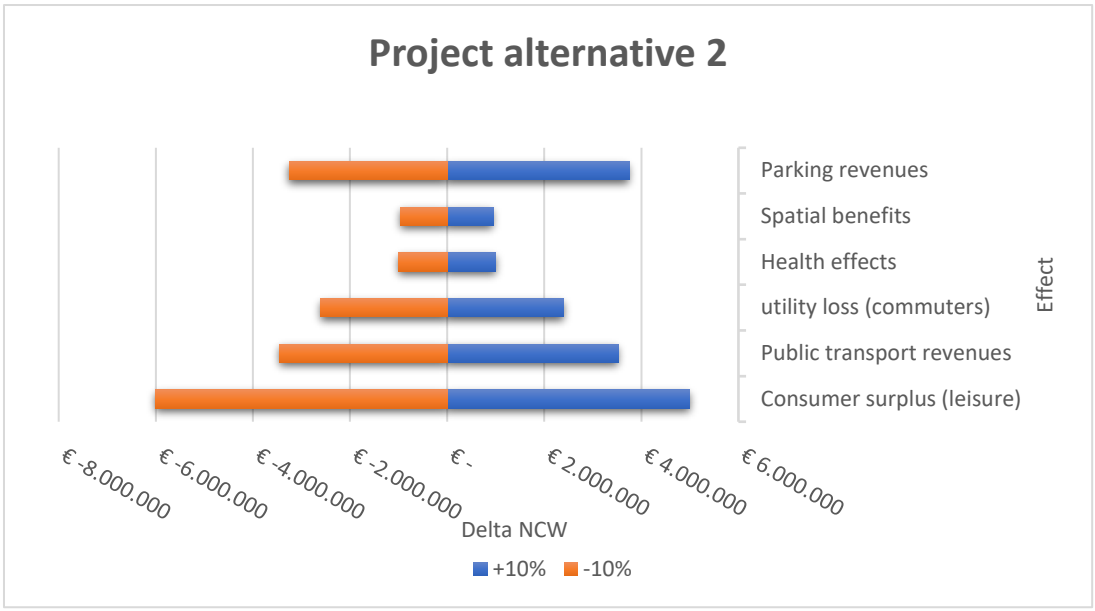

Figure 16 Impact selected effects on net present value project alternative 2

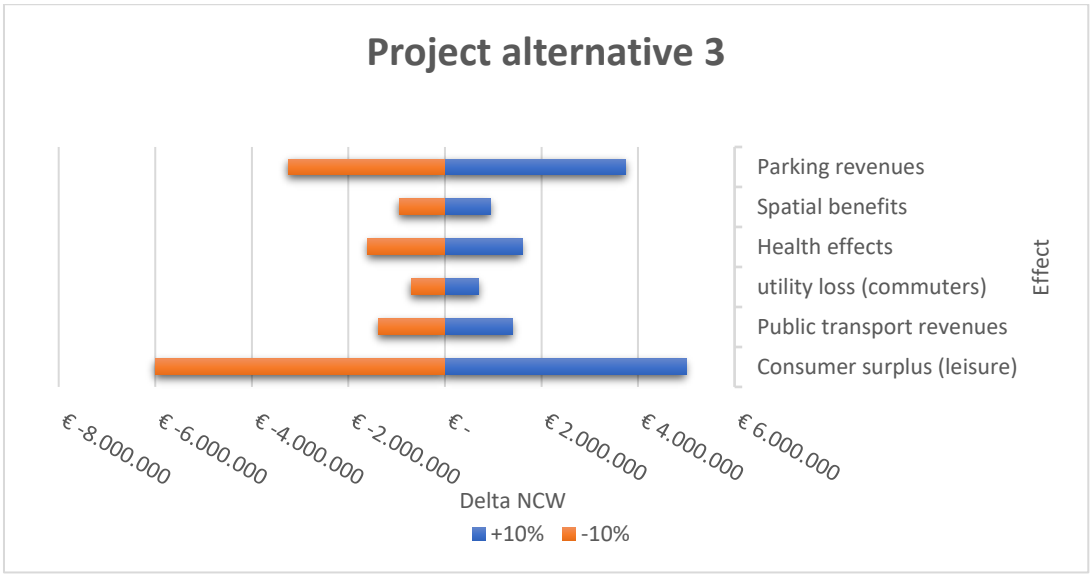

Figure 17 Impact selected effects on net present value project alternative 3

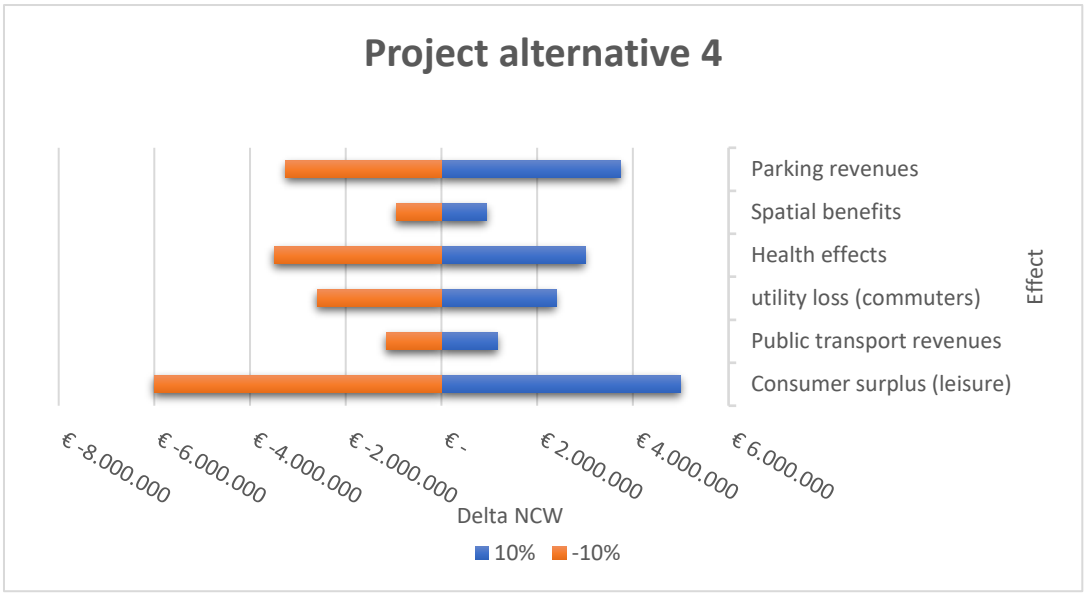

Figure 18 Impact selected effects on net present value project alternative 4

7. CBA as an improvement tool

Given the input data, assumptions and estimations it is concluded the CBA outcomes are not economically feasible for society. However, insights can be derived by using the CBA to learn lessons. As Rienstra (2008) concluded, the CBA can also be used as 'improver' instead of 'assessor'. The gained results can be used to alter project alternatives in order to create a more optimal alternative. Therefore, this chapter will look into the key effects to derive more positive results. Firstly, the most important effects are distinguished. Thereafter, new configurations, see Appendix E, are created in order to assess the impact of alterations. At last, to answer sub-question 6, conclusions to improve project alternatives are drawn.

7.1 Where to improve?

The results derived by the roughly created project alternatives provide valuable insights. Despite not being able to create a profitable project alternative, insights to create a possible profitable alternative are obtained. These lessons learned are important to determine the focus and aim of a project alternative.

By taking a look into the results it can be seen that the loss of consumer surplus has a very big costs share. However, these costs are hard to alter. A cost reduction can be achieved by allowing cars to park in the city centre, but since that is no option these costs have to be incorporated in the calculations. The consumer surplus costs can be seen as fixed costs in every alternative to safeguard a car-free concept. However, by altering these fixed costs and inherently allowing cars in the city centre, the effect of a more traffic-calm intervention can be assessed. Besides that, it is interesting to research fluctuating effects which are altered per project alternative and inherent circumstances. Alterations to these kind of effects are useful to reduce costs and increase benefits. In other words a more beneficial project alternative can be created.

Project alternative 1, wherein no investments in alternative infrastructure are made, is one of the best alternatives. It seems that investments in other alternatives have such an impact on the cost-benefit ratio that additional gained benefits due to investments are neglected by the investment costs. Project alternative 2 is in economic terms as good or bad as alternative 1 despite investments are made. The additional gained benefits, mainly from public transport revenues, are so big that the investment costs are covered. Alternative 4 distinguishes itself by substantial earnings on health effects due to an increased amount of cyclists. Nevertheless, these additional benefits do not cover the investment costs made compared to project alternative 1. Alternative 3 is left out of scope since it is the worst project alternative.

Project alternative 2 benefits mainly from more public transport travellers and thereby public transport earnings while project alternative 4 mainly benefits from more cyclists and thereby an increased amount of health effect. A tension field occurs between the division of cyclists and public transport users. More public transport users result in more public transport revenues and thereby in less cyclists inherent less beneficial health effects and vice versa. Additionally, the division of substituted car travellers over the alternative modes, results in crowdedness on the designated network. The costs for crowdedness in the public transport network increase more rapidly and it is favourable to minimise those costs. A more optimal division of car traveller substitutes over the public transport and bicycle mode might result in a more beneficial project alternative.

7.2 Improved configurations CBA

Configuration 1

This configuration focusses on the alteration of project alternative 2. As mentioned, there is a tension field between the division of additional public transport users and cyclists. In this configuration the car substitutes are divided differently than in project alternative 2. The investments in public transport results in more public transport users than in project alternative 2 and inherent less cyclists. In this configuration it is assumed 90% of the car trips are substituted to public transport and 10% to bicycle.

As a result some costs and benefits change. The public transport earnings increase due to a greater amount of travellers. Moreover, the increased amount of travellers result in more travellers experiencing a waiting time reduction and thereby society benefits more than in project alternative 2. The decrease in cyclists leads to a decrease in cycling crowdedness costs. Next to that, the health effect benefits are smaller since less cyclists benefit. The altered division of travellers over the alternative modes of transportation results in a benefit-cost ratio increase from 0,71 to 0,73.

Configuration 2

Project alternative 2 has a focus on public transport, project alternative 4 focusses on Rotterdam as a bicycle city. In this configuration the impact of an increased amount of cyclists is assessed. Therefore, in the division of car substitutes, 90% of the travellers are assigned to a change to the bicycle while the remaining 10% makes use of public transport.

By increasing the amount of cyclists, the health effects increase substantially. Next to that, more cyclist profit from a reliable cycling network and thereby the network benefits increase. Crowdedness in public transport results in serious costs, the decrease in additional public transport users reduces this costs. The downside of more cyclists is less public transport users and thereby smaller public transport earnings. Overall, the change in costs and benefits is neglectable since the cost-benefit ratio does not change compared to project alternative 4 and keeps constant at 0,68.

Configuration 3

In this configuration it is assumed still some cars are allowed to park in the city centre. This configuration intends to assess the impact of allowing a small amount of cars to park in the city centre and thereby reduce costs. By allowing cars to park in the city centre disutility of leisure travellers is reduced and parking earnings are generated. Hereby, the city will not be entirely car-free but major costs can be reduced. Therefore, in the configuration it is assumed 25% of the current leisure car parkers are allowed to park in the city centre.

Project alternative 1 is altered to assess the impact of the cost reduction. Project alternative 1 is chosen as base case since no investments are made and thereby the most pure effect impact can be determined. In project alternative 1, the price for parking is raised to € 70 per day since no leisure travellers is willing to park their car anymore at that price. In this configuration 25% of the travellers are allowed, or 75% of the travellers have to be averted by a certain price increase. Only 25% of all leisure travellers is willing to park in the city centre if the price increases to € 52.50 per day per traveller. As a result, the consumer surplus loss for leisure travellers amounts € 35.000.000 per year. The impact of a € 20.000.000 costs reduction by allowing a small amount of cars to park in the city centre results in a benefit-cost ratio of 0,90. In other words, by allowing 25% of the leisure travellers to park their car in the city centre, the benefit-cost ratio substantially improves from 0,71 to 0,90.

7.3 Lessons learned

Designers and decision makers might learn from insights, derived in the configurations, to assess where improvements, regarding a beneficial CBA, can be made. These insights add to knowledge regarding the creation of an optimal as possible car-free city intervention.

The configurations, Appendix E, showed the importance of a preferable division of travellers over alternative modes of transportation. In case investments in public transport are made then it is preferable to have as much travellers to switch to public transport as possible. The more public transport users, the better the benefit-cost ratio. In addition, configuration 2 showed in case the bicycle is centralised and more travellers make use of the bicycle that no substantial additional benefits are made. Based on these insights, it can be concluded that benefits derived from additional public transport users increase more rapidly than benefits derived from cyclists. Therefore, given the used input data and assumptions in this research, it is recommendable to favour public transport over the bicycle in an economic sense.

If public transport usage is centralised, the benefits will mainly flow to public transport providers. Governmental bodies might dislike this since public transport providers are supported by the government. They might prefer users of the system to benefit instead of the public transport providers. Mainly, because cycling results in health effects which are very important for society. If the bicycle is centralised it can be noted that the more travellers will not result in greater benefits. However, this insight can also be useful since it might be preferable to intensify cycling and thereby substantiate health effects. In case results can be generalised it can be concluded that the cost-benefit ratio will not deteriorate due to the amount of cyclists. Therefore, if governmental bodies prefer benefits for users instead of public transport providers, they can push to increase the amount of cyclists without a decline on the CBA.

Configuration 3 proved the impact of a utility loss for leisure car travellers to park their car in the city centre is substantial. By allowing travellers to park their car in the city centre, these costs can be reduced massively resulting in a more beneficial NPV and benefit-cost ratio. Moreover, the parking revenue loss is smaller since some cars are allowed to park. In other words, a transition from completely car-free towards traffic-calm results in less costs and thereby might be more socially feasible. However, by reducing these costs and allowing cars to park in the city centre, the concept of a car-free city centre cannot be achieved. Moreover, by allowing only a small amount of cars willing to pay a high parking fee, this distinguish might be unfair. Next to that, it might lack a public support base. In the past, the city of Rotterdam had an idea to create a special lane only for electric vehicles (Kristiaan Leurs, personal communication, March 13, 2020). The next day, newspapers were writing about an elite lane due to the expensive image of electric vehicles. In relation to a car-free intervention, parking in the city centre will only be exclusive to rich, elite, travellers. A visualisation of all benefit-cost ratios per alternative and configuration is presented in figure 19.

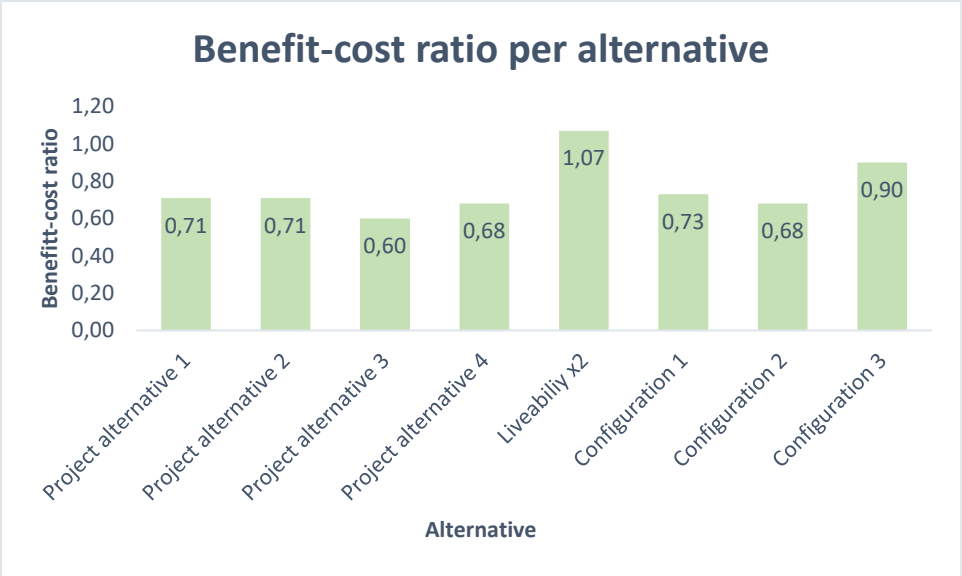

Figure 19 Benefit-cost ratio per alternative

8. Discussion

The explorative nature of this research requires some reflection, nuance and discussion. Multiple assumptions have been made and certain design choices regarding the incorporation of effects in the CBA are made. By critical reflecting on those assumptions and choices and by discussing the limitations of this research, the results can be interpreted by a more clear perspective regarding the intention of this research. The following three topics, inherent their limitations, are discussed: the analysis part, the incorporation of effects and the results.

8.1 Analysis

It is chosen to carry out a stakeholder analysis to discover the most important effects regarding a car-free city application. These stakeholders are determined by brain storming and the selection of Rydningen et al., (2017). Obviously, it is possible more stakeholders have a stake concerning this matter. Despite, the stakeholder analysis might be limited or not complete, it is assumed complete enough to carry out a sufficient analysis. This assumption is made because a stakeholder analysis is seen as a snapshot. Enserink et al., (2010) argue that stakes change continuously and therefore it is possible stakeholders will have a different opinion or vision by in this case 2030. Next to that, it is possible that the division of seats within the municipality changes and with it the vision and possible implementation. Despite the given uncertainty, it is chosen to use this snapshot of stakeholders to predict the future in 2030. Based on this uncertainty, nuance regarding the outcomes is required.

After the stakeholder analysis, a scenario analysis is carried out to predict explorative project alternatives. The scenarios are generated based on the identified factors. Given the limited time frame of this research, it is chosen to create a limited amount of scenarios by hand. Preferably, the generating phase is more extensive. Followed by an integration phase and consistency check via numerous modelling techniques. By using this techniques an optimal scenario can be determined. Börjeson et al., (2006) value the importance of the generating phase in the creation of explorative scenarios. They prefer an extensive generating phase by using for example workshops as it is a common technique. Börjeson et al., (2006) view the Delphi method as a fitting method with expert and stakeholder panels. This method would be suitable with a stakeholder analysis as is performed in this research.

8.2 The incorporation of effects

Multiple effects have been incorporated in the CBA calculations. Arguable some effects are missing, wrongly valued or intendedly not incorporated. By missing out, or mis valuing on certain effects, the CBA calculations are influenced. Currently, the NPV and benefit-cost ratio are negative, implying a bad investment for society in an economic sense. However, it might be more positive in a different research. As mentioned in the introduction, the researcher is able to play with values in the CBA. Although the valuation are represented as transparent as possible, the CBA is limited by both a lack of empirical evidence and assumptions.

8.2.1 Double count

An obvious made mistake by users in the CBA methodology is double counting. Double counting must be prevented in order to account for overestimations of the NPV. Therefore, some effects are

left out which are likely to be discussed in the policy debate. Amongst others, the increase of house prices is left out. Wright (2005) argues, based on several cases such as Venice, Capri and Zematt, that car-free locations boosts the economic value of residential property. This might be a positive benefit for society but cannot be incorporated in the CBA because the value of residential property increases due to less noise or more green space, resulting in spatial benefits, for example. In general, improved liveability increases house prices as evaluated in Centraal Planbureau (2018).

Another example of a not incorporated effect due to a double count, is the increase of revenues for local businesses. Multiple sources (i.e. (Pojani, 2007; Szarata et al., 2017; Wright, 2005)) indicate a significant increase in earnings for local businesses in car-free environments due to an increased amount of cyclists and pedestrians. Despite the majority of business owners feared a decrease in earnings due to a car-free intervention, research proved otherwise. However, research by Mingardo & van Meerkerk (2012) concluded there is no relation between parking capacity and revenues turnover. Indicating that if no cars are parked the revenues will not change and thereby contradict previous made claims about increased earnings. Whether businesses profit or not is outside the scope of this research, it is a possibility local business owners profit of a car-free intervention.

8.2.2 Traveller utility

In this research, roughly three different traveller groups are distinguished: car users, public transport users and cyclists. The majority of effects are car related and thereby the question arises if the costs and benefits must be divided more equally over all three groups. This is a fair question and arguably a limitation to this research. However, it is not chosen to incorporate these effects because there is chosen to assess the impact of banning cars. This research does not attempt to advise an optimal alternative but to provide useful insights in the development towards an optimal alternative.

The division of former car users over alternative modes is important to realise an optimal alternative. If many travellers substitute to public transport crowdedness will occur. Batarce et al., (2016) found evidence that if public transport gets more crowdy, demand drops. Due to this paradox of an increased amount of public transport users and a demand drop, it is possible travellers are more likely to switch to bicycle. The bicycle group, as assumed in the CBA calculation, might be much bigger if no investments, to prevent crowdedness, are made in order to prevent a demand drop. However, this conclusion is drawn based on more assumptions. Will demand drop or will the infrastructure of public transport be sufficient to account for crowdedness? This research attempted to provide, by making use of a proxy, to get insights in costs related to crowdedness. Crowdedness can also occur if more cyclists make use of the same infrastructure but strong scientific evidence to value this crowdedness is missing. Therefore, in this research, it is assumed the costs for crowdedness are similar to the crowdedness costs for public transport. A more detailed valuation of bicycle crowdedness is required since it will be important into the realisation of a final design for a car-free intervention since traveller utility seems to be an important effect.

It is interesting to zoom in on the utility of public transport users and cyclists, additionally to crowdedness. Next to additional users, current users of public transport and bicycle systems are affected by investments made in the respective infrastructure. A frequency increase of metros decreases waiting time and thereby travellers gain utility. Investment in the bicycle network on the other hand will improve the reliability of the network and users derive utility from this improvement. Next to the estimated utility changes in this research, it is likely both public transport users and cyclists derive utility from different aspects such as comfort or dependency. These kind of additional aspects can be assessed in more detail if more robust scenarios are formalised. For now, since there is no robust project alternative, the elaboration on car effects can be carried out with more care.

The biggest car costs are utility related. Apparently, travellers value their car highly since the loss of utility results in big costs. Both leisure travellers and commuters lose utility but these costs might be mis valued. Currently, the utility loss for leisure travellers is estimated by a proxy regarding the elasticity of parking while the commuters utility loss is determined by very rough assumptions. In the calculations it is assumed that 70% of the car trips are commuter related and thus 30% is leisure related. Despite that the group commuter trips is more than double the amount of leisure trips, the estimated costs for the leisure group are bigger than the commuters group. It is likely that the utility loss for commuters is either over- or underestimated. On the one hand, it could be overestimated because the additional travel time is determined based on bad connected areas. Out of all bad connected areas, just four places are considered in the approach. Obviously, commuters from different areas can experience an utility loss as well. In further research a more detailed study into the origin and destination of commuters must take place in order to estimate the utility loss more precisely. On the other hand, the utility loss could be underestimated because a far bigger group experiences this loss of utility. Moreover, the utility loss is solely based on additional travel time while more factors could affect this loss. For example, travellers can experience an utility loss because of the ban of their preferred mode. The preference for the car could be based on multiple factors such as travel time but it can also be based on independency, luxury or status. The effect of these factors on the utility loss are not incorporated and could boost the impact of this effect.

Private parking as an effect is not incorporated in this research. It is likely residents with a private parking spot or permit experience disutility because they cannot park their car close to their house. This effect is not incorporated because it is assumed this effect is neglectable from 2030 and onwards. In the city centre of Rotterdam an average household owns 0,4 cars (CBS, 2016). This is already one of the lowest car ownership rates in the Netherlands and it is still decreasing. Due to good accessibility to many facilities in the city centre, residents do not need a car and prefer other modes of transportation. Since the municipality of Rotterdam is already taking actions to limit car usage in the city centre, it is assumed the car ownership rate drop significantly the coming years.

Another traveller utility that is not incorporated in this research is the travel time savings utility. Rotterdam is a very congested city. Due to the congestion, mainly during rush hours, travellers in Rotterdam have 25% more travel time resulting in 115 hours travel time loss over the year per traveller (TomTom Traffic Index, 2020). According to a representative of the KiM (Dutch knowledge institute for mobility) an hour travel time loss by car is valued at € 15,64 (Staat van Utrecht, 2017). Research by Beerepoot & Dijkers (2013), for the Ministry of Infrastructure & Environment, mapped the percentage of travellers travelling in a certain timeframe during the day. Based on this report it can be concluded that during working days approximately 30% of the travellers travel during rush hour. In the current situation, with cars, a lot of congestion affects travellers travel time. The lost time, due to congestion, is saved in a car-free situation and thereby significant costs can be spared. After all, time is money. Despite, Rotterdam is very congested and a lot of travellers lose time during the rush hours resulting in serious costs, these costs cannot be incorporate in the CBA. The CBA methodology expresses costs and benefits as a delta, or in other words the difference in costs and gains between the 0-alternative and a certain project alternative. These costs cannot be incorporated because there is no delta gain on travel time savings. Apparently, travellers during rush hours value being stuck in traffic. There would be a gain if a traveller decided to travel outside the rush hours, switch mode or route. By banning the car option there is no gain on travel time savings. However, in the political debate it could be very interesting how travel time and congestion develops due to the removal of the car alternative. Therefore, it would be interesting to look into the development of cycling and public transport traffic during rush hours.

8.2.3 Governmental costs and benefits

The government has an excise duty and there will be missed out on this income by banning cars. In the CBA, only the distance covered in the city centre is considered in the calculations. However, it is likely that this effect has a different impact than estimated in this research. Due to a lack of data, the estimations are just based on assumptions of known information. A gap in the estimations is the lack of information regarding the development of trips. Travellers who travel through the city centre will need to use another route. This could result in additional kilometres and thereby a different valuation of the excises. Inherent to the change of trip distance, the emissions are affected too. Regarding the emissions, the emissions are only calculated for the scope of this research, the city centre. Due to the ban it is likely travellers substitute their entire trip by car and thereby the benefits for society are much bigger. These benefits outside the city centre cannot be incorporated with the CBA methodology but are certainly there.

Parking seems to be an important effect in a car-free city centre application. Currently, the municipality of Rotterdam earns a huge amount on parking. Mainly the city centre is an important income source for these earnings since a lot of expensive parking spots are located there. By banning the cars out of the city centre, the municipality will miss out on these earnings. The loss of these earnings are incorporated as costs in the CBA. Nevertheless, these costs must be reflected with care. The municipality determines the income on parking by the sum of the costs and earnings. Most of these costs are made in the city centre. But by banning the cars out of the city centre, these costs will not be necessary anymore because no parking spot need maintenance anymore. Therefore, the effect of parking on the NPV might be overestimated.

8.3 Results

As discussed in previous chapters, the incorporation of effects and their valuation is questionable. An as fair and transparent as possible CBA model is estimated. However, due to the discussed limitations and the lack of robust scenarios, the results require nuance. Therefore, the CBA outcomes are used as ‘improver’ as argued by Rienstra (2008). The valuations and thereby the results may lack empirical evidence to portrait a realisable project alternative for society, but the results can be assessed to learn lessons.

By taking a look at the effects it can be concluded that travellers car utility is highly valued. Travellers do not wish to be kicked out of their car. The exclusion of the car alternative results in serious costs which outweigh the benefits. Assuming the effect valuations are a correct approach of the costs, the sum of total costs are probably still undervalued. In this research it is assumed an entire car-free city is not realisable and concessions must be made. Therefore, exceptions are made such as the facilitation of disabled transport. If the research into car-free cities further develops, and disabled transport will not be facilitated anymore, more negative costs regarding car utility will follow.

Despite a negative NPV, it can be concluded that the prevented emissions are a positive benefit for society. Although, it must be noted that it is possible the emissions problem is moved to another area due to changes in travel behaviour. The most important benefit is either the benefit regarding health or increased public transport revenues. Intensified use of the bicycle will result in more efficient productivity and thereby a serious benefit for society while additional public transport users increase the public transport revenues. The division of travellers over the modes will determine the amount of gained benefits of these effects.

Based on the most important costs and benefits, it can be concluded, based on this research, that it is recommendable to facilitate travellers, whom have to switch to another mode of transportation, as good as possible to prevent crowdedness and gain specific infrastructure benefits such as a waiting time reduction in public transport and network benefits in the bicycle network. In order to gain the biggest benefits it is recommendable to facilitate public transport users. The more car trips are substituted to public transport, the bigger the benefits. If public transport is better accessible and travel time is minimised, the utility loss will be smaller. However, arguably it is preferable for governmental bodies to facilitate cyclist due to a higher acceptability and beneficial health effects. Literature mentions many more health effects but those are not incorporated to prevent for double counting. For example, because of less noise, emissions and stink, the life expectancy of residents increases. Another example is less obesity because travellers walk and cycle more. It is imaginable decision makers prefer societal health benefits for cyclists over the likes of a public transport provider. Thus, in a more optimal scenario, it would be recommendable to facilitate cyclists as much as possible, even if a traveller can only partly make its trip by bicycle. Additionally, to partly facilitating cyclists, it is important to facilitate the first part of the travellers trip which can either be done by improved public transport or sufficient P+R facilities in the city of Rotterdam. However, these investments result in bigger costs than benefits, it might be preferable for society.

The negative NPV is dominated by serious costs. This might be misleading after all since it is very likely society benefits even more from spatial benefits than depicted in the CBA. A more robust design can provide insight in the development of urban areas and thereby the valuation of spatial benefits. Moreover, as a result of spatial benefits, more benefits, such as increased house prices or revenues increase for local businesses, can follow as discussed in the double count paragraph. These benefits are not considered in the CBA but society can certainly benefit further than the CBA depicts. Moreover, liveability effects are often underestimated in CBA calculations. As evaluated by Centraal Planbureau (2018) these underestimations can be immense. Despite this might not be the case in every infrastructure project, it can be concluded that it is reasonable to account for underestimation. If the liveability benefits in this research are only twice as big, in comparison with the predefined valuations, the benefit-cost ratio and NPV are already positive. This indicates that a car-free intervention is a beneficial intervention. If the liveability benefit multiplier is even bigger, many more benefits are generated.

8.4 Lessons to improve the CBA

By altering the input variables of project alternatives and thereby creating new configurations, it is attempted to gain a deeper understanding of the development towards a societal feasible CBA and thereby add to existing scientific knowledge. This research indicates that the NPV and benefit-cost ratio will improve for society if more public transport users make use of the public transport network. The benefits generated by increased public transport revenues outperform any other benefit increase. It must be noted that investments in infrastructure must be made regardless, in order to prevent crowdedness. In other words, this research indicates the most beneficial scenario can be created by controlling for public transport crowdedness and with an increase in public transport users. Nevertheless, this indication must be interpreted with great nuance. The estimated investments in public transport only includes new infrastructure and exploitation. It is likely travellers are affected by many more influences, such as comfort, independency and reliability, which can result in additional costs or benefits. Hence, since limited costs and benefits regarding the utility of a public transport traveller are included in this research, the interpretation of the results might be exaggerated.

By allocating more car substitutes to the bicycle, a new configuration showed no benefit-cost ratio improvement. Indicating that despite more health and bicycle network benefits are gained, the loss of additional public transport revenue benefits equal the gain. It is imaginable that claiming there is no delta benefit gain due to an increased amount of cyclists is an underestimation. As mentioned before, many more health effects are generated but not included in the CBA estimations. Moreover, health effects are classically seen as an effect defining liveability and thereby there is a possibility it is underestimated. If more health effects are estimated and liveability is underestimated it is very likely the cycling benefits are far bigger than estimated in this research. Hence, it is to be expected that if more car substitutes change to the bicycle the benefit-cost ratio should increase. If it turns out that cycling generates more benefits than estimated in this research, it is arguably desirable, from a societal perspective, to prefer investments in cycling over public transport.

A car-free intervention or policy can be seen as car-bullying and car travellers experiencing this bullying effect lose a lot of utility. By being a bit more lenient, the loss of utility can be reduced and thereby serious costs can be limited. Therefore, traffic-calm concepts might be more feasible than a more radical car-free intervention. By doing so, policies to reduce car usage in the city centre might have a bigger support base. Moreover, the created configuration indicates that interventions to reduce car usage can go quite far to almost car-free and still be beneficial for society. However, by being more lenient, the concept of being entirely car-free will not be achieved. Additionally, it must be noted that decision makers must be aware of the possibility that a more lenient car-free intervention might result to inequality. Therefore, if a more lenient car-free policy is considered, it is advisable for governmental bodies to elaborate on the implications for society.

9. Conclusion and recommendations for further research

This final chapter will elaborate on the conclusions and recommendations for further research. Firstly, the research itself is discussed where after the main research question will be answered. Second, the recommendations for further research based on findings in this research are provided and lastly the scientific relevance of this research will be summarised.

9.1 Main findings

The Netherlands is in need to reduce emissions. By 2030 the emissions must almost be halved compared to 1990 and in 2050 the emissions must be reduced by 95% compared to 1990. This requires drastic measures and interventions regarding cars are already taking place. The city of Rotterdam has an ambition to be more sustainable, energy-efficient and improve the air quality. Currently, measures to reduce emissions, are already taking place in the city of Rotterdam and more initiatives are considered. Based on the idea to reduce emissions, this research attempts to get by an explorative nature, insight in the societal feasibility of a car-free city centre. The research aims to provide insight in the costs and benefits occurring in case a car-free intervention, in this case a car-free city centre intervention in the city of Rotterdam, would be implemented. The literature lacks to give useful insights in costs and benefits related to effects occurring in car-free environments. Hence, it is unclear which elements are important to realise a car-free city centre. To get insight in this gap and learn lessons, the following research question is to be answered:

Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam?

Based on a stakeholder analysis, providing insights in implications and the most important factors for stakeholders, scenarios are created. These scenarios are created in a limited time frame and thereby may lack robustness. However, given the explorative nature of this research, rough scenarios are regarded sufficient to get insight in the effects of a car-free city centre. The explorative scenarios will be limited regardless since they will be effective starting from 2030. The scenarios analysis resulted in four different project alternatives:

1. No additional investments
2. Invest in public transport
3. Invest in P+R & shared mobility
4. Rotterdam bicycle city

In each scenario the current car trips are substituted by both public transport and cycling. The difference between the alternatives is the division of travellers over the modes. Based on these project alternatives in can be concluded that either no investments or investing in public transport is most beneficial for society. Investing in the bicycle infrastructure is less beneficial but it might be recommendable to consider centralising the bicycle. In comparison with the other alternatives, significant health benefits are generated and these benefits are arguably more important for society. Investing in P+R facilities, to partly facilitate car travellers, is estimated as the worst alternative since both highly beneficial effects, public transport revenues and health effects, are limited. The NPV is in each scenario negative and out of an economic perspective it is not recommendable to implement a car-free city centre in the city of Rotterdam. Despite, a negative NPV and not economically feasible alternatives, the research provides insights in the impact of certain effects on society. Decision

makers might prioritise beneficial effects for society over costs. Therefore, arguably, a car-free city centre intervention is beneficial for society despite a negative NPV.

It can be concluded that travellers value car utility highly and is thereby an important element in the CBA calculation. Commuters experience a big utility loss due to additional travel time. Next to that, leisure travellers are not able to park in the city centre anymore and that results in a loss of consumer surplus. Parking by itself can be a big issue in the political debate since it generates a lot of income and by banning cars the municipality loses this source of income. However, by banning cars, space comes available and society can profit from spatial benefits. The municipality has less car related maintenance and the space can be restructured with for example more green. The exact impact of this effect is not assessed in this research since the design of a car-free city centre is out of scope of this research.

Society benefits from reduced emissions, however the impact of this effect might be neglected since it is possible travellers change their travel behaviour and the impact of this change could result in a shift of emissions. Despite the impact of emissions might be neglected, liveability effects in general are important elements to evaluate. Often, liveability effects are underestimated. If the effects, defining liveability, are underestimated, a true valuation might result in a beneficial CBA outcome. If the liveability effects are twice as big as estimated, the benefit-cost ratio already indicates a beneficial investment for society. An interesting benefit are the health effects due to more cyclists. Commuters are more healthy if they cycle and this results in a productivity gain. This effect is very beneficial for society. Another very beneficial effect for society is the increased public transport revenues due to more users. The health effects and public transport revenues are estimated by the division of additional travellers over the public transport or bicycle mode. Because either mainly health effects or public transport revenues are gained, there is a tension field between those effects. Thereby, the division of travellers over alternatives mode is a decisive element.

In this research, the CBA is used as a design instrument for further research and it provides insights in the most important effects to improve project alternatives. An important lessons learned is by altering the division of travellers over the alternative modes of transportation, it can be concluded that investing in public transport is more beneficial, in an economic sense, for society than any other alternative. Mainly the influence of additional public transport revenues and prevented crowdedness are important effects. Additional cyclists do not result in an improved benefit-cost ratio. However, health effects, the main benefit by centralising the bicycle, are likely more substantial than estimated in this research and thereby underestimated.

If decision makers decide to be not entirely car-free but focus on a more traffic-calm solution, the benefit-cost ratio improves. Each additional allowed car will result in greater benefits because disutility amongst car users is prevented. This insight can be a valuable lesson in order to reduce costs and resistance. A transition from traffic-calm towards car-free is less extreme and it is likely utility losses are smaller.

Researchers, looking into the most optimal car-free city centre design, are recommended to focus on the facilitation of travellers in order to minimise the utility loss. Moreover, it is important to stimulate public transport usage since it generates additional public transport revenues. Overall, a car-free city centre might not be the optimal intervention to reduce emissions because in an economic sense, it has only a minor impact on society. Although, despite high costs, a car-free intervention might be suitable to achieve the goals of the municipality of Rotterdam.

9.2 Recommendations for further research

This research provides a rough insight in the economic impact on society from certain effects. It is important to research parts in more detail since many assumptions have been made and proxies have been used to estimate. As Stebbins (2001) concluded, explorative research lacks finality and many studies must be carried out to generate validity. Therefore, to elaborate on limitations and explore gaps in further detail, the following recommendations for further research are provided:

- **Elaborate on scenarios:** It is recommendable to create more robust scenarios. Therefore, it is important to verify the added value of all stakeholders. As Börjeson et al., (2006) argue, a Delphi method would be fitting to both get a greater understanding of the stakeholders and identify more solid variables to be included in the scenario analysis. By the use of appropriate software, an optimal scenario can be predicted based on the inserted variables.
- **Development of cyclists crowdedness:** The development of crowdedness in other modes of transportation is valuable to research. Batarce et al., (2016) found evidence for a demand drop by a crowdedness increase and therefore it is important that crowdedness is prevented in case another mode of transportation needs to adopt car travellers. If investments in an alternative mode of transportation are made, then it is preferable this mode lives up to the standards. In this research, a proxy value for crowdedness, derived from a public transport proxy, is used to calculate cyclists crowdedness. Arguably this proxy is not generalisable to other modes of transportation and therefore empirical evidence to value cyclists crowdedness is required.
- **Alternative modes during rush hour:** Next to crowdedness, it is recommendable to look into the development of alternative modes, such as cycling and public transport, during rush hours. Is the current infrastructure sufficient to facilitate an enormous increase in users? Obviously, it is not the intention to move congestion from the road to another mode of transportation.
- **O/D of commuters:** In order to value the utility loss more robustly, it is recommendable to research the origin and destination of commuters. By doing so, insights in travel time loss can be approached more accurately. Next to that, more specific investments in infrastructure of alternative modes of transportation can be made in order to reduce the travel time loss.
- **Specify valuations:** In order to substantiate the valuations it is recommendable to research into specific aspects or elements of car-free cities such as health, social cohesion or travel behaviour. By doing so more accurate valuations can be estimated.
- **Transition from traffic-calm towards car-free:** This research indicates a traffic-calm intervention might be more desirable since the CBA results indicate it is more beneficial for society. This might imply a sudden car-free intervention is to extreme and cannot be accepted by society. It is interesting to look into the transition from traffic-calm to car-free to research the acceptability and disutility by such a transition.

9.3 Scientific relevance

In this research it is attempt to shine light on important elements regarding the implementation of a car-free city centre in the case of Rotterdam. Different elements are found to be important by the development of a car-free city centre design. These elements should substantiate to the realisation of a more societal feasible scenario. This research contributes to scientific knowledge by the identification of important effects inherent derived insights, and thereby the opportunity to research new gaps into the field of more robust designs towards the realisation of a car-free city centre.

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Appendix A – Scientific article

A societal beneficial car-free city centre in Rotterdam?

An explorative research into the lessons learned of societal cost-benefit results regarding a car-free city centre

Sjoerd Keijzer

Master student Complex Systems Engineering and Management (COSeM) at faculty Technology, Policy and Management – Delft University of Technology (TU Delft), Jaffalaan 5, 2628 BX Delft.

Abstract: *Rotterdam has to reduce emissions and different interventions are being implemented to contribute to the mission of achieving a sustainable, energy-efficient Rotterdam, with improved air quality. An unidentified intervention is the implementation of a car-free city centre which might be perfectly applicable in the specific case of Rotterdam. This research will focus on the societal feasibility of a car-free application and important monetary elements defining the feasibility. Based on insights derived from gained results, lessons can be learned for future developments. Therefore, the following research question will be researched: Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam? Car-free project alternatives are created as input for a Cost-Benefit Analysis (CBA). Valuated effects are incorporated in the CBA per project alternative to approach important effects and the societal feasibility of a possible car-free implementation. Based on the attempted CBA estimations, a car-free city centre is not feasible in each given project alternative. However, the CBA results can be used as a design instrument by using insights, derived from created configurations wherein input variables are altered, to create a more optimal project alternative. Travellers value car utility highly resulting in major costs. Major benefits can be achieved by an increased amount of commuters switching from the car to the bicycle. In order to create a more optimal project alternative, it is advisable to stimulate public transport usage and reduce the loss on car utility related effects and thereby be traffic-calm instead of car-free.*

Keywords: Car-free city, Cost-Benefit Analysis, Effects, Traffic-calm, Explorative

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1. Introduction

In Paris' climate agreement in 2015, the reduction of global warming was agreed upon. The Dutch national climate agreement centralised the goal to reduce emissions by 49% compared to 1990 in 2030 and by 95% in 2050 compared to 1990 (Rijksoverheid, 2019). Last decade, among several big cities in the Netherlands, Rotterdam was regulating heavy emitting cars more strictly by so-called environment zones to reduce emissions. Moreover, the municipality is elaborating on initiatives for cleaner city logistics, intensifying electric car usage and incentivising bicycle utilisation (Gemeente Rotterdam, n.d.-c). Herewith, the range of interventions attempts to achieve cleaner air and a more attractive city for residents and businesses. One of the five area visions of Rotterdam, elaborates on

a healthy city by centralising goals such as, life expectation, cleaner air and noise reduction (Gemeente Rotterdam, n.d.-b). Within this vision, the municipality has a mission to achieve a sustainable, energy-efficient Rotterdam, with improved air quality (Gemeente Rotterdam, n.d.-d).

Currently, to strengthen the goal, one of the main streets, the Coolsingel, is being renovated. This renovation will result in a more sustainable traffic-calmed street, wherein pedestrians and cyclists enjoy more space (Gemeente Rotterdam, n.d.-a). Reduced car usage results in cycling and walking becoming faster, safer and a preferred mode of transportation (Gundlach et al., 2018). Furthermore, car usage affects land usage by traffic and parked vehicles, reducing the potential of other modes of transport and the optical quality of the environment (Nieuwenhuijsen et al., 2019). Lowering the amount of cars, inherent their infrastructure and parking spaces, allows for opportunities to increase sustainable networks in a city and enlarge green areas, that can result into valuable health effects (Nieuwenhuijsen et al., 2019; Nieuwenhuijsen & Khreis, 2016).

The idea of the initiative is focussed on a lively and safe city centre. Even though a car-free intervention might be a rigorous measure, it is not unthinkable that in the future the municipality of Rotterdam will support such an initiative. Multiple ideas to be car-free or traffic-calm are considered already by the municipality. A car-free intervention might be a suitable solution but it is unclear if this intervention is economically feasible and which elements are important to realise a feasible intervention. Literature indicates several positive effects of a car-free environment but it is unclear whether these positive benefits outweigh costs due to the loss of cars. Therefore, this research attempts to carry out a societal cost-benefit analysis (CBA) to explore costs and benefits regarding a car-free city centre, in the case of Rotterdam, in order to assess the impact and derive insights to learn lessons in relation to realising a societal feasible car-free city intervention. Hereby, this research attempts to extent scientific knowledge regarding important elements to realise a societal feasible car-free application.

1.1 Research question

The measurement of positive versus negative, or discomforting, effects in a car-free application is unclear. Next to that, it is unclear if the benefits outweigh the costs and if a car-free intervention, in an economic sense, is a feasible alternative to make a positive change in society. Besides that, the individual impact of effects on the societal feasibility is not studied yet. By researching the costs and benefits of individual effects and thereby the societal feasibility of a car-free intervention as an alternative, the decision-making process can be provided with valuable insights. Insights that might change the political view or approach regarding the implementation of a car-free application.

In order to approach the elements that define an economic feasible car-free intervention, it is important to define monetary effects in order to identify how a feasible car-free application in the city centre of Rotterdam can be realised. The insights retrieved from these estimations can be used to learn how to create a more optimal car-free intervention. Therefore, the following main research question is formulated:

Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam?

2. State-of-the-art knowledge

A few concepts, regarding car-free, will be discussed in order to catch up with the state-of-the-art knowledge. Therefore, there will be elaborated on the definition of a car-free city concept, current car-free applications and why to research the car-free concept.

2.1 What is the concept of car-free city

The definition of a car-free city throughout the literature is pretty similar. The definition refers to a regulatory measure to limit car traffics by the establishment of a ban. (Topp & Pharoah, 1994) However, the idea of car limitations or a car-free city implementation can be considered differently. Nieuwenhuijsen et al. (2019) view a car-free city as a city without private cars but wherein still, among other things, buses, taxis and emergency vehicles are able to drive. Melia (2014) differently defines car-free as a development wherein designs are created to facilitate the movement by non-car means and thus thereby offer no car facilities such as parking or accessibility. Multiple articles such as, Gundlach et al. (2018) & Loo (2018), use the definition by Melia (2014) as their definition of a car-free city. Although, the identified 'limitation' by Nieuwenhuijsen et al. (2019) to a car-free city, must be considered, since it is imaginable an entire car-free city is not achievable.

In this research a combined vision, based on insights of both Melia (2014) and Nieuwenhuijsen et al., (2019) on car-free, will be used. Based on these visions the following definition of a car-free city is formulated: '*car-free cities are developed to ban private and public car movements out of the city by traffic-free developments, focussing on the facilitation of sustainable non-car means, wherein still exceptions, such as emergency vehicles and disabled transportation, are facilitated.*' The author argues that this definition is more comprehensive to all related dimensions of car-free developments.

2.2 Car-free applications

In recent years multiple car-free developments have been made. These developments range in a wide spectrum of regulations. Wright (2005) clearly visualised the size difference of the impact of these regulations, figure 1. Those regulations vary from limited restrictions to long-term bans. Regarding the case of a car-free city centre in Rotterdam the focus should be on permanent largescale measures.

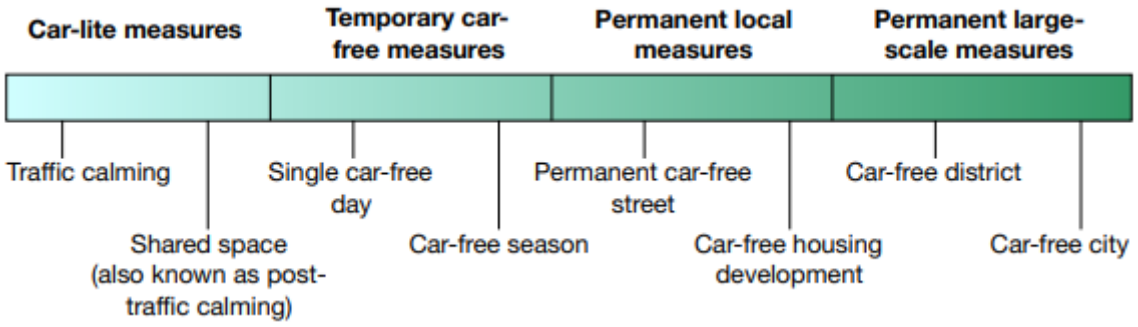

Figure 20 Car-free spectrum by Wright (2005)

Wright (2005) provides multiple examples of successful regulations or measures as depicted in his spectrum. Wright (2005) elaborated on examples of car-free cities such as Fez and Venice, but these cities are car-free because of historical infrastructure. Currently, no entire car-free city, by regulation, exist (Urry et al., 2017). A car-free city centre can be framed as a permanent large-scale measure. The size is obviously smaller than an entire city but arguable bigger than a district. Despite no entire car-free city exist, some car-free developments, approaching the car-free city centre concept, are applied in the real world.

In 2017, the city of Oslo researched the possibilities to realise a car-free city centre. Based on a thorough stakeholder analysis and an in-depth case study analysis, regarding the cities of Strasbourg, Freiburg and Nuremberg, it could be concluded that there always should be exceptions for certain user groups and stakeholder (Rydningen et al., 2017). Throughout the literature, the same challenge

regarding car-free cities re-emerges on how to be entirely car-free and still be inclusive. Every attempt to be entirely car-free had it challenges and limitations and thereby compromises have been made to still partly facilitate (sustainable) car transport.

2.3 Why car-free?

The application of car-free interventions on a largescale still lacks solid examples. Therefore, there are still opportunities to research the feasibility of the intervention. Throughout the literature, multiple effects are mentioned but the exact impact lacks evidence. First of all, car-free interventions are intended to ban cars out of the city and thereby decreases congestion and inherent exhaust gases as for example in the case of Masdar city which is intended to be low carbon (Manghnani & Bajaj, 2014; Nobis, 2003). Additionally to the traffic related effects, valuable health effects can occur due to the absence of car traffic (Nieuwenhuijsen et al., 2019). In general, due to, amongst others, the decrease of carbon emissions, multiple environmental benefits occur (Ornetzeder et al., 2008). In the extension of environmental benefits, the banning of cars offers significant spatial benefits, increasing the value of environmental effects due to improved liveability, safety and attractiveness (Loo, 2018; Ornetzeder et al., 2008; Szarata et al., 2017). Survey research by Szarata et al., (2017) in the city of Cracow, proved that a vast majority of the respondents were very satisfied with car-free areas in the city. Without cars, respondents valued tranquillity and appreciated the landscape and atmosphere even more. Szarata et al., (2017) drew another interesting conclusion. Based on their research, they concluded that 75% of the respondents would not want to restore back to the former situation with cars.

3. Methodologies

Based on the fact that it is unclear how the costs and benefits relate to each other, a chronological design road will be followed to stipulate the process. To get a hold on what costs and benefits are in play with respect to the city of Rotterdam, it enlightens to get insight in what factors and effects are at stake. Accordingly, these effects can be monetised and be used to approach the economic feasibility of a car-free city centre. Moreover, the division of the costs and benefits can be evaluated to add value to decision-making processes regarding the implementation of a car-free city centre. Since there is no blueprint on how to design a car-free city centre, possible designs will be explored. To do so the following steps will be taken to approach the costs and benefits.

4. Stakeholder analysis
5. Creation of project alternatives
6. Cost-benefit analysis

3.1 Stakeholder analysis

A stakeholder analysis is of great importance to provide insight into the range of stakeholders, including their networks, involved (Enserink et al., 2010). Gained insights can add value to policy analysis in multiple ways. Enserink et al., (2010) make use of the hexagon model by Mayer et al., (2004), as depicted in figure 2. A stakeholder analysis contributes to all activities but in this research the main focus is on the blue triangle between Design and recommend and Advise strategically. According to Enserink et al., (2010), these activities possibly contribute to the creation of strategies to satisfy particular stakeholders and by assessing the feasibility and potential to implement a certain policy intervention.

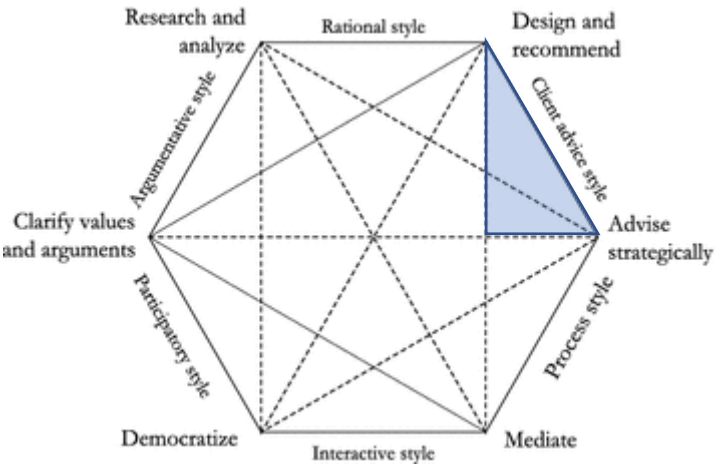

Figure 21 Policy activities hexagon by Mayer et al., (2004) derived from (Enserink et al., 2010)

To construct scenarios, or project alternatives, a conceptual design must be made. This conceptual design forms the dimensions of the car-free city centre system. With the identification of major stakeholders, inherent their needs and requirements, important context regarding system requirements or design constraints can be formalised (Faulconbridge & Ryan, 2018). By setting the right context, stakeholder implications regarding the intervention can be discussed. These implications mark the boundaries of the conceptual design.

In this research the method is applied by distinguishing important stakeholders. Thereafter, by assessing relations between those stakeholders and the power and interest per stakeholder the context is formalised. By setting the context, implications, affecting stakeholder groups by the implementation of a car-free city centre application, are elaborated on and discussed in detail.

3.2 Creation of project alternatives

By setting the context, rough project alternatives can be created. These project alternatives are rough sketches due to a lack of scientific evidence but will provide insights in costs and benefits. To create the project alternatives, a scenario analysis will be carried out. To create scenarios different typologies can be used. Börjeson et al., (2006) distinguishes three different typologies as visualised in figure 3.

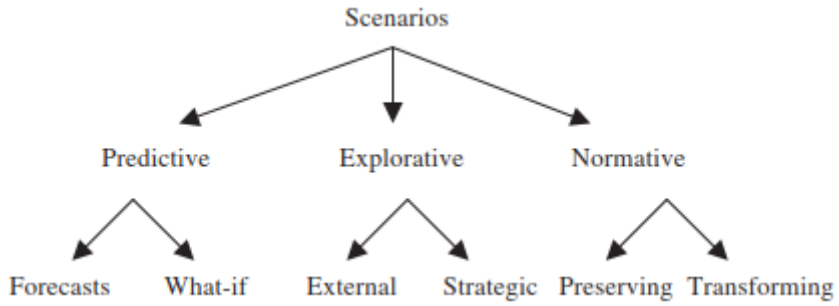

Figure 22 Different typologies distinguished by Börjeson et al., (2006)

In this research, strategic scenarios fit the requirements regarding the creation of project alternatives. Strategic scenarios aim to illustrate a range of consequences due to strategic decisions. The scenarios incorporate policy measures in order to handle a specific issue. Börjeson et al., (2006) stipulate that these strategic scenarios focus on internal factors and external influences are considered. Target variables are defined and by varying future developments the consequences of a

change or specific design can affect the impact on the target variables. The studied variables are relevant for decision makers and other interested stakeholders. The project alternatives will be created in order to study the development of certain variables and their share in the success of the economic feasibility of a car-free application.

The creation of scenarios as presented by Börjeson et al., (2006) is followed as much as possible in this research. Börjeson et al., (2006) follow three different steps in the scenario creation process. Firstly, a generation phase wherein ideas and concepts are proposed. This generation step is carried out and input derived from the stakeholder analysis is used to substantiate the generated ideas. Secondly, the integration step, as suggested by Börjeson et al., (2006), is carried out wherein generated input is processed to create scenarios. This step is carried out more simplistic and not optimised by quantitative models due to high uncertain and unclear input variables. Lastly, a consistency check must be carried out but since no quantitative optimum is found this step is not carried out. Despite, a simplified analysis is carried, rough scenarios to evaluate in the CBA are constructed.

3.3 Cost-Benefit Analysis

The cost-benefit analysis (CBA) is a tool to monetise effects and evaluate the economic feasibility. Van Wee & Roeser (2013) describe the CBA as a method that provides an overview of on the one hand all the pros (benefits) and on the other hand all the cons (costs). Benefits can also be defined as harms a regulation will avoid (Driesen, 2006). These costs and benefits are monetised and thus quantified for a project or policy alternative. The costs and benefits are interpret by the change of utility or human welfare (Hwang, 2016). This change is usually monetised based on the willingness to pay (WTP) and willingness to accept (WTA) (Hwang, 2016; van Wee & Roeser, 2013).

All incorporated effects are monetised despite this might be difficult for some effects. The consequences of the project or policy intervention affect environmental effects which are commonly known as difficult to monetise. By expressing these effects, a broad view on the consequences of the intervention on society can be approached. However, the CBA methodology lacks to quantify the full set of environmental impacts (soft effects) (Dong et al., 2017). Although the CBA has its flaws and criticasters, it is arguably seen as a fair and neutral method. It is mainly regarded neutral because the methodology decides upon the appropriate stringency of safety, health and environmental regulations (Driesen, 2006). In other words, the method might not be perfect but it is a transparent methodology to approach the value of (soft) effects.

Under the assumptions that monetised values might lack the quantification of the full set of environmental impacts and some nuance is required, the methodology will be used to elaborate on the welfare effects for the city of Rotterdam. These welfare effects are calculated over a period of time and discounted by a rate of 5,5% per year in order to accumulate the costs and benefits (Koopmans & Lieshout, 2014). The sum of the accumulated outcome is defined as the Net Present Value (NPV). Additionally, next to the NPV, the benefit-cost ratio can be determined, indicating the difference between the costs and benefits (van Wee & Roeser, 2013). Basically, if the benefit-cost ratio exceeds 1, it implies that the benefits are bigger than the costs and vice versa if the costs outweigh the benefits, the benefit-cost ratio indicates a negative investment.

In this research, process steps are carefully outlined in order to work towards answering the main research question. Firstly, a 0-alternative, or business-as-usual, alternative is created. Thereafter, the project alternatives in relation to a car-free city centre are explained. Hereafter, detailed effect valuations are given. By explaining all the alternatives and effects, the CBA estimations can be made. The CBA estimates a delta difference of a project alternative in comparison with the 0-alternative to

estimate the effect impact relative to a business-as-usual situation. The obtained results provide an indication of all the gained benefits and made costs due to a car-free city intervention. Since the results are rough estimations the sensitivity is tested accordingly. The method is in the first place used to assess the societal feasibility of a car-free city centre. Based on the obtained results the method is used as an improvement tool for decision makers. Thereby, the intention to shine a light on the development of a car-free city centre comes in play and lessons can be learned.

4. Results

The results of the analysis, regarding the distinguished methods, will be presented in this chapter. Based on current knowledge assumptions are made for future expectations. The analysis's are very explorative and therefore results require some nuance. A detailed description of the analysis's carried out can be found in Keijzer (2020).

4.1 Stakeholder analysis

Research by Rydningen et al., (2017) emphasised on the importance of involving stakeholders in the planning process of the realisation of a car-free city centre in Oslo. According to their research, it is essential to incorporate stakeholders in the process with their view and demands in order to facilitate exceptions. A car-free city application will affect car users since they are not able to drive through the city centre anymore. Such a policy measure affects way more stakeholders and thereby implications for society occur. To assess the impact on society it is valuable to identify the stakeholders and their interest. Therefore, stakeholder groups as distinguished by Rydningen et al., (2017) and other important stakeholders are assessed in greater detail. Roughly, three different stakeholder groups are distinguished: users, transport suppliers and governmental bodies.

The analysis provides insights in the most important stakeholders, their relationships and their power & interest. Here from, stakeholder implications regarding a car-free city centre intervention are assessed. Multiple implications affect the stakeholders in the playing-field. Multiple positive implications arise by the regulation of a car-free city centre. Current used car space can be redeveloped in more green areas or offers opportunities for the improvement of alternative modalities. The redevelopment of used space must be considered carefully since multiple factors come at stake. Current transport networks might not live up to a sudden increase in travellers. Moreover, logistic suppliers potentially have to make use of these transport networks as well. Next to that, social inclusion might be a challenge by banning the car. Some negative implications can be accounted for by creating a balanced city and by the prevention of certain aspects such as resistance and inherently social exclusion. The most important implications per stakeholder group are summarised in table 1.

Table 9 Stakeholder implications

Users	Transport suppliers	Governmental bodies
Travel time	Travel quality	Acceptability
Comfort	Travel capacity	Inclusiveness
Liveability	Investments	Infrastructure adequacy
Revenue increase	Traffic flow	Health
	Exception accessibility	Social cohesion

4.2 Project alternatives

The project alternatives will be realised in 2030 and thus are highly uncertain. Therefore, scenarios will be based on current knowledge in order to guarantee feasible outcomes. Future changes can thereby only improve the scenarios. The created scenarios will result in car-free project alternatives within the dimensions of the formed definition of a car-free city. This research defined a car-free city as follows, by recapping to chapter 2, '*car-free cities are developed to ban private and public car movements out of the city by traffic-free developments, focussing on the facilitation of sustainable non-car means, wherein still exceptions, such as emergency vehicles and disabled transportation, are facilitated.*'

Based on the given definition, it is assumed that in each scenario private and public cars will be banned. However, exceptions are allowed such as the facilitation of emergency vehicles and disabled transit. Moreover, it is assumed that, just as in the city of Den Bosch, logistic suppliers are regulated to enter the city. The exact design of the logistic supply is assumed out of scope in this research because it is assumed logistic suppliers will develop their processes to facilitate the most optimal delivery based on infrastructure, opportunities, regulations and customer needs. These effects can therefore be neglected in the CBA.

The method by Börjeson et al., (2006) requires the generation of knowledge, future views and concept ideas in order to construct scenarios. The stakeholder implications are used as input alongside state-of-the-art knowledge. Since empirical findings to establish robust scenarios is lacking, it is chosen to provide general scenarios without too much detail. Each scenario facilitates switching car-users by either public transport or cycling. Therefore, the scenarios mainly differ in the division of travellers over the alternative modes. The following scenarios are created and used as project alternatives in the CBA:

5. No additional investments (50% public transport, 50% bicycle)
6. Invest in public transport (75% public transport, 25% bicycle)
7. Invest in P+R & shared mobility (50% car towards P+R, 25% public transport, 25% bicycle)
8. Rotterdam bicycle city (25% public transport, 75% bicycle)

4.3 Cost-Benefit results

Multiple effects have been estimated in order to approach the economic feasibility of the project alternatives and get insights in what elements or effects have the biggest impact on NPV. The detailed valuation and rationale per effect are provided in the research by Keijzer (2020). In this research the following effects are considered in the CBA calculations:

- Emissions
- Noise
- Stink
- Traffic safety
- Public transport revenues
- Excise duty
- Spatial benefits
- Parking revenues
- Utility loss leisure car travellers (estimated via parking consumer surplus)
- Utility loss commuter car users (estimated via travel time losses)
- Health effects
- Crowdedness for public transport

- Crowdedness for cyclists
- Waiting time reduction public transport
- Bicycle network benefits

The delta costs and benefits of each individual effect per project alternative compared to the business-as-usual scenario are calculated and discounted over a period over 20 years (2030 – 2050). The sum of the costs and benefits per effect, NPV and benefit-cost ratio are provided in table 2.

Table 2 CBA results

Effects * 1.000.000	Project alternative 1	Project alternative 2	Project alternative 3	Project alternative 4
Investment	-	€ -225	€ -250	€ -252
Operating costs	-	€ -22	€ -29	€ -3
Consumer surplus loss (leisure)	€ -638	€ -490	€ -638	€ -638
Utility loss (commuters)	€ -290	€ -223	€ -85	€ -290
Parking revenues loss	€ -302	€ -232	€ -226	€ -302
Public transport revenues	€ 294	€ 338	€ 176	€ 147
Health effects	€ 255	€ 98	€ 190	€ 383
Crowdedness public transport	€ -171	-	€ -168	€ -160
Prevented car accidents	€ 163	€ 125	€ 163	€ 163
Reduction car emissions	€ 116	€ 89	€ 116	€ 116
Spatial benefits	€ 131	€ 100	€ 131	€ 131
Network benefits (bicycle)	-	-	-	€ 94
Waiting time reduction	-	€ 107	-	-
Reduction of traffic noise	€ 78	€ 60	€ 78	€ 78
Exploitation costs	-	€ -68	-	-
Excise income loss	€ -58	€ -45	€ -58	€ -58
Crowdedness cyclists	€ -55	€ -32	€ -47	-
Stink reduction	€ 46	€ 36	€ 46	€ 46
Net present value	€ -433	€ -384	€ -602	€ -547
Benefit-cost ratio	**0,71**	**0,71**	**0,60**	**0,68**

The CBA has a negative net present value in all given scenarios. The costs and benefits are ranked by their value and thereby their impact. By taking a closer look to the specific costs and benefits, it can be noticed some costs have serious impact on the net present value. It turns out that travellers, value car utility very high since major costs are car related. On the one hand, governmental bodies miss out on parking earnings. On the other hand, commuter car users, who prioritise car travelling over other modes due to a lack of sufficient alternatives, experience a big utility loss because they are not able to travel their journey by car anymore. Moreover, leisure car users, preferring the car as a transportation mode to the city centre over any other transportation mode, experience a major consumer surplus loss. This 'car bullying' policy affects travel behaviour and thereby has a major effect on individuals travel time, mode choice and inherent utility loss. Because car travellers switch to another mode of transportation, it is possible travellers of alternative modes experience an utility loss as well due to crowdedness. Investments in infrastructure must be made to prevent crowdedness.

Despite the utility loss, and inherent costs to this loss, outweigh the benefits, still some remarkable benefits are made. Society benefits from prevented negative effects related to cars, such as emissions, noise and car accidents. A consequence of banning cars in the city centre is that the car infrastructure can be replaced for another purpose. The vacant space can be used for recreation purposes and the municipality saves infrastructure maintaining costs, resulting in spatial benefits. Out of all benefits, the most interesting benefits are the health effects and the increased public transport revenues. Significant benefits occur by the substitution from cars to bicycle. The more people switch to bicycle, the more benefits are generated. These health benefits have such an impact that it seems the switch from car to bicycle will be crucial in the transition towards a car-free city centre. Next to that, if the occupancy rate of the metro increases and more traveller kilometres are travelled, the public transport supplier makes significant benefits. The only disadvantage of this benefits is the impact of crowdedness which neglects the benefits earned. Therefore, investments to prevent crowdedness from happening are required.

This research make use of a classic sum of effects to interpret liveability. Therefore, the following effects are used to define liveability: reduction car emissions, reduction of traffic noise, prevented car accidents, stink reduction and spatial benefits. The valuations of these effects are estimated by making use of key figures commonly used in CBA calculations. A project evaluation by Centraal Planbureau (2018) concluded that the valuation of liveability benefits, in urban infrastructure projects, with key figures might result in underestimation. The liveability effect estimations in project alternative 1 are multiplied by two to assess the impact of underestimated liveability effects. In case the benefits are twice as big as expected, the benefit-cost ratio represents a value of 1,07. This indicates that the investment in a car-free city is beneficial for society given the circumstances and incorporated effects. If the liveability benefit multiplier is even bigger, many more benefits are generated.

5. CBA as an improvement tool

Given the input data, assumptions and estimations it is concluded the CBA outcomes are not economically feasible for society. However, insights can be derived by using the CBA to learn lessons. As Rienstra (2008) concluded, the CBA can also be used as ‘improver’ instead of ‘assessor’. The gained results can be used to alter project alternatives in order to create a more optimal alternative. Therefore, three different configurations are created wherein alterations are made to earlier created project alternatives.

In configuration 1 the car substitutes are divided differently than in project alternative 2. The investments in public transport results in more public transport users than in project alternative 2 and inherent less cyclists. In this configuration it is assumed 90% of the car trips are substituted to public transport and 10% to bicycle. The altered division of travellers over the alternative modes of transportation results in a benefit-cost ratio increase from 0,71 to 0,73.

In configuration 2 the impact of an increased amount of cyclists is assessed by altering project alternative 4. Therefore, in the division of car substitutes, 90% of the travellers are assigned to a change to the bicycle while the remaining 10% makes use of public transport. By assigning more cyclists, the cost-benefit ratio does not change compared to project alternative 4 and keeps constant at 0,68.

Configuration 3 assumes still some cars are allowed to park in the city centre. This configuration intends to assess the impact of allowing a small amount of cars to park in the city centre and thereby reduce costs. By allowing cars to park in the city centre disutility of leisure travellers is reduced and

parking earnings are generated. Hereby, the city will not be entirely car-free but major costs can be reduced. Therefore, in the configuration it is assumed 25% of the current leisure car parkers are allowed to park in the city centre. Project alternative 1 is altered to assess the impact of the cost reduction. Project alternative 1 is chosen as base case since no investments are made and thereby the most pure effect impact can be determined. By allowing 25% of the leisure travellers to park their car in the city centre, the benefit-cost ratio substantially improves from 0,71 to 0,90.

In case investments in public transport are made then it is preferable to have as much travellers to switch to public transport as possible. The more public transport users, the better the benefit-cost ratio. In addition, configuration 2 showed in case the bicycle is centralised and more travellers make use of the bicycle that no substantial additional benefits are made. Based on these insights, it can be concluded that benefits derived from additional public transport users increase more rapidly than benefits derived from cyclists. Therefore, given the used input data and assumptions in this research, it is recommendable to favour public transport over the bicycle in an economic sense.

Configuration 3 proved the impact of a utility loss for leisure car travellers to park their car in the city centre is substantial. By allowing travellers to park their car in the city centre, these costs can be reduced massively resulting in a more beneficial NPV and benefit-cost ratio. Moreover, the parking revenue loss is smaller since some cars are allowed to park. In other words, a transition from completely car-free towards traffic-calm results in less costs and thereby might be more socially feasible. However, by reducing these costs and allowing cars to park in the city centre, the concept of a car-free city centre cannot be achieved. A summary of the benefit-cost ratio per alternative and configuration is given in figure 4.

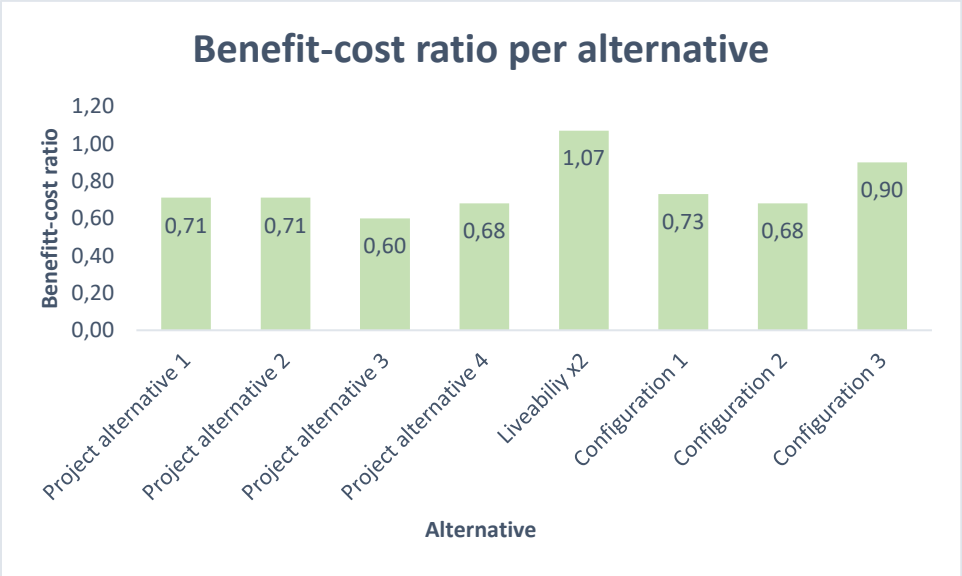

Figure 23 Benefit-cost ratio per alternative

6. Discussion

The incorporation of effects and their valuation is questionable. An as fair and transparent as possible CBA model is estimated. However, due the lack of robust scenarios, the results require nuance. Therefore, the CBA outcomes will be used as 'improver' as argued by Rienstra (2008). The valuations and thereby the results may lack empirical evidence to portrait a realisable project alternative for society, but the results can be assessed to learn lessons.

By taking a look at the effects it can be concluded that travellers car utility is highly valued. Travellers do not wish to be kicked out of their car. The exclusion of the car alternative results in serious costs which outweigh the benefits immensely. Assuming the effect valuations are a correct approach of the costs, the sum of total costs are probably still undervalued. In this research it is assumed an entire car-free city is not realisable and concessions must be made. Therefore, exceptions are made such as disabled transport. If the research into car-free cities further develop, and disabled transport will not be possible anymore, more negative costs regarding car utility will follow.

Despite a negative NPV, it can be concluded that the prevented emissions are a positive benefit for society. Although, it must be noted that it is possible the emissions problem is moved to another area due to changes in travel behaviour. An important benefit for society is the benefit regarding health. Intensified use of the bicycle will result in more efficient productivity and thereby a serious benefit for society.

Based on the most important costs and benefits, it can be concluded, based on this research, that it is recommendable to facilitate travellers, whom have to switch to another mode of transportation, as good as possible to prevent crowdedness and gain specific infrastructure benefits such as a waiting time reduction in public transport and network benefits in the bicycle network. In order to gain the biggest benefits it is recommendable to facilitate public transport users. The more car trips are substituted to public transport, the bigger the benefits. If public transport is better accessible and travel time is minimised, the utility loss will be smaller. However, arguably it is preferable for governmental bodies to facilitate cyclist due to a higher acceptability and beneficial health effects. Literature mentions many more health effects but those are not incorporated to prevent for double counting. For example, because of less noise, emissions and stink, the life expectancy of residents increases. Another example is less obesity because travellers walk and cycle more. It is imaginable decision makers prefer societal health benefits for cyclists over the likes of a public transport provider. Thus, in a more optimal scenario, it would be recommendable to facilitate cyclists as much as possible, even if a traveller can only partly make its trip by bicycle. Additionally, to partly facilitating cyclists, it is important to facilitate the first part of the travellers trip which can either be done by improved public transport or sufficient P+R facilities in the city of Rotterdam. However, these investments result in bigger costs than benefits, it might be preferable for society.

The negative NPV is dominated by serious costs. This might be misleading after all since it is very likely society benefits even more from liveability effects than depicted in the CBA. A more robust design can provide insight in the development of urban areas and thereby the valuation of liveability Moreover, as a result of improved liveability, more benefits, such as increased house prices or revenues increase for local businesses, can occur. These benefits are not considered in the CBA but society can certainly benefit further than the CBA depicts.

A car-free intervention or policy can be seen as car-bullying and car travellers experiencing this bullying effect lose a lot of utility. By being a bit more lenient, the loss of utility can be reduced and thereby serious costs can be limited. Therefore, traffic-calm concepts might be more feasible than a more radical car-free intervention. By doing so, policies to reduce car usage in the city centre might have a bigger support base. However, it must be noted that decision makers must be aware of the possibility that a more lenient car-free intervention might result to inequality. Therefore, if a more lenient car-free policy is considered, it is advisable for governmental bodies to elaborate on the implications for society.

7. Conclusion

The Netherlands is in need to reduce emissions. By 2030 the emissions must almost be halved compared to 1990 and in 2050 the emissions must be reduced by 95% compared to 1990. This requires drastic measures and interventions regarding cars are already taking place. The city of Rotterdam has an ambition to be more sustainable, energy-efficient and improve the air quality. Currently, measures to reduce emissions, are already taking place in the city of Rotterdam and more initiatives are considered. Based on the idea to reduce emissions, this research attempts to get by an explorative nature, insight in the societal feasibility of a car-free city centre. The research aims to provide insight in the costs and benefits occurring in case a car-free intervention, in this case a car-free city centre intervention in the city of Rotterdam, would be implemented. The literature lacks to give useful insights in costs and benefits related to effects occurring in car-free environments. Hence, it is unclear which elements are important to realise a car-free city centre. To get insight in this gap and learn lessons, the following research question is to be answered:

Which policy lessons can be learned from societal cost-benefit results of a car-free city centre intervention in Rotterdam?

Based on a stakeholder analysis, providing insights in implications and the most important factors for stakeholders, scenarios are created. These scenarios are created in a limited time frame and thereby may lack robustness. However, given the explorative nature of this research, rough scenarios are regarded sufficient to get insight in the effects of a car-free city centre. The explorative scenarios will be limited regardless since they will be effective starting from 2030. The scenarios analysis resulted in three different project alternatives:

1. No additional investments
2. Invest in public transport
3. Invest in P+R & shared mobility
4. Rotterdam bicycle city

In each scenario the current car trips are substituted by both public transport and cycling. The difference between the alternatives is the division of travellers over the modes. Based on these project alternatives in can be concluded that either no investments or investing in public transport is most beneficial for society. Investing in the bicycle infrastructure is less beneficial but it might be recommendable to consider centralising the bicycle. In comparison with the other alternatives, significant health benefits are generated and these benefits are arguably more important for society. Investing in P+R facilities, to partly facilitate car travellers, is estimated as the worst alternative since both highly beneficial effects, public transport revenues and health effects, are limited. The NPV is in each scenario negative and out of an economic perspective it is not recommendable to implement a car-free city centre in the city of Rotterdam. Despite, a negative NPV and not economically feasible alternatives, the research provides insights in the impact of certain effects on society. Decision makers might prioritise beneficial effects for society over costs. Therefore, arguably, a car-free city centre intervention is beneficial for society despite a negative NPV.

It can be concluded that travellers value car utility highly and is thereby an important element in the CBA calculation. Commuters experience a big utility loss due to additional travel time. Next to that, leisure travellers are not able to park in the city centre anymore and that results in a loss of consumer surplus. Parking by itself can be a big issue in the political debate since it generates a lot of income and by banning cars the municipality loses this source of income. However, by banning cars, space comes available and society can profit from spatial benefits. The municipality has less car

related maintenance and the space can be restructured with for example more green. The exact impact of this effect is not assessed in this research since the design of a car-free city centre is out of scope of this research.

Society benefits from reduced emissions, however the impact of this effect might be neglected since it is possible travellers change their travel behaviour and the impact of this change could result in a shift of emissions. Despite the impact of emissions might be neglected, liveability effects in general are important elements to evaluate. Often, liveability effects are underestimated. If the effects, defining liveability, are underestimated, a true valuation might result in a beneficial CBA outcome. If the liveability effects are twice as big as estimated, the benefit-cost ratio already indicates a beneficial investment for society. An interesting benefit are the health effects due to more cyclists. Commuters are more healthy if they cycle and this results in a productivity gain. This effect is very beneficial for society. Another very beneficial effect for society is the increased public transport revenues due to more users. The health effects and public transport revenues are estimated by the division of additional travellers over the public transport or bicycle mode. Because either mainly health effects or public transport revenues are gained, there is a tension field between those effects. Thereby, the division of travellers over alternatives mode is a decisive element.

In this research, the CBA is used as a design instrument for further research and it provides insights in the most important effects to improve project alternatives. An important lessons learned is by altering the division of travellers over the alternative modes of transportation, it can be concluded that investing in public transport is more beneficial, in an economic sense, for society than any other alternative. Mainly the influence of additional public transport revenues and prevented crowdedness are important effects. Additional cyclists do not result in an improved benefit-cost ratio. However, health effects, the main benefit by centralising the bicycle, are likely more substantial than estimated in this research and thereby underestimated.

If decision makers decide to be not entirely car-free but focus on a more traffic-calm solution, the benefit-cost ratio improves. Each additional allowed car will result in greater benefits because disutility amongst car users is prevented. This insight can be a valuable lesson in order to reduce costs and resistance. A transition from traffic-calm towards car-free is less extreme and it is likely utility losses are smaller.

Researchers, looking into the most optimal car-free city centre design, are recommended to focus on the facilitation of travellers in order to minimise the utility loss. Moreover, it is important to stimulate public transport usage since it generates additional public transport revenues. Overall, a car-free city centre might not be the optimal intervention to reduce emissions because in an economic sense, it has only a minor impact on society. Although, despite high costs, a car-free intervention might be suitable to achieve the goals of the municipality of Rotterdam.

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Appendix B – Overview of literature

In the following table 1 the literature is presented to provide an overview of the inclusion of literature on certain aspects. The 5 core articles are highlighted bold.

Table 10 Literature overview

Literature	**Papers that address the core concept of car-free cities**	**Papers that address effects occurring in a car-free environment**	**Papers that address the acceptance of car-free concepts**
Borgers et al. (2008)			X
Borges & Goldner (2015)			X
Brown (2017)		X	
Gundlach et al. (2018)			X
Loo (2018)		X	X
Nieuwenhuijsen et al. (2017)		X	
Nieuwenhuijsen & Khreis (2016)	X	X	
Nieuwenhuijsen et al. (2019)	X		
Melia (2014)	X	X	
Melia et al. (2013)			X
Morris et al. (2009)			X
Nobis (2003)		X	
Ornetzeder et al. (2008)		X	
Pojani (2007)			X
Topp & Pharoah (1994)	X		

Appendix C – Interviews

C.1 Interview Kristiaan Leurs

Senior adviseur mobiliteit Rotterdam – 13-3-2020

1: Wat is jouw functie binnen de gemeente Rotterdam en met wat voor werkzaamheden houd jij je bezig?

Mijn naam is Kristiaan Leurs en ik ben senior adviseur bij de afdeling mobiliteit voor de gemeente Rotterdam. Ik houd mij bezig met strategische vraagstukken (midden) lange termijn. Ik schrijf o.a. de mobiliteitsaanpak voor de gemeente. Dit is een visieplan voor het beleid en hoe voeren we dit uit. Daarna ga je naar concrete uitwerkingen zoals de Coolsingel autoluw maken. Daarnaast focus ik mij op zaken die heel normaal lijken maar weinig aandacht krijgen. Zo heb ik mij twee jaar terug gefocust op het boosten van de positie van de voetganger. Binnen de gemeente hebben we de switch gemaakt van focussen op de auto naar focussen op de voetganger. Dus wat we eigenlijk doen is denken vanuit de mens waarbij lopen de primaire vorm van transporteren is. De eerste gedachte in verkeerskunde is vaak vanuit het autoperspectief.

Vanuit Rotterdam wordt vaak gezien als een fantastische auto stad. Experts zien juist Rotterdam als dé OV stad van Nederland. We waren de eerste stad met een metro bijvoorbeeld. Daarnaast heeft Rotterdam het meest aantal voetgangers van de vier grote steden in Nederland. Dit komt ook omdat het autobezit vrij laag is in Rotterdam (0,6 auto's per huishouden).

2: Hoe hebben jullie door de jaren heen het autogebruik gereduceerd?

Dit komt vooral door de politieke dynamiek, een soort modernisme. Vanuit de beleidsmakers was er bijna 40 jaar geleden al een progressief verhaal om dit te reduceren. Vanaf 2005-2010 hebben we in het nieuwe binnen stadsplan ingezet om een andere vorm van naamgeving. Dit plan was gericht op 'city lounge'. We zagen een hele grote opkomst in flexibel en een andere manier van werken door het internet bijvoorbeeld. Daarom creëerde we betere verblijfruimtes op straat maar ook de inrichting van hotels en restaurants. Mensen waardeerde deze manier van werken hoger dan het reizen naar een bepaalde locatie om daar te werken over een hoger aantal rijbanen. We faciliteerde weggebruikers om een mentaliteitsswitch te maken. Een voorbeeld is het veranderen van parkeerkades in grote groene gebieden waar mensen graag samen kwamen.

Daarnaast hebben we ook flink geïnvesteerd in P+R om het aantal parkeerplekken in de stad te reduceren. Een ander goed voorbeeld is de verbouwing van het centraal station. Hier hebben we extra geïnvesteerd in de buitenruimte. Mensen zijn trots op het station en de stad. De auto kwam onder de grond en kreeg in een minder prominente plek in het stadsbeeld. Hierna volgde de verbouwing aan de Coolsingel. Vanuit de gemeente zijn er ook flinke discussies geweest om de auto component. Mensen moeten voelen dat er ook een verbetering is voor hun aan bv woonomgevingen of de straat. Daarnaast hechten ze veel waarde aan groen.

3: Is het haalbaar in de economische zin om een volledige autovrij centrum te implementeren? Dit brengt natuurlijk veel verschillende effecten met zich mee.

Voorheen heb ik gewerkt bij de gemeente Den Haag op de mobiliteits afdeling. In het centrum hadden we de vieste straat van Nederland door de uitstoot. Dus hier moesten we een verandering maken. De winkelstraten zijn nagenoeg autovrij gemaakt, je kan overal wel inrijden maar niet

doorrijden. Ondanks dat er fel protest was van ondernemers zagen we dat inkomsten toenamen, waardering omhoog ging en dat er een waardestijging was van grond. Wel zagen we een hele sterke differentiatie want er zijn winkels en ondernemers failliet gegaan. Dus ondanks dat een tak zeker profiteerde in de economische zin zagen we ook dat er een keerzijde was.

We hebben veel studies gedaan naar parkeren en omzet. Bijvoorbeeld op de Meent hebben we studies gedaan naar klanten die voor de deur parkeren of klanten die te voet komen. Het blijkt dat voetgangers veel meer uitgeven.

4: Denkt u dat bepaalde modaliteiten uit het straatbeeld verdwijnen?

In de huidige politiek is het wel steeds meer aan de orde dat we kritisch kijken naar de prestatie van een modaliteit. Daarbij zien we een verandering in de gedachte van verkeersstroom naar de belangrijkheid van de plek. Hierbij bedoel ik te zeggen dat we niet meer kijken naar het is belangrijk dat je hier 50 km/u kan rijden maar kijk kritisch naar hoe je wegennetwerk is ingericht zodat de plek centraler komt te liggen. Daarbij focussen we op nieuwe ontwerprichtlijnen waarbij we focussen op verschillende snelheden en kies harder voor of de modaliteit wel of niet past. Dus als de tram de kwaliteit niet haalt dat je die weglaat. Of als je de auto uit het straatbeeld wil houden dat je een harde keuze maakt om de auto te schrappen en de tram vol te verbeteren.

In Rotterdam presteert de metro enorm goed, we zien vooral dat bussen en trams onderbezet zijn. We kunnen een keuze maken om dit sterk te verbeteren maar dan moet het wel rendabel zijn.

5: In 2030 moeten jullie 49% CO2 hebben gereduceerd t.o.v. 1990, wat is jullie plan om dit te bereiken?

Dat is heel breed maar als we ons even focussen op de mobiliteit dan zijn er veel maatregelen gefocust op emissie loos rijden, dus door in te zetten op bijvoorbeeld laadpalen, subsidie trajecten etc. De koppeling tussen fysieke maatregelen, dus dat je ergens niet mag rijden, zijn wel doorgedacht maar niet hard gemaakt met modellen. Één van de doelstellingen is wel minder doorgaand autoverkeer in de binnenstad. Dit moeten we wel koppelen aan een modalshift. Want als mensen op een andere plek gaan rijden heb je een verschuif effect. Daarbij moeten we dus ook investeren in OV etc. Onze missie is vooral om alternatieven te stimuleren. Waar we vroeger op en en en inzetten, laten we mensen nu een hardere keuze maken voor een modaliteit.

6: Hoe staan huidige bewoners in het centrum tegenover een verdwijning van de auto in het straatbeeld?

Dat heeft te maken met de beeldvorming die je iemand voorspiegelt. Als we ze een verhaal verkopen met meer groen, betere fietspaden, hoogwaardig OV maar 3 minuten langer reistijd dan is dat een heel ander verhaal dan dat ze ergens niet meer mogen rijden of parkeren. We moeten heel concreet maken wat de maatregelen voor impact hebben op de reiziger.

Mensen willen het liefste niet veranderen behalve als je heel scherp kan maken wat de (positieve) gevolgen voor hun zijn.

7: Denk je dat we zonder de auto inclusiviteit kunnen waarborgen?

Je ziet een aantal effecten, zoals dat huizenprijzen stijgen. Hierbij zie je een verdringing. Een bepaalde groep van de bevolking komt verder van de stad te wonen en daarmee de alternatieven als goed OV vervoer of de fiets. Die mensen die worden verdrongen die werken over het algemeen niet in de stad maar op bijvoorbeeld bouwplaatsen of in de haven. Deze mensen zijn dus heel erg auto

afhankelijk. Hierdoor zien we een soort dubbel versneld effect. De mensen die de auto willen gebruiken die vertrekken uit de stad.

De grootste relatie tussen het hebben van een auto is de relatie met beschikbaar inkomen. Autoprijzen zullen dalen in de toekomst en daarmee wordt de keuze voor de auto steeds gemakkelijker. Hieruit concludeer ik dat er nog steeds een best wel grote noodzakelijkheid is voor een auto. Uit studies blijkt ook dat als je wil dat mensen welvarender worden dan moet je ze een auto geven. Op die manier kunnen mensen bijvoorbeeld hun werk bereiken (denk hierbij aan de loodgieter bijvoorbeeld). Veel van deze mensen werken overal en nergens en kunnen dan ook niet met het OV hun bestemming bereiken.

Met inclusie willen we eigenlijk mensen dichter bij elkaar brengen. Maar eigenlijk zet nieuwe technologie alleen maar mensen verder uit elkaar. In Rotterdam wilde we bijvoorbeeld een e-lane bouwen voor elektrische auto's. De volgende dag stond in de krant dat het een elite-lane was voor de rijke Tesla rijder.

Dus om te voorkomen dat mensen worden uitgesloten proberen we gehoor te geven aan burger initiatieven en om die manier mee te denken met hun belang. Het lastige is dat deze initiatieven wel vaak komen vanuit de bovenkant van de maatschappij.

8: Zou je deelverkeer een mooi alternatief vinden in de binnenstad?

Rotterdam is een experimentenstad dus we bieden ruimte aan deelvervoerders om hun product te testen. Het is een mooi alternatief om mensen van A naar B te brengen maar of het helemaal toereikend is betwijfel ik. Het aanbod is beperkt tot bepaalde regio's waarbij bijvoorbeeld Rotterdam-Zuid is uitgesloten omdat aanbieders bang zijn voor vandalisme. Hierdoor is het deelvervoer niet voor iedereen toereikend en wordt zeker niet het meeste verkeer naar de binnenstad ontzien.

Nu hebben we ook nog uitdagingen met handhaving van bijvoorbeeld het parkeren van de fiets. We willen uiteraard geen zwerffietsen die het straatbeeld verloederen. De discussies over fietsenstallingen in het algemeen zijn nog vrij lastig omdat het erg dure investeringen zijn. Deze investeringen hebben ook invloed op de ontwikkeling van de auto in het stadsbeeld. Als de fiets niet goed wordt gefaciliteerd dan is het niet verleidelijk om over te stappen vanuit de auto.

Wat wel interessant is dat met name jongeren niet per se een auto willen bezitten maar er wel over willen kunnen beschikken. Vanaf 40 jaar een ouder is die behoefte veel sterker omdat, zeker vroeger, een auto hebben status was. We zien dus nu dat het hebben van een auto minder belangrijk is maar dat het wel noodzakelijk is om de auto te kunnen gebruiken als vervoersmiddel. Deze mentaliteit verandering komt ook doordat services beter zijn gefaciliteerd met bijvoorbeeld apps.

9: Wat is uw visie op de toekomst qua mobiliteit betreft het stadscentrum?

Ik denk vaak na over wat een stad een stad maakt. Wat zijn drijfveren? Waarom willen mensen er wonen of werken? Hierin onderscheid ik drie componenten: veiligheid, werk en zelf ontplooiing. Vanuit die dynamiek heb ik een visie. Ik denk dat hierin het perspectief van bijvoorbeeld gezondheid en veiligheid de indeling van je stad sterk beïnvloed. Als mensen bang zijn voor terrorisme dan worden er bijvoorbeeld terrorisme paaltjes geplaatst. Dus hoe wordt mijn vrijheid voor beweging bepaalt? Waar bouwen we? Dit soort thema's hebben invloed op de mobiliteits ontwikkeling van de stad. Economie blijkt uiteraard belangrijk maar ik denk dat in de toekomst de drijfveren voor de ontwikkeling van mobiliteit anders zullen zijn.

10: Wat zijn voor jullie belangrijke parameters betreft de implementatie van een autovrij centrum? Wat is voor jullie een hoog agendapunt?

Parameters als veiligheid en aanrijtijd van hulpdiensten staan stipt op 1, die zijn leidend. Ik heb een document (het UMPR) waarin 59 parameters staan met input en output die we gebruiken in mobiliteitsbeleid.

C.2 Interview Halmar Kranenburg

Beleidsadviseur RET – 7-4-2020

1: Wat is uw functie binnen de RET?

Officieel ben ik een beleidsadviseur bij strategie en ontwikkeling. Ik focus mij primair op hoe het vervoer zich ontwikkelt over de jaren heen. Groeien de reizigers aantallen, moeten we extra metro's inzetten, is de dienstverlening nog toereikend of moeten we extra ritten aanbieden of juist bezuinigen en minder ritten rijden? Mijn takenpakket varieert van de jaarlijkse dienstregeling (die per december steeds ingaat) tot en met ver in de toekomst onderzoek doen naar bijvoorbeeld de mogelijkheid om de automatische metro te implementeren.

In typische werkgroepen werk ik samen met de gemeente, MRDH natuurlijk als opdrachtgever en productontwikkelaars.

2: Recent sprak ik Kristiaan Leurs, senior adviseur mobiliteit binnen de gemeente Rotterdam. Hij gaf aan dat de RET eigenlijk heel goed presteert. Zou het huidige OV netwerk in Rotterdam een autovrij centrum aankunnen?

Op dit moment hebben we al een dusdanige groei dat de capaciteit nijpend wordt. Als de autonome groei als zo hoog is (4 tot 5% per jaar) laat staan wat de impact van een autovrije stad op ons netwerk heeft. Daarom zijn we momenteel al met de gemeente in gesprek over beleidsmaatregelen. Het is nog niet duidelijk welke beleidsmaatregelen daadwerkelijk gaan worden doorgevoerd.

Rotterdam heeft best een groot deel al van het centrum afgesloten. Zo is de lijnbaan de eerste autovrije straat van Europa, het gebied is ook al best wel breed waar je niet met de auto kan komen. Dit wordt met huidige OV netwerk prima opgevangen.

Wel beginnen we al aan onze grenzen te komen. Met grenzen bedoel ik dat we over 5 jaar aan onze capaciteit zitten (zonder in te grijpen). Dit jaar hebben we al een bezettingsgraad van 100% gehaald wat betekent dat we dit jaar al meer metro's gaan inzetten. Die metro's zijn al eerder aangeschaft maar het aanschaf traject duurt wel 5 tot 6 jaar. Idealiter hebben we een bezettingsgraad van 80 tot 85 %. 100% is niet wenselijk omdat dan sommige ritten zo vol zitten dat we Japanse toestanden krijgen. Daarnaast kan de situatie ontstaan dat als we boven de 100% bezettingsgraad hebben dat we reizigers moeten achterlaten op het perron. Dat is zeker niet wenselijk.

Als we kijken per modaliteit dan zien we dat de trams en bussen wat leger zijn en daar zit zeker nog wat capaciteit. Op het moment dat de intensiteit toeneemt dan moeten we gewoon nieuwe voertuigen aanschaffen, zo simpel is het. Op de trajecten is nog ruimte om meer voertuigen te laten rijden.

3: U geeft aan dat er ruimte is bij bijvoorbeeld de trams. Veel dezelfde reizen binnen het centrum kunnen worden gemaakt met dezelfde modaliteit en daarmee is het aantrekkelijk om mensen in plaats van met de metro te laten reizen met de tram bijvoorbeeld. Zo zouden jullie bijvoorbeeld de spreiding over de modaliteiten kunnen waarborgen. Hebben jullie invloed op met welke modaliteit de reiziger reist?

We hebben niet erg veel middelen om dat te doen. We kunnen de tramkaartjes goedkoper maken maar als mensen dan 2 haltes met de tram reizen en vervolgens als nog op de metro moeten overstappen dan heeft deze interventie weinig zin en dan kiezen reizigers ook niet voor de tram. Wat

wel helpt is de reistijd bespelen door de tram reistijd gelijk te maken aan die van de metro, maar goed dit is wel 'faken'.

4: Is er toenemende druk op het OV door een autoluwe Coolsingel? Is er rekening gehouden in het beleid door bijvoorbeeld te investeren in OV?

Nee er is geen rekening gehouden in het beleid met een mogelijke toenemende druk op het OV netwerk. De Coolsingel interventie is wel een stukje beleid om het gebied autoluwer te maken en auto's hiermee rondom de omgeving te laten rijden. De tram is er ook gelijktijdig uitgehaald, desondanks hebben we nog geen effect gezien. Wellicht is het in het aantal metro gebruikers te zien maar dit beeld is weer vertekend door de autonome groei.

Voor nu kunnen we nog groeien in het huidige metro netwerk. We kunnen nog een slag van 10 minuten extra per uur aan wat neerkomt op een toename van 30%. Het aanleggen van een metrolijn is financieel niet haalbaar naar waarschijnlijkheid.

Wellicht ontstaat er meer druk rond het centraal station. Momenteel vervoeren om en nabij evenveel reizigers vanaf het station als de NS. De RET heeft ook nagedacht over deelfietsen om het netwerk te ontzien of juist een boost te geven. Alleen zien we dat deelvervoer meer incidenteel wordt gebruikt en geen volledig vervangend alternatief is.

5: Waar verwacht je knelpunten? Bijvoorbeeld bij P+R of een bepaalde hub/station?

Ik denk dat de P+R heel druk gaan worden. Net zoals de locaties vanaf waar de stad autovrij wordt. Mensen zullen in de buurt willen gaan parkeren waar ze nog met de auto mogen komen.

Het OV heeft momenteel een aandeel van om en nabij 30% marktaandeel reizigers in het centrum. Waarschijnlijk zal een centrale hub zoals Beurs enorm groeien in reizigers aantallen. Nu kijken we al of we Beurs kunnen ontzien door bijvoorbeeld te investeren in de Oeververbinding.

6: Zie je de tram verdwijnen uit het straatbeeld en wat voor implicaties heeft dit voor de rest van het netwerk?

Ik denk het niet. Mijn insteek is dat de tram in een hogere frequentie gaat rijden. Daarnaast hoop ik dat de tram (semi) geautomatiseerd wordt. Daarnaast is het enorm belangrijk om vervoer naar het centrum te hebben als je er niet kan komen heb je ook geen leefbaar centrum. Vergelijk het met de toevoer weg van Venetië. Het is autovrij van oudsher maar toch zal je een vervoersmiddel naar het centrum toe moeten hebben anders komen de toeristen ook niet.

Bovendien als we de tram niet meer gebruiken dan komt er een te grote druk op het metro netwerk en zullen we een nieuwe lijn moeten aanleggen. Daarnaast is het voor ons niet mogelijk om alle huidige reizen van A naar B te blijven faciliteren. De metro transporteert over afstanden van ongeveer 500 meter terwijl de tram over veel kleinere afstanden vervoerd.

Daarnaast zie je ook andere type reizigers in de tram en metro. Zo reizen bijvoorbeeld veel meer oudere, 'shoppers', of ouders met een kinderwagen met de tram omdat het toegankelijker is en zeker voor kortere afstanden een geschikte modaliteit is.

De tram is relatief een fraai vervoersmiddel. De tram kan door het gras rijden (op rails uiteraard) en kan op die manier bijdragen aan een fraaier straatbeeld of wel de leefbaarheid. Zo is er ook sprake van de Coolsingel onder water zetten. De tram zou prima hier tussendoor kunnen rijden. Ruimtelijk gezien heb je met een tram veel meer mogelijkheden.

7: Zou het OV een voldoende toereikend alternatief bieden om de auto te vervangen?

Momenteel niet, we moeten investeren in het volledige OV netwerk. P+R moeten in capaciteit toenemen net als het aantal voertuigen per modaliteit. Bijkomend is dat we moeten investeren in opslaglocaties en elektriciteit.

Los daarvan als we ingaan op de verschillen tussen de vervoersmiddelen, dan moeten we inzetten op een mentaliteit verandering bij reizigers. Wij werken daarom aan het interieur en de 'luxe' van onze voertuigen zoals luxere bekleding, het laden van je telefoon of het gebruik van wifi. Het OV heeft als toegevoegde waarde ten opzichte van de auto dat je niet zelf niet hoeft te rijden en daardoor kunnen reizigers andere handelingen zoals sociaal contact of werk uitvoeren.

Daarnaast zie je in andere steden zoals New York of Berlijn dat het ook als zakenman heel normaal is om met het OV te reizen omdat de mentaliteit van reizigers veranderd. Mensen beginnen ook steeds groener te denken over hun manier van reizen.

8: Waar liggen nog kansen voor innovaties?

Met name in het automatiseren van transport modaliteiten. Zonder chauffeur kunnen we veel vaker rijden. Daarnaast liggen er kansen voor betalen met andere systemen om dat te vereenvoudigen. Verder moet nog meer worden ingezet op schonere innovatie, zero emmission.

Binnen de RET zijn we momenteel aan het inzetten op een stukje marketing. We proberen onze voertuigen zo in te richten dat het voor meerdere type reizigers toegankelijk is. Zoals in de trein loungebanken zijn geplaatst waar bijvoorbeeld jongeren graag willen zitten. Door in het openbaar vervoer meerdere smaken te maken kunnen we op een andere manier hoogwaardig vervoer te accommoderen.

C.3 Interview Bart Eigeman

Voormalig wethouders Den Bosch – 6-4-2020

1: Wat is precies allemaal autovrij gemaakt en uit welke gedachte is dit gedaan?

Destijds waren emissies één van de redenen maar het was niet zo'n belangrijk punt als dat het hedendaags is. De gedachte kwam vanuit de infrastructuur. Den Bosch is vanuit oudsher een middeleeuwse stad en het verkeer stroopt op. Dit verkeer 'infarct' taste de leefbaarheid, geluidsniveau en kwaliteit van de verkeersstroom aan en daarom moest er een verandering teweeg worden gebracht. Daarnaast heerste er de gedachte dat de binnenstad moest 'overleven' ook voor het winkelend publiek dan moeten we de auto anders gaan faciliteren. Als je gedachte aan Den Bosch is, dat is die stad waar je je vast rijdt, dan komen bezoekers niet meer terug. Ik wilde juist een herinnering creëren aan hoe mooi en gezellig de stad was en wat kunnen we er goed shoppen. Dus een economische reden vanuit milieu, leefbaarheid & ruimtebeslag lag ten grondslag van dit idee.

Vanuit hier hebben we een koersnota gemaakt in samenspraak met andere partijen om te bepalen waar moet die auto komen. Daarop hebben we benoemd waar de hoofd toegangswegen moeten komen. Dus waar moet de auto goed geaccommodeerd worden dat het ook goed door rijdt. Dus niet autootje pesten maar autootje faciliteren. Daarbij dachten we na over waar kunnen we mensen naar toe verlijden dichtbij de binnenstad maar ook wat verder weg om te parkeren.

Het centrum van Den Bosch is typerend bij de kathedraal St Jan en het bijliggende plein de Parade. Voorheen kon je voor de deur van de Kathedraal parkeren. Dit gebied en omliggende winkelstraten zijn autovrij gemaakt. Dit hebben we gedaan door duizend parkeer plekken te schrappen. Je kan op sommige stukken nog wel rijden maar dit is een gelimiteerde autozone met paaltjes. Zo kan je er nog rijden alleen strikt noodzakelijk want parkeren is niet mogelijk.

De geschrapte parkeerplekken hebben we gefaciliteerd door het bouwen van hoogwaardige P+R locaties waar je heel goedkoop kan parkeren. Met een bus kan je vanaf zo'n transferium naar het hartje centrum Den Bosch. Het was heel belangrijk om te investeren in deze P+R en een kwalitatief hoge faciliteit te bouwen. Het moest meer zijn dan een garage en het idee brengen bij gebruikers van de garage dat ze in een geweldige stad kwamen, waar je dichtbij het centrum op een goed gefaciliteerde parkeerplek kon staan en kon genieten van een autovrij levendig centrum.

Het idee is ontstaan vanuit de gedachte om auto's te verplaatsen naar een andere plek maar ook om het aantal te reduceren. Het reduceren hebben we gefaciliteerd door hoogwaardig OV in te zetten en met name in te zetten op de fiets. Het was ook van belang omdat destijds maar +/- 2% reisde met het OV naar de binnenstad en +/- 30% met de fiets, dit zijn relatief lage aantallen ten opzichte van de auto wat een aandeel had van +/- 50%. We hebben daarom flink geïnvesteerd in het fietsnetwerk wat resulteerde in dat Den Bosch de fietsstad van Nederland was in 2011. Uiteindelijk was een totaalpakket van maatregelen noodzakelijk om de mentaliteit van reizigers te veranderen om niet meer met de auto te reizen of in ieder geval niet naar de binnenstad van Den Bosch.

2: Wat was de grootste weerstand en hoe is hiermee omgegaan?

De grootste weerstand kwam vanuit de ondernemers en horeca uit de binnenstad. Dit kwam vanuit de gedachte dat de binnenstad zou leeglopen en dat daardoor hun inkomsten zouden dalen. De voorzitter van de ondernemers, Tinie, was iemand anders uit de gemeente die bij de VVD zat. Hij was fel tegen mijn plan. Desondanks snap ik ook wel hoe economie werkt en ben ik snel bij hem op de koffie gegaan. Hierbij heb ik mijn plan toegelicht en heb ik geprobeerd zijn argumenten te

weerleggen. Desondanks gaf ik toe dat Tinie een goed punt had betreft de inkomsten en stelde ik voor dit te laten onderzoeken. In Montpellier en Gent hadden ze al vergelijkbare onderzoeken gedaan waaruit bleek dat, omgerekend naar Nederlandse tarieven, een fietser 75 euro uitgeeft in de binnenstad terwijl een automobilist tientjes minder uitgeeft. Deze uitkomst kwam mij natuurlijk heel goed uit. Daarom hebben we onderzocht of we goed konden inzetten op de fiets.

Vlakbij het stadhuis stond een groot leegpand die we hebben gehuurd en hebben omgetoverd tot een hoogwaardige fietsopslag met kluisjes en een toilet. Het parkeren van de fietsen was gratis en het was een enorm succes. Momenteel is de opslagplek al te klein en mijn opvolger is nu bezig met het realiseren van meer fiets garages. Op deze manier konden we dus juist de ondernemers tegemoet komen omdat die fietsers zoveel meer geld uitgeven. We zagen ook daadwerkelijk een omslag vanuit de ondernemers. De ondernemers werden ook gefaciliteerd door het bevoorraden nog steeds te dogen via de auto. Weliswaar met een paaltjes systeem om te accommoderen dat auto's alleen met een bepaalde reden de stad kunnen betreden. Nog een positief effect dat hieruit volgde is dat bevoorrade veel beter konden doorrijden en dit resulteerde in tijdswinst en minder negatieve effecten zoals geluid en vervuiling.

3: Hoe is omgegaan met inclusiviteit van kwetsbare groepen zoals ouderen of gehandicapten?

Dat was in 2007 nog wel minder aan de orde. Desalniettemin speelde dit uiteraard wel een rol. Ik ben voor de verkiezingen op bezoek geweest in Hasselt waar gratis openbaar vervoer wordt gefaciliteerd. Hier was de inclusiviteit dus al wel. Door het gratis OV is bijvoorbeeld het ziekenhuisbezoek verviervoudigt in Hasselt doordat met name oudere makkelijker konden reizen. Daarom hebben we vanaf het Centraal station een gratis elektrisch busje laten rijden om mensen naar de binnenstad te vervoeren die dan konden uitstappen waar ze maar wilde.

Daarnaast zijn langs de parade nog wel gehandicapten parkeerplekken. Het centrum is dus autovrij met een kleine uitzonderingen voor leveranciers en gehandicapten.

4: Was er sprake van een economische impact? Bijvoorbeeld dat het MKB er onder leed of juist een stijging/daling in het aantal bezoekers van de pleinen?

Ik moet een beetje voorzichtig zijn want ik ken de absolute cijfers niet. Wat we wel zagen is dat er een ontvolking ontstond in de binnenstad doordat je je auto er niet meer kon parkeren. De bewoners die bleven die waren vooral erg positief over de welvaartseffecten zoals verminderde stank en herrie. Vervolgens zag je een nieuwe toestroom van bewoners die juist voordelen zagen van in de binnenstad wonen.

Wat we ook zagen was dat er een toename was in evenementen in de binnenstad en dan specifiek op en rondom de Parade. Dit resulteerde in meer inkomsten voor met name de (kleine) ondernemers.

5: Merkt u ook een keerzijde aan het beleid?

Je ziet een paar dingen. De fiets is enorm populair en met name de elektrische fiets. In regionale kernen zie je ook dat de auto minder ruimte krijgt en dat het aantal fietsers daar ook toeneemt. Hierdoor neemt het aantal fietsende bezoekers naar Den Bosch steeds meer toe.

Ook hebben we shared space ingevoerd waar de fietser en voetganger dezelfde ruimte deelt. Doordat het aantal bezoekers in de binnenstad zo enorm is toegenomen zien we dat er te weinig shared space is. Shared space leidt in principe tot een veiligere situatie omdat de weggebruikers rekening houden met elkaar want niemand wil natuurlijk een ongeluk. Het gebrek aan ruimte

resulteert in onveilige situaties, met name op bijvoorbeeld een marktdag. Het succes van de fiets is de keerzijde van het beleid.

Daarnaast maken nog steeds niet alle mensen gebruik van de fietsenstallingen. Deze liggen in principe in hoeken van het centrum maar mensen parkeren het liefst nog steeds voor de deur. Vanuit oudsher is Nederland een fietsland dus destijds wilde dit absoluut ook niet verbieden. Maar het succes van de fiets zorgt nu dat mensen bijna struikelen over de fietsen die voor winkels of andere faciliteiten staan. Daarom zet de huidige wethouder nu in op het reduceren van dit aantal fietsen met het programma Vak de fiets. Dit moet mensen aanzetten tot het netjes parkeren van hun fiets op de toegewezen plekken. Handhaven is dan ook een belangrijk om het succes van een autovrij centrum te waarborgen.

6: Als u nu nog een keer vergelijkbaar beleid zou moeten maken, wat zou u anders hebben gedaan?

Poeh dat is een goede, even nadenken hoor! Ik denk dat ik de distributie van begin af aan beter had gefaciliteerd. Destijds was het een discussiepunt of je als overheid een ondernemer mocht reguleren de ja of de nee. Dat zouden we tegenwoordig anders aanpakken, meer coöperatief. Ik zou meer inspelen op het individuele belang van de ondernemer en hierbij onderzoeken wat zij hier zelf aan kunnen bijdragen. Ik zou ze medeverantwoordelijk willen maken voor de oplossing. Dan kan de oplossing ook specifieker worden gemaakt. We kunnen dan gerichter aansluiten bij het eigenbelang van in dit geval de ondernemer.

Het gaat er om dat we de tegenstander verleider om te komen met oplossingen zodat iedereen betrokken is bij de oplosvorming. Dit werkt ook om weerstand te reduceren.

C.4 Interview Bonne de Roos

Redacteur Rotterdamse dromers 10-4-2020

1: Wat is jouw rol en het doel van Rotterdamse dromers?

We zijn met 5 'dromers'. De vier andere komen uit de hoogbouw en hadden verschillende ideeën over de stad maar er is geen plek om te delen. Ik ben daar vervolgens bij gevraagd omdat ik ook zo mijn ideeën heb over de stad en ik kan goed schrijven omdat ik dit ook voor m'n werk doe.

Het doel van de Rotterdamse dromers is een platform bieden aan ideeën die ik en de 4 andere dromers hebben. We hebben gewoon een aantal ideeën over de stad en wij zochten een manier om dat te ventileren. Dus op dit moment is het vooral een platform voor onszelf waar wij onze plannen plaatsen maar waar wel ruimte is voor bezoekers van de site om te reageren op deze ideeën.

2: Waar komt het idee vandaan en wie vertegenwoordigen jullie?

Het is niet dat we per se een groep vertegenwoordigen want wij verzinnen zelf de ideeën. Maar veel ideeën ontstaan wel uit gesprekken met burgers of ondernemers. Dus in die zin komen we wel ideeën van bepaalde groepen tegemoet. Daarnaast biedt ons discussie forum ruimte om over de ideeën te brainstormen. Wat ook mooi is dat we contacten verkrijgen uit reacties op de ideeën. Deze contacten willen dan bijdragen aan een oplossing bijvoorbeeld. Uiteindelijk willen we er wel naartoe dat het platform een soort punt wordt voor burgerinspraak. Op die manier kunnen we de 'dromen' van andere breed dragen. Ons platform heeft toch duizenden volgers dus we kunnen op die manier toch een flinke groep representeren.

3: Wat zijn voor jullie de belangrijkste argumenten om een autovrij centrum te realiseren?

Nou eigenlijk klinkt het hartstikke logisch om in ieder geval bepaalde straten zoals de Witte de With autovrij te maken. Qua verkeersvervoersfunctie heeft deze straat gewoon weinig toegevoegde waarde en dan zeker in het weekend. De dwarsstraten hierachter zijn prima bereikbaar om bijvoorbeeld op een taxi over te stappen of iets dergelijks. De levendigheid van de straten wil je versterken en niet beperken door bijvoorbeeld gevaarlijk autovervoer. Rotterdam is natuurlijk heel erg autovriendelijk, zo is de stad ontworpen. Maar als je ziet wat er in dit gebied rondrijdt dan zijn dat of taxi's of gasten met veel te dure bakken.

Wij willen dat gedrag wordt aangepast door de auto niet meer of minder te faciliteren. Dus dat mensen denken op het moment dat ze naar Rotterdam komen, ik laat die auto wel thuis. Voor ons is echt het belangrijkste punt dat het zo fijn moet zijn om in Rotterdam te zijn betreft leefbaarheid en vrijheid. De binnenstad moet met name van de voetganger zijn.

4: Hebben jullie politieke inspraak?

Dat niet maar wij worden wel soms gevraagd om mee te denken. Zo zijn wij bijvoorbeeld gevraagd om aan te schuiven bij de planvorming omtrent de rijnhaven. Daarnaast zijn we wel eens door de VVD gevraagd om van gedachte te wisselen. We willen geen politieke denktank worden maar een onafhankelijk platform met eigen ideeën.

5: Hoe hoop je jullie droom te kunnen realiseren?

Hier hebben we nog niet per se verder over nagedacht. Op dit moment weet ik dat nog niet. In ieder geval zouden we geen verkeer in de stad willen zien en dit willen faciliteren met een ringweg. Rondom die ringweg moet je goed kunnen parkeren zodat mensen echt niet verder met hun auto

komen. De bevoorrading van winkels gebeurt op de lijnbaan al aan de achterkant. Zo'n idee zou goed implementeerbaar kunnen zijn op meerdere winkels en horeca gelegenheden in de stad.

C.5 Interview Roxy Tacq

Adviseur public affairs ANWB – 13-5-2020

1: Wat is jouw functie binnen de ANWB en waar focus je je momenteel op?

Als ANWB zijn wij een belangenvereniging en ondanks dat iedereen ons kent van de wegenwacht vertegenwoordigen we 4,7 miljoen leden. Een hele diverse groep. Wij proberen de belangen van onze leden te behartigen op het vlak van recreatie, vervoer en toerisme. Dit doen we door in gesprek te gaan met de overheid, de politiek en andere stakeholders. Ik zelf houd mij bezig met public affaires oftewel de relaties richting de overheid. Aan de ene kant werk ik inhoudelijk aan projecten en aan de andere kant voer ik gesprekken met overheden. We gaan bijvoorbeeld in gesprek met wethouders en andere bestuurders.

Dit interview doe ik vanuit mijn rol als adviseur Public Affairs van de ANWB. Echter niet op alle punten heeft de ANWB een uitgewerkt standpunt. Waar dat het geval is zal ik een persoonlijke kijk/analyse geven, hoe ik denk dat we hier tegenaan kijken als ANWB (vanuit het collectieve belang van de leden).

2: Hoe kijkt de ANWB aan tegen het verbieden van auto's in een specifiek gebied? Autobezitters zien het gebruik van de auto namelijk als een vrijheid. Zou dit tegen het zere been van de autobezitter zijn of een potentieel heel goed idee?

Op dit moment is er nog geen mening vanuit de ANWB. Wel zijn we bezig met het ontwikkelen van een visie. Ik denk dat je twee dingen moet onderscheiden, enerzijds de bezoekers van de stad en anderzijds de inwoners en woon-werkverkeer. Vanuit de ANWB denken we wel dat de rol van de auto zal afnemen maar nooit helemaal zal verwijden uit de stad. Als je kijkt naar de inwoners zijn er altijd mensen in de stad die afhankelijk zijn van de auto omdat ze bijvoorbeeld 's nachts werken of hun werk niet veilig kunnen bereiken met openbaar vervoer. Er wordt dan wel eens makkelijk gezegd 'dan ga je maar ergens anders wonen' maar dit is te eenvoudig en kort door de bocht. Verhuizen doe je niet zomaar, een baan heb je niet voor altijd en je bent vaak ook afhankelijk het werk van je partner. Voor sommige bewoners is er wellicht geen alternatief voor de auto, maar dit geldt zeker niet voor iedereen in de stad.

We zien ook dat gemeentes met gebiedsontwikkeling bezig zijn om bijvoorbeeld minder parkeerplekken te faciliteren. Nieuwe bewoners van dit soort gebieden hebben automatisch minder auto's. We hebben nog geen concrete mening over "autovrij" maar we zien wel dat mensen die nu al een auto hebben we niet zomaar kunnen verplichten om geen auto meer te gebruiken. Daarnaast is de auto ook een stukje veiligheid. Veel vrouwen vinden het niet fijn om 's nachts met het OV te reizen bijvoorbeeld.

Ik weet niet of mensen bereid zijn om de auto zomaar in te ruilen voor een andere modaliteit. Dat zal ik even moeten navragen. Wel hebben we onderzoek, onder onze leden, gedaan naar het bezoeken van de stad Amsterdam. We zien dat het reisgedrag ook sterk afhankelijk is van het type mens dat woont in de stad. Het is belangrijk om te weten dat mijn focus ligt op alle relatief grote steden en niet specifiek Rotterdam. Ik weet te weinig van Rotterdam om echt uitspraken te doen over de situatie in die staat. Maar Rotterdam staat bekent als de arbeidersstad, mensen die niet op een kantoor werken maar bijvoorbeeld in de haven of industriële processen zijn vaak afhankelijker van hun auto, omdat ze werken op moeilijk bereikbare plekken waar wellicht nog helemaal geen OV komt. Deze mensen zijn dus afhankelijker van hun auto en waarschijnlijk doen ze daar liever geen afstand van hun auto.

Daarnaast heb je nog te maken met economische verschillen. Rijke mensen met een eigen oprit kunnen makkelijk hun auto kwijt terwijl mensen in een achterstandsbuurt wellicht (betaalt) op straat moeten parkeren of hun auto helemaal niet kwijt kunnen. Of denk aan de typische twee verdieners huishoudens die beide moeten forensen. Deze mensen zijn gewoon afhankelijker van goede voorzieningen voor hun auto. Als ANWB zien we het maatschappelijke debat waarinde ene persoon het prima vindt dat de auto minder ruimte krijgt en de ander direct klaagt dat ze de auto nodig hebben en niet kunnen missen.

Naast een benodigde mentaliteitsswitch hebben we ook te maken met andere voorwaarden. Mensen zijn vaak best bereid om te verduurzamen maar kunnen dit simpelweg financieel niet. Een oud puch scootertje, welke veel schadelijke stoffen uitstoot, is veel goedkoper dan een duurzame elektrische scooter. Veel van de mensen die een Puch rijden kunnen simpelweg niet met volledig overstappen op het OV of de overstap maken naar een elektrische scooter, omdat het veel duurder is. Bottom line moeten gemeentes ook kansen creeeren voor mensen om andere keuzes te maken en niet alleen maar gedragsverandering proberen te bewerkstelligen. Het is dus van belang om goede randvoorwaarden voor verandering te creëren .

Als ANWB zijn we er voor alle moblisten en hierin vinden we keuzevrijheid heel belangrijk. Daarom vinden we dat op heel veel verschillende alternatieven moet worden ingezet om elk individu de keuzevrijheid te geven. Vanuit de ANWB hebben we een visie waarbij we streven naar 0 doden, 0 emissies en 0 files, oftewel 3 keer 0. Voor de verkeersveiligheid, bereikbaarheid, duurzaamheid en luchtkwaliteit. De fiets past in die visie, maar we moeten ook andere opties kunnen bieden. Een elektrische scooter of een elektrisch stepje is ook goed. Naast de fiets zijn er veel meer vervoersmiddelen die ook een klein ruimtebeslag en geen uitstoot hebben.

3: Wat is voor de ANWB de balans tussen enerzijds het gebruik van de auto waarborgen, inclusief de negatieve externe effecten, en anderzijds duurzaamheidsontwikkelingen waarin potentieel geen ruimte voor de auto is?

We hebben een plan ontwikkeld dat heet "verkeer in de stad" en dat kijkt naar ruimte (ruimtelijke kwaliteit) en verkeer. Dit plan kijkt o.a. naar een verkeersbalans in de stad. Dit gaat om bijvoorbeeld ontsluiting (van verkeer) en de mogelijkheden over te stappen naar een andere modaliteit (model switch). We hebben geen blauwdruk voor de stad maar een ontwerpmethodiek, waarmee gemeenten in een aantal stappen tot een oplossing kunnen komen voor hun stad. Uiteindelijk zetten we als ANWB vooral in op duurzaamheidsontwikkelingen en het bieden van veel keuze mogelijkheden om (als consument) zelf een afweging te maken tussen welke modaliteit je gebruikt. Hierdoor zou het kunnen dat autogebruik afneemt maar dan verdwijnt de auto niet.

4: Hoe ziet de ANWB de auto als onderdeel van een leefbare stad? Wat voor factoren zijn hiervoor belangrijk?

We vinden de overstap naar elektrisch vervoer heel belangrijk. Uiteindelijk gaan we naar een volledig duurzaam Europa (elektrisch wagenpark en opwekking duurzame energie). Duurzaam elektrisch vervoer kan de auto waarborgen in de stad. Dat heeft invloed op een leefbare stad in de zin van dat emissies afnemen. Aan de andere kant blijft de impact op verkeersveiligheid (helaas) onveranderd (als we het aantal auto's niet verminderen). De ANWB vindt ook dat een goed laadnetwerk moet worden aangelegd om te voorzien in de energie behoefte van de auto. Momenteel is er nog vooral een politiek debat om wie dit zou moeten betalen. Het vraagstuk hoe we deze transitie gaan doormaken is ook erg actueel en complex.

5: Hoe ziet de ANWB de toekomst van binnenstedelijk verkeer?

Het plan verkeer in de stad benadert onze visie maar de exacte visie zal per stad afhankelijk zijn. Allereerst zouden we inzetten op een andere inrichting van de stad. MAAS (Mobility as a Service) kan een extra component zijn om de keuzevrijheid te vergemakkelijken en te vereenvoudigen. In het verlengde van MAAS zien wij een belangrijk element voor informatie voorziening. Waar staan laadpalen? Hoeveel vrije parkeerplekken zijn er? Hoe druk is het in het OV? Mensen kunnen veel efficiënter hun reis plannen of hun reis uitstellen. Op deze manier kunnen we de verdichting van de stad tegengaan. Een volledige oplossing hebben we niet. Dit soort aspecten die ik aandraag zijn een deel van de oplossing. Met alleen slimme technologie en meer informatie zijn echt niet alle problemen opgelost. Het is én én én, een combinatie van meerdere aspecten om verbeterde leefbaarheid en bereikbaarheid te bewerkstelligen. Het is niet op meerdere paarden wedden, daar geloof ik niet in. Maar een combinatie van de elementen, een soort totaal plaatje, om het tastbaar te maken.

We hebben niet echt een standpunt over meer autovrij vervoer in de stad. Wel denk ik dat er een belangrijke rol komt voor autoluw. Steeds meer behoefte komt er aan een vermindering van de auto. Maar autovrij is wat te zwart-wit. Autoluw is een meer voor de hand liggende oplossing.

6: Hoe staan jullie tegenover de invoering van andere, schonere en kleinere, voertuigen zoals de Lev auto en elektrische steps?

We zijn daar zeker voor! Dit soort kleinere modaliteiten hebben minder ruimte beslag en zijn een stuk schoner. We pleiten nu ook bij het ministerie (I&W) voor dat de elektrische step kan worden gelegaliseerd. Dat zelfde regels voor e-steps gelden als voor e-bikes. Momenteel zijn er veel uitdagingen omtrent verzekeringen en onder welke regeling deze modaliteit valt. Nu valt het onder het kopje "bijzondere bromfiets" (zet zoals de stint). Door het ongeluk met de stint zijn overheden heel voorzichtig om zo'n stepje goed te keuren. Ook is er veel discussie over waar deze voertuigen moeten rijden. Delen meerdere modaliteiten zoals de fiets, scooter en e-step één rijbaan? Of maken we hier een verschil in? Vanuit de ANWB stellen we voor om dit (de plek op de weg) in te delen op massa. Dus de zwaardere voertuigen op een gescheiden baan van de lichte voertuigen zoals de fiets. Op deze manier kunnen we een veilig netwerk voor alle voertuigen creëren. Voor meer details, zie het rapport op www.anwb.nl/verkeerindestad, met daarin de voertuigfamilies.

Het is ook ons standpunt om alle voertuigen te omarmen omdat we ze nodig hebben om aan iedereens behoeftes willen voldoen. Mits het voertuig zelf technisch veilig is uiteraard.

7: Tot slot, wat is je persoonlijke mening. Is het denk je haalbaar om een autovrij stadscentrum te realiseren?

Mijn tegenvraag zou zijn, waarom streef ik dat na? Als ik ergens aan het winkelen ben of je bent aan het shoppen, dan snap ik dat autovrij heel wenselijk is. Een goed voorbeeld is de Witte de With straat, waar je heerlijk op het terras kan zitten maar waar enorm veel auto's rijden. Waarom moeten er auto's in dit straatbeeld? Hier is het met name 'zien en gezien worden' en dat vinden voorbij rijders blijkbaar leuk. Als andere bezoekers aan de straat dat ook leuk vinden, dan moet je het niet veranderen. Ik denk dat je echt als stad samen met bewoners en bezoekers moet kijken of autoluw/autovrije wenselijk is en waar dit moet worden geïmplementeerd. Ook zou je kunnen denken aan een tijdelijk autovrij centrum, auto's wel toestaan op bepaalde momenten bijvoorbeeld overdag en 's avonds als het rustig is en minder mensen er last van hebben. Eigenlijk zie ik het niet per se zitten om een geheel autovrij centrum te maken maar denk ik wel dat je kritisch moet kijken naar waar je autovrij/autoluwe straten kunt maken.

Appendix D – CBA valuation estimations

This appendix will provide an overview of the calculations made, to determine the values of the effects incorporated, in the CBA. All outcomes are rounded since the estimations are already limited by itself. Some calculations might differ per scenario and only 1 excel calculation per alternative is given. Nevertheless, it is explained how the calculations in different alternatives can be carried out. All outcomes are the costs or benefits for one year per effect.

Crowdedness in public transport

Input data:

- Amount of public transport travellers
    - 308.000 existing metro users
    - New users determined by x% of 156.000 car trips. This amount is thereafter multiplied by 1,5, the average occupancy rate of passengers per car in Rotterdam. Out of all public transport users travellers, 70% makes use of the metro. Therefore, the amount of new public transport users is multiplied by 70%. Example project alternative 1: 50% car trips substituted by public transport. Thus 78.000 car trips substituted and multiplied by 1,5 to determine the amount of passengers. Therefore, 117.000 new public transport users will make use of the network. 70% makes use of the metro, thus 82.000 new metro users.
- Average travel time public transport
    - 22 minutes per traveller per trip.
- Delta increase value of time passenger/m^2/hour spent in crowdedness
    - 3 passengers/m^2 is used as proxy. Value of time spent in crowdedness with proxy 3 is 5,53. If there are no passengers, or proxy 0 is chosen, the value of time is 3,15.
- Amount of hours crowdedness per day
    - 4 hours per day there is crowdedness during rush hours.
- Amount of days per week crowdedness
    - Assumed 5 working days per week crowdedness occurs. During the weekend days there is no crowdedness.

Calculation in excel (alternative 1 – 50% car trips substituted to public transport):

(308.000 (existing travellers) + 82000 (new users)) * (5,53-3,15)(delta increase value of time passenger/m^2/hour) / 60*22 (amount of minutes crowdedness per hour) / 24 * 4 (amount of hours crowdedness per day) * (52*5) (amount of days crowdedness per year) = 14.750.000

In other alternatives the amount of new users might differ and thereby the outcome. All other variables are kept constant.

Crowdedness by bicycle

Input data:

- Amount of cyclists
    - 114.000 existing bicycle users
    - New users determined by x% of 156.000 car trips. This amount is thereafter multiplied by 1,5, the average occupancy rate of passengers per car in Rotterdam. %. Example project alternative 1: 50% car trips substituted by bicycle. Thus 78.000 car

trips substituted and multiplied by 1,5 to determine the amount of passengers. Therefore, 117.000 new cyclists make use of the bicycle network.

- Average cycling distance
    - A cyclists cycles 2,35 kilometre per day.
- Average cycling speed
    - 12 kilometres/hour.
- Average cycling time
    - 2,35 kilometre divided by 12 kilomteres/hour * 60 minutes = 12 minutes
- Delta increase value of time passenger/m^2/hour spent in crowdedness
    - 3 passengers/m^2 is used as proxy. Value of time spent in crowdedness with proxy 3 is 5,53. If there are no passengers, or proxy 0 is chosen, the value of time is 3,15.

Calculation in excel (alternative 1 – 50% car trips substituted to bicycle):

(114.000 (existing cyclists) + 117.000 (new cyclists)) * (5,53-3,15)(delta increase value of time passenger/m^2/hour) / 60*12 (amount of minutes cycled per day) / 24 * 4 (amount of hours crowdedness per day) * (52*5) (amount of days crowdedness per year) = 4.760.000

In other alternatives the amount of new cyclists might differ and thereby the outcome. All other variables are kept constant.

Health effects

Input data:

- Amount of additional commuting cyclists
    - X% of car trips are substituted to the bicycle. Out of all these new cycling trips, 7 out of 10 trips are commuter related. Only commuting trips are incorporated in the calculations. The amount of commuting trips is multiplied by 1,1 (the average occupancy rate of a commuting car). Example project alternative 1: 50% car trips substituted by bicycle. Thus 78.000 car trips substituted and 7 out of 10 of this amount of trips is commuter related. By multiplying the remaining 54.600 car trips by 1,1 it can be determined that the amount of new commuting cyclists are equal to 60.000.
- Productivity gain
    - 364 euro yearly productivity profit per commuting cyclist.

Calculation in excel (alternative 1 – 50% car trips substituted to bicycle):

60.000 (additional cyclists) * 364 (productivity profit) = 22.000.000

In other alternatives the amount of new cyclists might differ and thereby the outcome. All other variables are kept constant.

Waiting time reduction

Input data:

- Amount of existing users
    - 308.000
- Amount of new users (rule of half applies to new travellers)
    - 122.850
- Average waiting time metro

    - Reduced from 5 minutes to 3 minutes
- Costs for waiting
    - Value of time during rush hours 16,14 euro.
- Amount of hours crowdedness per day
    - 4 hours per day there is crowdedness during rush hours.

Calculation in excel (alternative 2 – 75% car trips substituted to public transport):

(308000 (existing users) * (16,14/60 * 2)(benefits for reduced waiting time per hour) / 24 * 4 (amount of hours crowdedness per day) *365 days) + (122.850 (new users) * (16,14/60 * 2) (benefits for reduced waiting time per hour) / 24 * 4 (amount of hours crowdedness per day) * 365 days / 2 (rule of half)) = 12.000.000

Network benefits

Input data:

- Amount of existing cyclists
    - 114.000
- Amount of new cyclists (rule of half applies to new travellers)
    - 142.600
- Distance cycled in city centre per cyclists
    - 3 kilometre
- Benefits allocated to the reliability of the bicycle network
    - Between 1 and 8 cents per cycled kilometre, in this research 4 cents per cycled kilometre is used to calculate the travel time benefits allocated to the reliability of the network

Calculation in excel (alternative 4 – 75% car trips substituted to bicycle):

(114.000 (existing cyclists) * 3 (Distance cycled in city centre per cyclists) * 0,04 (benefits per cycled kilometre) * 365 (days)) + (142.600 (existing cyclists) * 3 (Distance cycled in city centre per cyclists) * 0,04 (benefits per cycled kilometre) * 365 (days) / 2 (rule of half)) = 8.100.000

Emissions

Input data:

- Amount of car trips per day
    - 156.000
- Average distance covered in centre per car
    - 3 kilometre
- Emissions costs per kilogram
    - CO_2 = 0,057 €/kg
    - NO_x = 34,70 €/kg
    - PM_{10} = 44,60 €/kg
    - $PM_{2,5}$ = 79,50 €/kg
- Amount of emissions per kilometre
    - CO_2 = 59,375 g/km
    - NO_x = 0,137 g/km
    - PM_{10} = 0,029 g/km
    - $PM_{2,5}$ = 0,008 g/km

Calculation in excel:

(156.000 (car trips per day) * 365 (days) * 3 (kilometres) * 59,375 (CO_2 emissions per kilometre) /1000) * 0,057 (CO_2 emission costs) + (156.000 (car trips per day) * 365 (days) * 3 (kilometres) * 0,137 (NO_x emissions per kilometre) /1000) * 34,70 (NO_x emission costs) + (156.000 (car trips per day) * 365 (days) * 3 (kilometres) * 0,029 (PM_{10} emissions per kilometre) /1000) * 44,60 (CO_2 emission costs) + (156.000 (car trips per day) * 365 (days) * 3 (kilometres) * 0,008 ($PM_{2,5}$ emissions per kilometre) /1000) * 79,50 (CO_2 emission costs) = 10.000.000

Noise

Input data:

- Total noise reduction in decibel
    - 12 dB
- Willingness to pay per decibel reduction
    - 16 euro per person
- Residents living in the city centre
    - 35.000

Calculation in excel:

35.000 (residents) * 12 (noise reduction) * 16 (willingness to pay per decibel reduction) = 6.700.000

Traffic safety

Input data:

- Amount of serious accidents per year
    - 20
- Amount of traffic deaths per year
    - 2
- Costs for serious injuries
    - 332.905 euro per person
- Costs for traffic deaths
    - 3.082.361 per case

Calculation in excel:

20 (serious accidents) * 332.905 (costs for serious injuries) + 2 (traffic deaths) * 3.082.361 (costs for traffic deaths) = 14.000.000

Stink

Input data:

- The loss of living pleasure
    - 185,42 euro per household
- Amount of households in city centre
    - 20970 households

Calculation in excel:

185,42 (loss of living pleasure) * 20970 (amount of households) = 4.000.000

Public transport revenues

Input data:

- Amount of traveller kilometres in city centre
    - It is assumed 50% of the 921.000.000 total travellers kilometres in Rotterdam are made in the city centre. Therefore, the amount of public transport kilometres in the city centre is equal to 460.500.000.
- revenues per traveller kilometre
    - 0,11 euro cents per kilometre.
- Additional traveller kilometres
    - X% per different alternative. By multiplying the public transport earnings with the increased percentage of travellers, the additional earnings can be calculated.

Calculation in excel (alternative 1 – 50% car trips substituted to public transport):

460.500.000 (current traveller kilometres) * 0,11 (revenues per kilometre) * 0,5 (50% more traveller kilometres compared to 0-alternative) = 25.300.000

In other alternatives the percentage additional travellers might differ and thereby the outcome. All other variables are kept constant.

Excise duty

Input data:

- Earnings government per kilometre driven
    - 0,03 euro cents per kilometre
- Amount of car trips per day
    - 156.000
- Average distance covered in city centre
    - 3 kilometre

Calculation in excel:

156.000 (car trips per day) * 365 (days) * 3 (kilometre) * 0,03 (earnings per kilometre) = 5.000.000

Spatial benefits

This effects consists out of two different benefits.

Input data:

1:

- Tourists willingness to pay for additional recreation activities
    - 1,14 euro per
- Amount of tourists in Rotterdam per year
    - 1.300.000 tourists per year

2:

- Parking infrastructure costs
    - 57 euro per 1000 vehicle kilometres
- Amount of car trips per day

    - 156.000
- Average distance covered in city centre
    - 3 kilometre

Calculation in excel:

(1,14 (WTP for additional recreation) * 1.300.000 (amount of tourists)) + (156.000 (car trips) * 365 (days) * 3 (distance covered in city centre) * (57/1000) (earnings per 1000 vehicle kilometres) = 11.250.000

Parking

Input data:

- Amount of parking benefits in Rotterdam
    - 35.000.000 euro per year
- Share earned in city centre
    - 75%

Calculation in excel:

35.000.000 (yearly parking earnings Rotterdam) * 0,75 (share earned in city centre) = 26.000.000

Loss consumer surplus leisure travellers

Input data:

- Daily parking price in Rotterdam
    - 21 euro per day per car
- Required price for no demand
    - 70 euro per day per car
- Amount of parked vehicles in city centre
    - 6120

Calculation in excel:

(70 – 21) (delta parking price to estimate new surplus loss) * 365 (days) * 6120 (amount of parked vehicles) / 2 (rule of half) = 55.000.000

Utility loss commuters car travellers

Input data:

- Amount of car trips experiencing utility loss
    - 23.500 car trips per day
- Travel time loss per trip
    - 34 minutes per trip
- Value of time by car
    - 9,25 euro per hour

Calculation in excel:

23.500 (car trips per day experiencing utility loss) * (9,25 (VoT) /60 * 34 (value of time loss per 34 minutes trip)) * 365 (days) / 2 (rule of half) = 25.000.000

Appendix E – CBA calculations

The calculations per effect, per year, per alternative are provided in this appendix. The values are discounted over a period of 20 years by 5,5% per year.

E1. Project alternative 1 – No additional investments

								Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73
				Present Value				Year	1	2	3	4	5	6	7
				0	Implementation costs										
				0	Operating costs										
				116.076.535	Reduction car emissions					9.478.673	8.984.524	8.516.137	8.072.167	7.651.344	7.252.458
				293.673.634	Public transport revenues					23.981.043	22.730.846	21.545.826	20.422.584	19.357.899	18.348.720
				-301.798.992	Parking revenues loss					-24.644.550	-23.359.763	-22.141.955	-20.987.635	-19.893.493	-18.856.392
				77.771.279	Reduction of traffic noise					6.350.711	6.019.631	5.705.812	5.408.352	5.126.400	4.859.147
				162.507.149	Prevented car accidents					13.270.142	12.578.334	11.922.591	11.301.034	10.711.881	10.153.442
				-58.038.268	Excise income loss					-4.739.336	-4.492.262	-4.258.068	-4.036.084	-3.825.672	-3.626.229
				46.430.614	Stink reduction					3.791.469	3.593.810	3.406.455	3.228.867	3.060.537	2.900.983
				130.586.102	Spatial benefits					10.663.507	10.107.590	9.580.654	9.081.188	8.607.761	8.159.016
				255.368.377	Health effects					20.853.081	19.765.953	18.735.501	17.758.768	16.832.956	15.955.408
				-290.191.338	Utility loss					-23.696.682	-22.461.310	-21.290.342	-20.180.419	-19.128.359	-18.131.146
				-638.420.944	Consumer surplus loss					-52.132.701	-49.414.883	-46.838.752	-44.396.921	-42.082.389	-39.888.521
				-171.212.889	Crowdedness public transport					-13.981.043	-13.252.173	-12.561.302	-11.906.447	-11.285.732	-10.697.376
				-55.252.431	Crowdedness cyclists					-4.511.848	-4.276.633	-4.053.681	-3.842.352	-3.642.040	-3.452.170
Net Present Value				**-432.501.170**											
Benefit-Cost Ratio				**0,71**											

0,69	0,65	0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
8	9	10	11	12	13	14	15	16	17	18	19	20
6.874.368	6.515.989	6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
17.392.151	16.485.451	15.626.020	14.811.394	14.039.236	13.307.332	12.613.585	11.956.005	11.332.706	10.741.902	10.181.897	9.651.087	9.147.950
-17.873.357	-16.941.571	-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
4.605.827	4.365.712	4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
9.624.115	9.122.384	8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.437.184	-3.257.994	-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.749.747	2.606.395	2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
7.733.664	7.330.487	6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
15.123.610	14.335.175	13.587.844	12.879.473	12.208.031	11.571.593	10.968.335	10.396.526	9.854.527	9.340.784	8.853.824	8.392.250	7.954.739
-17.185.920	-16.289.972	-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-37.809.024	-35.837.938	-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-10.139.693	-9.611.083	-9.110.032	-8.635.101	-8.184.930	-7.758.227	-7.353.770	-6.970.398	-6.607.012	-6.262.571	-5.936.086	-5.626.622	-5.333.291
-3.272.199	-3.101.611	-2.939.915	-2.786.650	-2.641.374	-2.503.672	-2.373.149	-2.249.430	-2.132.161	-2.021.006	-1.915.645	-1.815.778	-1.721.116

Figure 24 CBA estimation project alternative 1

E2. Project alternative 2 – Invest in public transport

				Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73	0,69	0,65
		Present Value		Year	1	2	3	4	5	6	7	8	9
		-225.000.000	Implementation costs		-225.000.000								
		-22.274.300	Operating costs						-2.018.042	-1.912.836	-1.813.115	-1.718.592	-1.628.997
		-68.426.651	Exploitation costs						-6.199.425	-5.876.232	-5.569.888	-5.279.515	-5.004.279
		89.097.201	Reduction car emissions						8.072.167	7.651.344	7.252.458	6.874.368	6.515.989
		338.123.879	Public transport revenues						30.633.875	29.036.849	27.523.079	26.088.227	24.728.177
		-231.652.724	Parking revenues loss						-20.987.635	-19.893.493	-18.856.392	-17.873.357	-16.941.571
		59.695.125	Reduction of traffic noise						5.408.352	5.126.400	4.859.147	4.605.827	4.365.712
		124.736.082	Prevented car accidents						11.301.034	10.711.881	10.153.442	9.624.115	9.122.384
		-44.548.601	Excise income loss						-4.036.084	-3.825.672	-3.626.229	-3.437.184	-3.257.994
		35.638.881	Stink reduction						3.228.867	3.060.537	2.900.983	2.749.747	2.606.395
		100.234.352	Spatial benefits						9.081.188	8.607.761	8.159.016	7.733.664	7.330.487
		98.006.922	Health effects						8.879.384	8.416.478	7.977.704	7.561.805	7.167.588
		-222.743.004	Utility loss						-20.180.419	-19.128.359	-18.131.146	-17.185.920	-16.289.972
		-490.034.608	Consumer surplus loss						-44.396.921	-42.082.389	-39.888.521	-37.809.024	-35.837.938
		0	Crowdedness public transport										
		-31.807.701	Crowdedness cyclists						-2.881.764	-2.731.530	-2.589.128	-2.454.149	-2.326.208
		106.916.642	Waiting time reduction						9.686.601	9.181.612	8.702.950	8.249.242	7.819.186
Net Present Value		**-384.038.505**											
Benefit-Cost Ratio		**0,71**											

0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
10	11	12	13	14	15	16	17	18	19	20
-1.544.073	-1.463.576	-1.387.276	-1.314.954	-1.246.402	-1.181.423	-1.119.833	-1.061.453	-1.006.116	-953.665	-903.948
-4.743.393	-4.496.107	-4.261.713	-4.039.538	-3.828.946	-3.629.333	-3.440.126	-3.260.783	-3.090.789	-2.929.658	-2.776.927
6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
23.439.030	22.217.090	21.058.854	19.960.999	18.920.378	17.934.007	16.999.059	16.112.852	15.272.846	14.476.631	13.721.925
-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
6.793.922	6.439.736	6.104.016	5.785.797	5.484.167	5.198.263	4.927.264	4.670.392	4.426.912	4.196.125	3.977.370
-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-2.204.936	-2.089.987	-1.981.030	-1.877.754	-1.779.862	-1.687.073	-1.599.121	-1.515.754	-1.436.734	-1.361.833	-1.290.837
7.411.551	7.025.167	6.658.926	6.311.778	5.982.728	5.670.832	5.375.197	5.094.973	4.829.358	4.577.591	4.338.949

Figure 25 CBA estimation project alternative 2

E3. Project alternative 3 – Invest in P+R & shared mobility

			Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77
	Present Value		Year	1	2	3	4	5	6
	-250.000.000	Implementation costs		-250.000.000					
	-29.019.134	Operating costs			-2.369.668	-2.246.131	-2.129.034	-2.018.042	-1.912.836
	116.076.535	Reduction car emissions			9.478.673	8.984.524	8.516.137	8.072.167	7.651.344
	176.204.180	Public transport revenues			14.388.626	13.638.508	12.927.495	12.253.550	11.614.739
	-226.349.244	Parking revenues loss			-18.483.412	-17.519.822	-16.606.466	-15.740.726	-14.920.120
	77.771.279	Reduction of traffic noise			6.350.711	6.019.631	5.705.812	5.408.352	5.126.400
	162.507.149	Prevented car accidents			13.270.142	12.578.334	11.922.591	11.301.034	10.711.881
	-58.038.268	Excise income loss			-4.739.336	-4.492.262	-4.258.068	-4.036.084	-3.825.672
	46.430.614	Stink reduction			3.791.469	3.593.810	3.406.455	3.228.867	3.060.537
	130.586.102	Spatial benefits			10.663.507	10.107.590	9.580.654	9.081.188	8.607.761
	190.365.518	Health effects			15.545.024	14.734.620	13.966.464	13.238.355	12.548.203
	-84.735.871	Utility loss			-6.919.431	-6.558.703	-6.216.780	-5.892.682	-5.585.481
	-638.420.944	Consumer surplus loss			-52.132.701	-49.414.883	-46.838.752	-44.396.921	-42.082.389
	-168.310.976	Crowdedness public transport			-13.744.076	-13.027.560	-12.348.398	-11.704.643	-11.094.448
	-47.359.226	Crowdedness cyclists			-3.867.299	-3.665.686	-3.474.584	-3.293.444	-3.121.748
Net Present Value	**-602.292.284**								
Benefit-Cost Ratio	**0,60**								

0,73	0,69	0,65	0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
7	8	9	10	11	12	13	14	15	16	17	18	19	20
-1.813.115	-1.718.592	-1.628.997	-1.544.073	-1.463.576	-1.387.276	-1.314.954	-1.246.402	-1.181.423	-1.119.833	-1.061.453	-1.006.116	-953.665	-903.948
7.252.458	6.874.368	6.515.989	6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
11.009.232	10.435.291	9.891.271	9.375.612	8.886.836	8.423.541	7.984.399	7.568.151	7.173.603	6.799.624	6.445.141	6.109.138	5.790.652	5.488.770
-14.142.294	-13.405.018	-12.706.178	-12.043.771	-11.415.896	-10.820.755	-10.256.640	-9.721.933	-9.215.103	-8.734.694	-8.279.331	-7.847.707	-7.438.585	-7.050.792
4.859.147	4.605.827	4.365.712	4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
10.153.442	9.624.115	9.122.384	8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.626.229	-3.437.184	-3.257.994	-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.900.983	2.749.747	2.606.395	2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
8.159.016	7.733.664	7.330.487	6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
11.894.032	11.273.964	10.686.221	10.129.120	9.601.062	9.100.532	8.626.097	8.176.395	7.750.138	7.346.102	6.963.130	6.600.123	6.256.041	5.929.897
-5.294.295	-5.018.289	-4.756.672	-4.508.694	-4.273.643	-4.050.847	-3.839.665	-3.639.493	-3.449.756	-3.269.911	-3.099.442	-2.937.860	-2.784.701	-2.639.527
-39.888.521	-37.809.024	-35.837.938	-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-10.516.065	-9.967.834	-9.448.184	-8.955.624	-8.488.743	-8.046.202	-7.626.732	-7.229.130	-6.852.256	-6.495.029	-6.156.426	-5.835.475	-5.531.256	-5.242.896
-2.959.003	-2.804.742	-2.658.523	-2.519.927	-2.388.557	-2.264.035	-2.146.005	-2.034.128	-1.928.083	-1.827.567	-1.732.291	-1.641.982	-1.556.381	-1.475.243

Figure 26 CBA estimation project alternative 3

E4. Project alternative 4 – Rotterdam bicycle city

					Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73	0,69
		Present Value			Year	1	2	3	4	5	6	7	8
		-252.153.070	Yearly investments		-20.000.000	-18.957.346	-17.969.048	-17.032.273	-16.144.335	-15.302.687	-14.504.917	-13.748.736
		-3.482.296	Operating costs			-284.360	-269.536	-255.484	-242.165	-229.540	-217.574	-206.231
		116.076.535	Reduction car emissions			9.478.673	8.984.524	8.516.137	8.072.167	7.651.344	7.252.458	6.874.368
		146.836.817	Public transport revenues			11.990.521	11.365.423	10.772.913	10.211.292	9.678.950	9.174.360	8.696.076
		-301.798.992	Parking revenues loss			-24.644.550	-23.359.763	-22.141.955	-20.987.635	-19.893.493	-18.856.392	-17.873.357
		77.771.279	Reduction of traffic noise			6.350.711	6.019.631	5.705.812	5.408.352	5.126.400	4.859.147	4.605.827
		162.507.149	Prevented car accidents			13.270.142	12.578.334	11.922.591	11.301.034	10.711.881	10.153.442	9.624.115
		-58.038.268	Excise income loss			-4.739.336	-4.492.262	-4.258.068	-4.036.084	-3.825.672	-3.626.229	-3.437.184
		46.430.614	Stink reduction			3.791.469	3.593.810	3.406.455	3.228.867	3.060.537	2.900.983	2.749.747
		130.586.102	Spatial benefits			10.663.507	10.107.590	9.580.654	9.081.188	8.607.761	8.159.016	7.733.664
		383.052.566	Health effects			31.279.621	29.648.930	28.103.251	26.638.153	25.249.434	23.933.112	22.685.415
		-290.191.338	Utility loss			-23.696.682	-22.461.310	-21.290.342	-20.180.419	-19.128.359	-18.131.146	-17.185.920
		-638.420.944	Consumer surplus loss			-52.132.701	-49.414.883	-46.838.752	-44.396.921	-42.082.389	-39.888.521	-37.809.024
		-160.185.619	Crowdedness public transport			-13.080.569	-12.398.643	-11.752.269	-11.139.591	-10.558.854	-10.008.392	-9.486.628
		0	Crowdedness cyclists									
		94.021.994	Network benefits			7.677.725	7.277.465	6.898.071	6.538.456	6.197.588	5.874.491	5.568.238
Net Present Value		**-546.987.470**										
Benefit-Cost Ratio		**0,68**										

0,65	0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
9	10	11	12	13	14	15	16	17	18	19	20
-13.031.977	-12.352.585	-11.708.612	-11.098.210	-10.519.630	-9.971.214	-9.451.387	-8.958.661	-8.491.622	-8.048.931	-7.629.318	-7.231.581
-195.480	-185.289	-175.629	-166.473	-157.794	-149.568	-141.771	-134.380	-127.374	-120.734	-114.440	-108.474
6.515.989	6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
8.242.726	7.813.010	7.405.697	7.019.618	6.653.666	6.306.793	5.978.002	5.666.353	5.370.951	5.090.949	4.825.544	4.573.975
-16.941.571	-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
4.365.712	4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
9.122.384	8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.257.994	-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.606.395	2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
7.330.487	6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
21.502.763	20.381.766	19.319.209	18.312.047	17.357.390	16.452.502	15.594.789	14.781.791	14.011.176	13.280.735	12.588.375	11.932.109
-16.289.972	-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-35.837.938	-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-8.992.064	-8.523.284	-8.078.942	-7.657.765	-7.258.545	-6.880.137	-6.521.457	-6.181.476	-5.859.219	-5.553.762	-5.264.229	-4.989.791
5.277.951	5.002.797	4.741.988	4.494.775	4.260.450	4.038.342	3.827.812	3.628.258	3.439.107	3.259.817	3.089.874	2.928.790

Figure 27 CBA estimation project alternative 4

E5. Liveability X2

					Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73	0,69
		Present Value			Year	1	2	3	4	5	6	7	8
		0	Implementation costs										
		0	Operating costs										
		232.153.070	Reduction car emissions				18.957.346	17.969.048	17.032.273	16.144.335	15.302.687	14.504.917	13.748.736
		293.673.634	Public transport revenues				23.981.043	22.730.846	21.545.826	20.422.584	19.357.899	18.348.720	17.392.151
		-301.798.992	Parking revenues loss				-24.644.550	-23.359.763	-22.141.955	-20.987.635	-19.893.493	-18.856.392	-17.873.357
		155.542.557	Reduction of traffic noise				12.701.422	12.039.262	11.411.623	10.816.704	10.252.800	9.718.294	9.211.653
		325.014.299	Prevented car accidents				26.540.284	25.156.668	23.845.183	22.602.069	21.423.762	20.306.883	19.248.231
		-58.038.268	Excise income loss				-4.739.336	-4.492.262	-4.258.068	-4.036.084	-3.825.672	-3.626.229	-3.437.184
		92.861.228	Stink reduction				7.582.938	7.187.619	6.812.909	6.457.734	6.121.075	5.801.967	5.499.494
		261.172.204	Spatial benefits				21.327.014	20.215.179	19.161.307	18.162.377	17.215.523	16.318.031	15.467.328
		255.368.377	Health effects				20.853.081	19.765.953	18.735.501	17.758.768	16.832.956	15.955.408	15.123.610
		-290.191.338	Utility loss				-23.696.682	-22.461.310	-21.290.342	-20.180.419	-19.128.359	-18.131.146	-17.185.920
		-638.420.944	Consumer surplus loss				-52.132.701	-49.414.883	-46.838.752	-44.396.921	-42.082.389	-39.888.521	-37.809.024
		-171.212.889	Crowdedness public transport				-13.981.043	-13.252.173	-12.561.302	-11.906.447	-11.285.732	-10.697.376	-10.139.693
		-55.252.431	Crowdedness cyclists				-4.511.848	-4.276.633	-4.053.681	-3.842.352	-3.642.040	-3.452.170	-3.272.199
Net Present Value		**100.870.509**											
Benefit-Cost Ratio		**1,07**											

0,65	0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
9	10	11	12	13	14	15	16	17	18	19	20
13.031.977	12.352.585	11.708.612	11.098.210	10.519.630	9.971.214	9.451.387	8.958.661	8.491.622	8.048.931	7.629.318	7.231.581
16.485.451	15.626.020	14.811.394	14.039.236	13.307.332	12.613.585	11.956.005	11.332.706	10.741.902	10.181.897	9.651.087	9.147.950
-16.941.571	-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
8.731.425	8.276.232	7.844.770	7.435.801	7.048.152	6.680.713	6.332.430	6.002.303	5.689.387	5.392.783	5.111.643	4.845.159
18.244.768	17.293.619	16.392.056	15.537.494	14.727.483	13.959.699	13.231.942	12.542.125	11.888.270	11.268.503	10.681.045	10.124.214
-3.257.994	-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
5.212.791	4.941.034	4.683.445	4.439.284	4.207.852	3.988.485	3.780.555	3.583.464	3.396.649	3.219.572	3.051.727	2.892.632
14.660.975	13.896.658	13.172.188	12.485.486	11.834.584	11.217.615	10.632.811	10.078.494	9.553.074	9.055.047	8.582.983	8.135.529
14.335.175	13.587.844	12.879.473	12.208.031	11.571.593	10.968.335	10.396.526	9.854.527	9.340.784	8.853.824	8.392.250	7.954.739
-16.289.972	-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-35.837.938	-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-9.611.083	-9.110.032	-8.635.101	-8.184.930	-7.758.227	-7.353.770	-6.970.398	-6.607.012	-6.262.571	-5.936.086	-5.626.622	-5.333.291
-3.101.611	-2.939.915	-2.786.650	-2.641.374	-2.503.672	-2.373.149	-2.249.430	-2.132.161	-2.021.006	-1.915.645	-1.815.778	-1.721.116

Figure 28 CBA estimation liveabilty X2

E6. Configuration 1 – increased share public transport users

					Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73	0,69
		Present Value			Year	1	2	3	4	5	6	7	8
		-225.000.000	Implementation costs			-225.000.000							
		-22.274.300	Operating costs							-2.018.042	-1.912.836	-1.813.115	-1.718.592
		-68.426.651	Exploitation costs							-6.199.425	-5.876.232	-5.569.888	-5.279.515
		89.097.201	Reduction car emissions							8.072.167	7.651.344	7.252.458	6.874.368
		405.748.655	Public transport revenues							36.760.650	34.844.218	33.027.695	31.305.872
		-231.652.724	Parking revenues loss							-20.987.635	-19.893.493	-18.856.392	-17.873.357
		59.695.125	Reduction of traffic noise							5.408.352	5.126.400	4.859.147	4.605.827
		124.736.082	Prevented car accidents							11.301.034	10.711.881	10.153.442	9.624.115
		-44.548.601	Excise income loss							-4.036.084	-3.825.672	-3.626.229	-3.437.184
		35.638.881	Stink reduction							3.228.867	3.060.537	2.900.983	2.749.747
		100.234.352	Spatial benefits							9.081.188	8.607.761	8.159.016	7.733.664
		39.202.769	Health effects							3.551.754	3.366.591	3.191.082	3.024.722
		-222.743.004	Utility loss							-20.180.419	-19.128.359	-18.131.146	-17.185.920
		-490.034.608	Consumer surplus loss							-44.396.921	-42.082.389	-39.888.521	-37.809.024
		0	Crowdedness public transport										
		-24.947.216	Crowdedness cyclists							-2.260.207	-2.142.376	-2.030.688	-1.924.823
		111.371.502	Waiting time reduction							10.090.209	9.564.179	9.065.573	8.592.960
Net Present Value		**-363.902.537**											
Benefit-Cost Ratio		**0,73**											

0,65	0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
9	10	11	12	13	14	15	16	17	18	19	20
-1.628.997	-1.544.073	-1.463.576	-1.387.276	-1.314.954	-1.246.402	-1.181.423	-1.119.833	-1.061.453	-1.006.116	-953.665	-903.948
-5.004.279	-4.743.393	-4.496.107	-4.261.713	-4.039.538	-3.828.946	-3.629.333	-3.440.126	-3.260.783	-3.090.789	-2.929.658	-2.776.927
6.515.989	6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
29.673.813	28.126.837	26.660.509	25.270.624	23.953.198	22.704.453	21.520.809	20.398.871	19.335.423	18.327.415	17.371.957	16.466.310
-16.941.571	-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
4.365.712	4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
9.122.384	8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.257.994	-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.606.395	2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
7.330.487	6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
2.867.035	2.717.569	2.575.895	2.441.606	2.314.319	2.193.667	2.079.305	1.970.905	1.868.157	1.770.765	1.678.450	1.590.948
-16.289.972	-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-35.837.938	-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-1.824.477	-1.729.362	-1.639.206	-1.553.749	-1.472.748	-1.395.970	-1.323.194	-1.254.213	-1.188.827	-1.126.850	-1.068.105	-1.012.421
8.144.986	7.720.366	7.317.882	6.936.381	6.574.769	6.232.009	5.907.117	5.599.163	5.307.264	5.030.582	4.768.324	4.519.738

Figure 29 CBA estimation configuration 1

E7. Configuration 2 – increased share cyclists

				Discount Factor	1,00	0,95	0,90	0,85	0,81	0,77	0,73	0,69	0,65
		Present Value		Year	1	2	3	4	5	6	7	8	9
		-252.153.070	Yearly investments		-20.000.000	-18.957.346	-17.969.048	-17.032.273	-16.144.335	-15.302.687	-14.504.917	-13.748.736	-13.031.977
		-3.482.296	Operating costs			-284.360	-269.536	-255.484	-242.165	-229.540	-217.574	-206.231	-195.480
		116.076.535	Reduction car emissions			9.478.673	8.984.524	8.516.137	8.072.167	7.651.344	7.252.458	6.874.368	6.515.989
		58.734.727	Public transport revenues			4.796.209	4.546.169	4.309.165	4.084.517	3.871.580	3.669.744	3.478.430	3.297.090
		-301.798.992	Parking revenues loss			-24.644.550	-23.359.763	-22.141.955	-20.987.635	-19.893.493	-18.856.392	-17.873.357	-16.941.571
		77.771.279	Reduction of traffic noise			6.350.711	6.019.631	5.705.812	5.408.352	5.126.400	4.859.147	4.605.827	4.365.712
		162.507.149	Prevented car accidents			13.270.142	12.578.334	11.922.591	11.301.034	10.711.881	10.153.442	9.624.115	9.122.384
		-58.038.268	Excise income loss			-4.739.336	-4.492.262	-4.258.068	-4.036.084	-3.825.672	-3.626.229	-3.437.184	-3.257.994
		46.430.614	Stink reduction			3.791.469	3.593.810	3.406.455	3.228.867	3.060.537	2.900.983	2.749.747	2.606.395
		130.586.102	Spatial benefits			10.663.507	10.107.590	9.580.654	9.081.188	8.607.761	8.159.016	7.733.664	7.330.487
		452.698.487	Health effects			36.966.825	35.039.644	33.212.933	31.481.453	29.840.240	28.284.587	26.810.036	25.412.356
		-290.191.338	Utility loss			-23.696.682	-22.461.310	-21.290.342	-20.180.419	-19.128.359	-18.131.146	-17.185.920	-16.289.972
		-638.420.944	Consumer surplus loss			-52.132.701	-49.414.883	-46.838.752	-44.396.921	-42.082.389	-39.888.521	-37.809.024	-35.837.938
		-141.613.373	Crowdedness public transport			-11.563.981	-10.961.119	-10.389.687	-9.848.044	-9.334.639	-8.847.999	-8.386.729	-7.949.506
		0	Crowdedness cyclists										
		100.986.586	Network benefits			8.246.445	7.816.536	7.409.039	7.022.786	6.656.669	6.309.639	5.980.700	5.668.910
Net Present Value		**-539.906.801**											
Benefit-Cost Ratio		**0,68**											

0,62	0,59	0,55	0,53	0,50	0,47	0,45	0,42	0,40	0,38	0,36
10	11	12	13	14	15	16	17	18	19	20
-12.352.585	-11.708.612	-11.098.210	-10.519.630	-9.971.214	-9.451.387	-8.958.661	-8.491.622	-8.048.931	-7.629.318	-7.231.581
-185.289	-175.629	-166.473	-157.794	-149.568	-141.771	-134.380	-127.374	-120.734	-114.440	-108.474
6.176.293	5.854.306	5.549.105	5.259.815	4.985.607	4.725.694	4.479.330	4.245.811	4.024.465	3.814.659	3.615.791
3.125.204	2.962.279	2.807.847	2.661.466	2.522.717	2.391.201	2.266.541	2.148.380	2.036.379	1.930.217	1.829.590
-16.058.361	-15.221.195	-14.427.673	-13.675.519	-12.962.578	-12.286.804	-11.646.259	-11.039.108	-10.463.610	-9.918.114	-9.401.055
4.138.116	3.922.385	3.717.900	3.524.076	3.340.357	3.166.215	3.001.151	2.844.693	2.696.392	2.555.822	2.422.580
8.646.810	8.196.028	7.768.747	7.363.741	6.979.850	6.615.971	6.271.063	5.944.135	5.634.251	5.340.523	5.062.107
-3.088.146	-2.927.153	-2.774.553	-2.629.908	-2.492.803	-2.362.847	-2.239.665	-2.122.905	-2.012.233	-1.907.330	-1.807.895
2.470.517	2.341.722	2.219.642	2.103.926	1.994.243	1.890.277	1.791.732	1.698.324	1.609.786	1.525.864	1.446.316
6.948.329	6.586.094	6.242.743	5.917.292	5.608.808	5.316.405	5.039.247	4.776.537	4.527.523	4.291.491	4.067.764
24.087.541	22.831.793	21.641.510	20.513.279	19.443.867	18.430.205	17.469.389	16.558.662	15.695.415	14.877.170	14.101.583
-15.440.732	-14.635.764	-13.872.763	-13.149.538	-12.464.017	-11.814.234	-11.198.326	-10.614.527	-10.061.163	-9.536.648	-9.039.476
-33.969.609	-32.198.682	-30.520.078	-28.928.984	-27.420.837	-25.991.315	-24.636.318	-23.351.960	-22.134.559	-20.980.625	-19.886.848
-7.535.077	-7.142.253	-6.769.908	-6.416.975	-6.082.440	-5.765.346	-5.464.783	-5.179.889	-4.909.848	-4.653.884	-4.411.264
5.373.375	5.093.246	4.827.721	4.576.039	4.337.478	4.111.353	3.897.018	3.693.855	3.501.285	3.318.753	3.145.738

Figure 30 CBA estimation configuration 2

E8. Configuration 3 – 25% leisure travellers allowed to park
