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Improvement of the Borculoseweg located in Neede

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Preface

I would like to thank Ramon ter Harmsel of the Municipality of Berkelland for providing me with this project and helping me contact the relevant people to interview them. These interviews that were planned made it possible to perform the research as intended. I would also like to thank Karst Geurs of the University of Twente for his guidance, feedback and helpful insights in the project. Furthermore, I want to thank the stakeholders in the Borculoseweg project for taking the time to speak with me about the project, which provided me with the needed information to perform the MAMCA analysis for the Borculoseweg. Lastly, I would like to thank Mobilise for providing me with a license for their MAMCA software, which made it possible to process the results of the interviews into a clear and understandable MAMCA analysis.

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1. Summary

The thesis aims to perform a MAMCA analysis of the redesign of the Borculoseweg in Neede. A MAMCA analysis is a method used to make a structured decision on which of the alternatives to implement. The alternatives must incorporate all stakeholders' criteria, which have an assigned weight to show their importance. After this, all alternatives will obtain a score on how well they perform. Meeting with all stakeholders involved is essential to get to know the criteria and the assigned weights. The stakeholders included in this thesis are Arriva, Kisveld, the police, a road manager, a water manager, a green manager, a traffic expert, and residents. Meetings were scheduled with these stakeholders, and five residents were questioned along the road as a sample of their opinions. These meetings aimed to know the stakeholders' criteria. These criteria needed to have an assigned weight, which values their importance.

Five alternatives were set up, which needed to be scored in the MAMCA, with each focus on a specific goal, for example, greenery, parking, or cycling. The first alternative was a balanced alternative, which is the current situation with cycle lanes. It still incorporated the shared parking and greenery alongside the road to help with other goals. The second alternative has a road profile with a separate two-way cycle path, but no green and parking. This is mainly focussed on the safety of the cyclists, as well as fewer obstacles on the road so the bus can maintain the speed limit of 50 km/h. The third alternative is a cycle street with some parking and mostly greenery alongside the road. This is focused heavily on the safety of cyclists while sacrificing the speed at which cars want to drive, and the bus needs to maintain its schedule. The fourth and fifth alternatives have a road section based on the first alternative. The fourth alternative is focussed on parking, therefore having parking on both sides of the road. The fifth alternative is focussed on greenery, therefore having greenery on both sides of the road and parking on the road itself.

These alternatives have been scored using the SMART method of the MAMCA software tool set up by Mobilise, which means that the alternatives obtain a score between 0 and 10 on how well they fit the criterion. These lead to the graph presented in section 9.6 in Figure 9.6. In this, it can be found that the best alternative to implement to satisfy all stakeholders on average is the greenery-focused alternative since it scores high for safety, greenery, and water, which are some of the top priorities for several stakeholders. The balanced alternative closely follows it. This is because the speed for cars and buses is higher, but safety is increased in the current situation by having cycle lanes and parking alongside greenery on the road. This rigorous MAMCA analysis ensures that the chosen alternative is not only the most suitable but also the most informed decision for the Borculoseweg redesign in Neede.

The main limitation is that setting up scores in association with experts, something that could only be done for the safety of this research, is preferable. This would make the scores better substantiated based on the experts' prior knowledge. Furthermore, it would be good to let stakeholders think more about the specific weight that they assign to a criterion since, in this research, it has been found that they often count from 10 downwards.

2. Introduction

This thesis concerns the Borculoseweg in Neede, where the possibilities for a new road profile are researched. This is because the road requires a new sewage system due to damage, which means the road needs to be demolished to get underground. The Borculoseweg is currently a road with only two car lanes and no cycling facilities, with parking combined with greenery and a sidewalk on both sides. A balance between traffic flow and safety is sought in a redesign. This means inevitable trade-offs need to be made to make the changes fit into the limited width of the Borculoseweg. The goal of the thesis is to determine which alternative road profile is best to implement based on the results of the MAMCA. For this, information from stakeholders is needed. The stakeholders need to set criteria and assign weights to show the importance. This ensures that meetings with the stakeholders are needed to get the information. However, the stakeholders in the area all have their own goals which they want to achieve with the redesign. For example, the bus company Arriva wants to keep its bus on schedule, while the road users want to increase the safety of the road by setting a speed limit of 30 km/h. The results of the MAMCA make clear the best road profile to implement on the Borculoseweg.

In recent years, the focus on increasing the capacity and the traffic flow has shifted towards more safety. More and more safety measures have been implemented in the road network, mainly focused on reducing driving speed in residential areas. These are, for example, speed bumps or narrowings on the road. An upcoming idea is to reduce the speed limit to 30 km/h on all roads within the city limits. However, due to the traffic demand, it is still necessary for the road to cope with sufficient amounts of traffic. This means a new road class, the distributor road 30 km/h, has been set up. This will exist beside the distributor road at 50 km/h and the through and access roads. CROW has set up an assessment framework that determines whether a speed limit of 50 km/h or 30 km/h is preferable. The assessment scheme takes the 30 km/h road as a basis and only implements 50 km/h if needed for public transport, for example. This depends on factors such as safety and specific reasons for implementing a lower speed limit, such as a school (CROW, 2021). The assessment framework does not consider the involved stakeholders alongside the road, but these are included in the research of this thesis. Amsterdam is an example of a city where the transition to 30 km/h is already implemented. Roads have been changed to 30 km/h, which puts them into the class of distributor road 30. This is done to have the beneficial effect of increased safety while maintaining good traffic flow. The change in speed limit on these roads did not mean that all roads were also changed physically. The change in safety that this speed limit change implies can translate into a decrease in traffic incidents between 24 and 64%. (Academische Werkplaats Gezonde Leefomgeving, 2023)

On the other hand, when people are used to driving at a higher speed limit or even speeding on roads before the speed limit is lowered, some drivers will likely be speeding. This will then negatively influence the safety of the road. This includes the safety of all road users, which can imply that someone might get injured in a traffic incident without even doing something wrong themselves. With the scope of the Borculoseweg in Neede, it can be seen that eight accidents have happened over eight years. None were fatal; 1 was a crash with injuries, and the remaining 7 had only material damage (Royal HaskoningDHV, 2021). It aims to reduce these numbers to increase road safety. One of the options is to reduce the speed limit, but it is also crucial to ensure that people drive the set limit.

This report will explain the research that will be performed for the municipality. The research context will be shown in the next section, namely section 3. This is followed by section 4, which discusses the objective and research questions. Section 5 clarifies which methods are used. In section 6, the theoretical framework is provided. Section 7 compares the interviews to the findings in the literature overview. After this, section 8 researched the interviews by comparing the results to the literature. In section 9, the MAMCA is performed based on the scored criteria and the assigned weights. This is followed by section 10, which is the discussion. Section 11 concludes based on the results that provide recommendations in section 12.

3. Context

This chapter discusses the assignment's context. It includes the study area where the project takes place and the parties involved in it. Furthermore, it explains the solutions that will be investigated and some possible other ideas. Lastly, a location visit has been provided to give insights into the current situation.

3.1 Study area

The study area is the Borculoseweg located in Neede, as can be seen in Figure 3.1 below. The Borculoseweg leads from the roundabout on the west side of Neede to the east to around the centre of Neede. This road is one of the major access roads from the N315, as seen on the west side. Using the Borculoseweg, people can enter Neede. Over the length of the road, houses and several businesses are connected. These are mainly detached houses, meaning the parking demand will be lower when compared to terraced houses. The businesses on the road have their own space for parking, but these have to remain accessible, of course. As can be seen, there are four places where the buses will stop. These bus stops are preferred to remain usable for quick transportation within their strictly timed schedule. It is also necessary to reserve space for the buses to remain stationary so people can enter and leave the bus, preferably not blocking other traffic. In the research performed by Royal Haskoning (2021), the option to change the speed limit on the road to 30 km/h was brought up. The effect of this will be that the traffic moves slower for better safety and less damage in case of an accident.

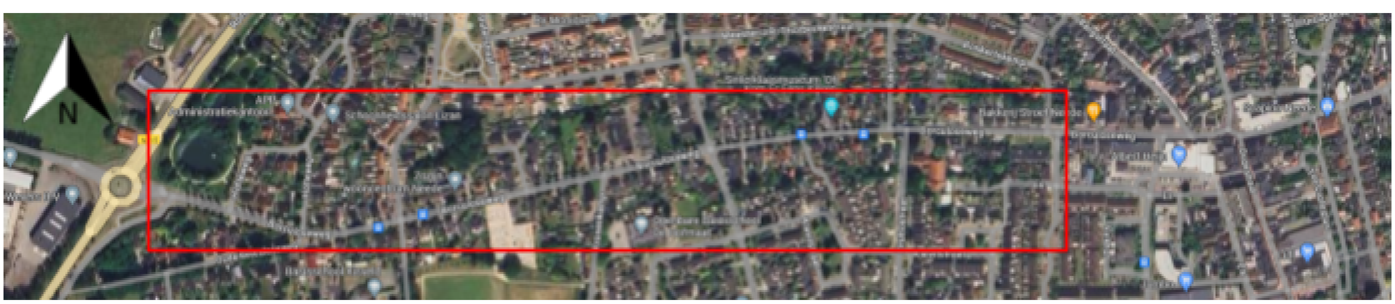

Figure 3.1: Study area Borculoseweg

3.2 Involved parties

- The municipality of Berkelland will decide what needs to be implemented based on the experts' proposals. The municipality also organized the research conducted by Royal Haskoning (2021) to predict traffic flow estimations for the coming years.
- The elementary school Kisveld, which is located at a side road of the Borculoseweg. They aim to increase the safety of small children walking and cycling to their house.
- The police, which has the goal to make sure the situation that will be implemented is enforceable.
- The house owners are alongside the road. They will be more affected since they use the road almost daily. They will note if the road looks more appealing and if the drivability has been improved. Parking is a concern for the people or possible visitors who can not park on their property.
- The public transport company that operates the buses on the road will be affected if it is chosen to change its speed limit to 30 km/h. The bus company is on a tight schedule and will, therefore, need to change the schedule to ensure buses arrive on time.
- General road users. These cyclists, car drivers and lorry drivers use the road to reach their destination. They are represented by experts of the municipality.

4. Objective and research questions

This research aims to find an alternative road profile based on stakeholders' perspectives that balances traffic flow and safety in the redesigned version of the Borculoseweg. It can be investigated what the criteria for the MAMCA are according to the stakeholders, which need to have a weight assigned. The alternatives in the MAMCA will get a total score based on their performance of the criteria, multiplied by the weight. The alternative with the highest score will be the best overall solution to implement based on the stakeholders' opinions.

In order to obtain the information needed for the research, the following research questions have been set up:

1. What alternative road profiles are possible on the Borculoseweg?
2. What are the criteria and assigned weights for the alternatives of the Borculoseweg according to the stakeholders?
3. What is the best scoring alternative to implement on the Borculoseweg?

5. Methodology

The research will start with interviews with the project stakeholders. From these interviews, information will be obtained about the criteria that they set for the project. These criteria will need to be weighted in order to perform the MAMCA analysis.

5.1 What alternative road profiles are possible on the Borculoseweg?

The research on alternative road profiles starts with studying the dimensions of specific road parts, such as the minimal size and the size of a parking space. After this is completed, several alternatives can be set up based on the space available on the Borculoseweg. Since Royal Haskoning already provided some alternatives, the alternatives that will be set up will include more radical changes to the current situation. This is mainly done by having another type of road or focusing on the alternative of scoring well for specific criteria. This way, an alternative focussing on a specific criterion can also have positive effects. The alternatives that will be set up and a selection of the ones provided by Royal Haskoning will be made the set of alternatives.

5.2 What are the criteria and assigned weights for the alternatives of the Borculoseweg according to the stakeholders?

The starting point for the research is to get in touch with the stakeholders involved in the project. By doing so, interviews can be planned with the stakeholders willing to participate in this research. This was different for the Borculoseweg residents since they were questioned without an appointment made at first. During the interviews, questions were asked to make people think about all general criteria of the road, with the option to add further criteria to the list. For this, the questionnaire of Appendix 1 was used. The general criteria were speed, safety, parking, greenery, water, and public transport. For this, their opinion about the current situation is asked, so it becomes clear what the improvement points are. Then, it was asked to rank the criteria on importance, of which it can be chosen to use all or only the highest-ranked few. Furthermore, an option is provided to add specific criteria for the stakeholder. When all the criteria are set, the weights will be set up based on a score between 1 and 10, of which each weight can only be selected once. This weighting scheme forces stakeholders to consider which criteria are more important.

5.3 What is the best scoring alternative to implement on the Borculoseweg?

Multi-Criteria Decision Analysis, or MCDA for short, is a method that can be used for thousands of different applications in which several options are compared to each other. In this case, it can be used to access different possible road profiles for the Borculoseweg. The following subsections will describe how the base and multi-actor methods work.

5.3.1 General information

The method was initially developed to help decision-makers make rational choices, considering all the different aspects of a choice. It has roots in several studies, including mathematics, psychology, and economics. Some critical aspects of the MCA methods can be seen in the analysis. First of all, there are different alternatives. These are options that someone wants to choose from. The next critical aspect is the criteria that will be set for the different alternatives. These will be used to access the different alternatives. It does not need to have many criteria. However, it is essential to specify the criteria carefully to avoid double counting. After setting up the criteria, weights will be assigned for the criteria to see which are most significant. The performance of each alternative for each criterion will be translated to a value on a set scale, for example, a percentage or a score number. This will be multiplied by the weight, which can also be a percentage or a number, as long as it is used consistently during the analysis. The alternative with the highest score will be the most suitable. In Figure 5.1 of Appendix 6, the process that will be followed has been shown.This process is adaptable and can be tailored to the specific needs of the Borculoseweg project, ensuring its relevance and applicability. Only some of these steps are performed explicitly since some are performed implicitly. An MCA can be an analysis that is performed once for a decision. This will be in the case of a limited number of alternatives that have already been set up and do not change over time. On the other hand, it is also possible to do MCA replications. This is needed in the case of alternatives changing over time. (1000minds, n.d.)

5.3.2 Multi-Actor MCA

The specific method that will be used in this project is the Multi-Actor MCA. This method uses the same basic principles as the regular MCA but differs in one fundamental way. This type allows multiple stakeholders to have a voice in the decision-making process. Using this method, each stakeholder or stakeholder group can bring up criteria and their assigned weight. Each stakeholder or stakeholder group will receive one optimal alternative based on their criteria and weights. Using this method, multiple actors can have an opinion about what needs improvement. In Figure 5.2 in Appendix 6, a schematic workflow of an MAMCA has been shown. (Boveldt, 2023)

6. Literature overview

In this section of the thesis, an overview of the literature is provided. This literature provides the information that is needed in order set up the alternatives.

6.1 Car-reducing measures

A factor that plays an important role in the redesigned road's characteristics is the number of cars that will use the road. This affects the design characteristics that will be set for the design and the safety once the measures have been implemented. If the traffic demand on the road is lower, then there are more options for the road design. According to the research and the predictions that Royal Haskoning makes, the traffic demand at the Borculoseweg will be 4700 mvt/item by the year 2030, which is based on an increase of 1.5% in the years leading up to 2030. In order to reduce this, several measures can be implemented. This is not the primary goal, but it will bring more possibilities for road design. These measures are shown together with their effects in Figure 6.1 of Appendix 7. The situation with parking and the roads can have the most effect on reducing car usage. Making fewer parking spaces and parking permits available reduces car use significantly and increases the hourly rate of parking spaces. According to this research, road design has less significant effects, but it is important to note that speed reduction also helps reduce car usage. Figure 6.2 of Appendix 7 shows the impact categories of the measures. It can be seen that a road set to 30 km/h has a high impact on the area's safety but scores low on the other categories. This can also be seen as a good thing because it, therefore, does not negatively influence the accessibility of the area. For safety, rearrangement of the road and improvements to the cycling infrastructure also play a significant role in increasing safety on the road. (Jorritsma et al, 2023)

It can, however, be argued if the car-reducing measures will have a measurable effect on the road in this research. For a well-functioning implementation, it is necessary to have sufficient other modes of transportation so that people can reach their houses. This often works best in densely populated areas. The effect is less in less densely populated areas, in which category Neede would be placed. This is mainly because car access still needs to be in place for the households, but a reduction in the traffic demand could still help the design characteristics, therefore, the issue of limited space and safety. (Jorritsma et al., 2023)

6.2 Speed limit change

The roads used for traffic can be separated into three categories, depicted in Figure 6.3 of Appendix 7. Through roads are the roads where car traffic has the highest priority, and cyclists are separated into alternative routes. The speed limit is high, often between 80 and 130 km/h.

Distributor roads are the connection between the through roads and the access roads. The speed is lower than on the through roads, often 50 or 70 km/h in urban areas and 80 km/h in rural areas. The last category is the access roads. These types of roads are used to access residential areas and have a speed limit of 15 or 30 km/h in urban areas and 60 in rural areas. (SWOV, 2023) An idea that has been looked into is to develop a new type of distributor road with a lower speed limit. This type of road features a speed limit of 30 km/h and will be developed for cases where there is not enough space to implement the needed facilities to set the speed limit to 50 km/h safely. Roads with a maximum speed of 50 km/h limit will only be implemented if it is safe and needed for the traffic flow.

This means that a choice will need to be made between three different classes of roads when implementing changes for a road. These classes are distributor road 50 km/h, distributor road 30 km/h and access road 30 km/h. This involves the function of the road in the road network. Access roads will only be used for roads with low traffic demands in which the flow is less important. When the traffic flow is concerned, the distributor roads will be used. The speed limit then depends on the characteristics of the road. Implementing safety measures to have a speed limit of 50 km/h should be possible. Otherwise, the road will have a speed limit of 30 km/h to ensure safety. However, design characteristics still need to be set for the distributor road 30 km/h. In the Figure 6.4 of Appendix 7, the assessment scheme is shown. In this assessment scheme, it is also stated that the network needs to be optimized for public transport, emergency vehicles and all modes of personal transportation.

For the Borculoseweg, this comes down to optimizing the road for emergency vehicles and having more traffic over the larger ring around Neede. In order to effectively improve the road for emergency vehicles, it is necessary that the road is sufficiently wide and uses speed-lowering measures that affect the emergency vehicles as little as possible. Due to the extra time it takes to drive over the Borculoseweg in case of a 30 km/h, traffic will likely take the larger ring to the east side locations. Furthermore, it needed to optimize the road well for the public transport that runs over the road. On the Borculoseweg, the bus currently runs for half an hour. This puts the bus into a category which makes it of a higher importance. A change to 30 km/h provides some challenges for the public transport company since a slower route makes it less appealing to use the bus route, leading to fewer travellers and, therefore, less profit. The decrease in speed of the bus is 13%, which has been found in a study by Goudappel and DTV Consultants. It is based on 18 routes with a speed limit of 30 km/h or 50 km/h. This data indicates the time the bus will take to drive its route, as shown in Figure 6.5 in Appendix 7 below. (Goudappel, 2022)

Of course, the main reason for implementing this road class is to improve everyone's safety when using the roads. However, there are no exact measurements on how the safety will improve. SWOV estimated the effects of this type of road: the number of severe accidents will decrease between 22% and 31% (CROW, 2021). Besides, the number of high-damage accidents will decrease from 30% on 50 km/h roads to 21% on 30 km/h roads (CROW, 2021). From these reductions, it is crucial to consider that these are estimations. Besides, the specific road layout that will be used for a 30 km/h road and the measures implemented to improve the existing 50 km/h roads will play a role in how the exact numbers will develop after measurements. (CROW, 2023)

6.3 Sustainable Road Safety

From 1998 until 2007, measures were implemented to make the traffic system safer. This was better known as the first iteration of the Sustainable Road Safety principles, which have led to a decrease in loss of life due to a traffic incident of 30%, as shown in Figure 6.6 in Appendix 7. This is equal to a reduction of 1600 to 1700 road deaths in this timeframe. Furthermore, the risk decreased from a 2.6% per year average decrease to a 5.8% decrease yearly. In 2018, a new vision of Sustainable Road Safety was introduced. Sustainable road safety has three ways of enhancing road safety. These are:

- Eliminating - Dangerous situations are ruled out so that they cannot happen.
- Minimizing - The choice of a dangerous mode of transport or situation is discouraged.
- Mitigating - When a risk is unavoidable, measures are taken to mitigate the risk.

The new version of Sustainable Road Safety consists of five principles that help to make the traffic system as safe as possible. These principles are explained in the following segments.

The functionality of roads is based on the different types of roads that exist, namely the through-roads, distributor roads, and access roads. These roads all should have only one function, which should be made clear by the road profile. These functions are a traffic flow function and an exchange function. A road with a traffic function does not interact with the environment. In an exchange function, there is interaction with the environment, implying unforeseen actions from other drivers can occur.

The following principle is biomechanics. This principle is about the compatibility of the speed and the transport modes with the speed, direction, mass, size and degree of protection. If this is not sufficient, the speed of all road users needs to be adapted to the most vulnerable road users, often pedestrians and cyclists. Table 6.1 of Appendix 7 provides the safe speed limits for different road types. In the case of traffic flows, motorized traffic should be separated in speed from low-speed traffic, traffic in the opposite direction, traffic with a significant difference in mass and width, and obstacles. This separation can be physical or in time. In traffic exchanges, traffic capable of high speeds is forced to drive at a safer low speed. This is done to reduce the risk of an accident and, in case a crash occurs, a reduction of the damages.

The principle of psychologics is about the alignment of the road with the general competencies and expectations of drivers. This means that road users can understand the information provided by signs or the road profile and will change their behaviour accordingly. In an ideal case, the road system is less dependent on individual choices. The people and the system can adapt to each other in two ways. The first option is to adapt the system to the people. Road layouts, signs, environments, vehicle systems, and other technologies can transfer information. Information can be implicit and explicit, making it harder to understand. Another way is to adapt the people to the system. This can be started at a young age through education, but it can also help during a drive-by, such as having a vehicle provide information for an intersection.

The organization's principal responsibility is to clarify which responsibilities are set for the parties involved in the traffic system. There is a system of ultimate responsibility and operational responsibility. The ultimate responsibility is set to the central government. It has to ensure that a short-term profit does not get in the way of obtaining long-term goals such as road safety.

Besides, the central government sets goals and conditions for the design of roads. The central government implements laws and regulations with an eye on the intended results and is responsible for the financial incentives to stimulate intended behaviour. Operational responsibility is for road authorities, lawmakers, spatial planners, enforcement officers, safety education officers and other traffic professionals. For example, they must ensure that the road is designed and maintained to operate as safely as possible.

The organization's principle of learning and innovating is that traffic professionals keep investigating crashes and, therefore, obtain knowledge on how accidents can be prevented in the future. The changes that can be made to the system make the plan. Then there is do, which implies setting changes to the traffic system. After that, there is a check in which the effectiveness of the measures is monitored. Lastly, there is an act in which necessary adjustments are made. These actions will create a cycle that can be repeated, therefore leading to a safer traffic system. This cycle is also shown in Figure 6.7 In Appendix 7.
(SWOV, 2019)

6.4 Case Study of Amsterdam

Within the city limits, Amsterdam is changing their roads to a speed limit of 30 km/h. In 2016, Amsterdam started with its plans to change the speed limit on most of their roads in phases to the new speed limit. Of all the roads planned to have their speed limit changed, 70% already have the new speed limit (Klein, 2023). However, not all roads in Amsterdam will be changed to a 30 km/h speed limit. Some of the roads will remain in their original state, meaning they will have a higher speed limit than most other roads in Amsterdam. The road network of Amsterdam with the roads that will be changed to 30 km/h or remain at 50 km/h is shown in Figure 6.8 in Appendix 7. (Gemeente Amsterdam, n.d.) The Academische Werkplaats Gezonde Leefomgeving has researched the impact of the speed limit change on several categories. The main part of this is the safety of the roads. It has been found that safety does increase on these roads. Traffic incidents are decreasing by between 24 and 64%, a significant decrease. Also, this value is in line with the 25% decrease found in similar research in Rotterdam. Lowering the speed limit also has a so-called spillover effect, which implies that drivers are also driving slower around the 30 km/h zones. (Academische Werkplaats Gezonde Leefomgeving, 2023)

6.5 Literature conclusion

The main factors affected by a change in the speed limit are the amount of car ownership and the increase in safety it could bring. A lower speed limit has been found to reduce car ownership, which also means fewer people will have a car that needs to be parked. From this knowledge, it can be assumed that fewer parking spaces are needed in an alternative road profile in case the road is changed to 30 km/h. Furthermore, it has been found that a more extensive scale change in the speed limit in Amsterdam has decreased the number of accidents between 24% and 64%. The principles of Sustainable Road Safety must be implemented in order to reduce the number of road deaths substantially. In 1998-2007, implementing the first iteration of the Sustainable Road Safety principles led to a decrease of 30% in road deaths. The principles are functionality, biomechanics, psychologics, responsibility, learning, and innovating. Functionality, biomechanics and psychologics are design principles that apply to a road profile of the Borculoseweg itself, while responsibility learning and innovating are operational principles. These factors will be considered when setting up the alternatives for the Borculoseweg.

Reducing car ownership and, therefore, car use can result in alternatives with a lower maximum car intensity than anticipated or will only work when the car intensity is low. The increased safety of a 30 km/h road will be used to argue against the higher speed limit to increase traffic flow.

7. Research to the Borculoseweg

In this section, other possible road profiles will be set up and tested alongside the alternatives set by Royal Haskoning. These alternatives will be more radical changes to the current situation. Furthermore, the road's parking demand will be researched to determine if the low number of parking spots is currently a problem.

7.1 Possible road profiles

This report section will examine possible alternative road profiles for the Borculoseweg. These will be tested in the MAMCA alongside the selected alternatives Royal Haskoning sets.

7.1.1 Dimension regulations

To start with other alternatives, checking the base rules first is essential. For example, the minimum width of a sidewalk. This is 1.80 meters, with a minimum width free of obstacles of 1.50 meters to account for the use of wheelchairs, for example. For busy shopping streets, this will be 2.50 meters. Then there is the space that is needed for parking. Parking can be divided into three categories. The first is parallel parking, with a minimum required space of 1.80 by 5.00 meters. However, reserving a space of 2.00 by 5.50 meters is optimal. The second category is perpendicular parking, for which the minimum space is 2.30 by 4.50 meters. This is short for some cars, so the overhang must be considered. The optimal dimensions for perpendicular parking are set to 2.50 by 6.00 meters. The last category is parked at an angle with the road. For this, the minimum will be 2.30 meters by 4.50 meters, with an optimal of 2.50 by 6.00 meters. Then, there are the dimensions of the roadway. For a one-way road, this is between 3.00 and 4.00 meters, depending on the intensity of the road. The roadway is between 4.50 and 5.50 meters wide for a two-way road.

If trucks also drive on the road, the width should be more extensive, namely between 6.00 and 7.00 meters (Public Space Info, 2013). Lastly, there are the cycling facilities. The width of a separated one-way cycle path is between 2.00 and 4.00 meters. The width of a separated two-way cycle path is between 2.00 and 4.00 meters. Both dimensions depend on the cycle intensity on a cycle path, as depicted in Figure 7.1 of Appendix 8 (Fietsberaad, 2004). The minimum width of a cycle lane on the main road is 1.25 meters. However, it depends on the road designer to determine the needed width, which means that suggestion lanes are often smaller (Fietsen123, 2020).

7.1.2 Cycle Street

The first of the alternatives that will be checked is a cycle street. These roads are tailored towards the safety of the cyclists that use the road, while cars need to adapt their speed to the cyclists if they are on the road. A cycle street with a speed limit of 30 km/h will be designed with unique design characteristics to show that the road is intended as a cycle road. It has been chosen to develop this alternative since it focuses on cyclists and their safety. It also increases cyclists' safety, according to research performed by SWOV. It has been found that cycle streets have a lower crash intensity and the number of accidents per km of the road compared to regular streets with cycle lanes or a separate cycling path. However, the crash cost rate and the risk of the accident corrected for the cycling intensity are higher for a cycle street compared to roads without cycling facilities. The study of SWOV also extended to the perceived safety of road users, which a survey has researched. The outcome was that more minor roads hurt the perceived safety of people cycling next to each other. On the other hand, when a road is too wide, the perceived safety is reduced by the higher motorized traffic speeds. This is due to the connection that has been found between the higher car intensities and the number of unsafe conflicts and overtaking actions. (SWOV, 2023)

Figure 7.2 of Appendix 8 shows that the cycle street considers the cycle facilities while still allowing other types of traffic to use the road. In the design of a cycle street, it is essential to make a balanced decision on the road's function, shape and use. In this case, the shape will be the technical design of the road. The primary function will be the cycle route through a residential area, while the use will be that cyclists can use the road safely. One of the constraints for this is that the vehicle intensity and speed will be low. This intensity will be between 200 mvt/hr for fewer cyclists and 400 mvt/hr for many cyclists. The average intensity on work days in 2030 on the Borculoseweg will be 4700 mvt/day (Royal HaskoningDHV, 2021). This comes down to 196 mvt/hr, so the intensity of cars will fit the cycle street well. The width used to calculate these numbers in the design is a road width of 6 to 7 meters.

For the design of the cycle street, it is essential to look at the number of cars and cyclists that use the road. As stated before, the number of cars that use the road is 196 per hour. However, no exact data is available for the number of cyclists that use the road, making it difficult to determine which alternative is designed for the Borculoseweg. The different road widths CROW gives based on the demand are provided in Figure 7.3 of Appendix 8. This Figure shows that the width of the road will be between 4.80 meters and 6.30 meters wide. In this case, it has been chosen to set the road width to 6.00 meters. This is also the minimum road width required for larger trucks to pass the road, as stated in section 7.1.1. This road width has been chosen since it fulfils the traffic demand on the road and leaves optimal space for walking paths and greenery on both sides of the road. With these dimensions set, the design of the road can look like the following road in Figure 7.4. In this case, a rebate strip of 0.30 meters has been used. It is vital to keep the width of this below 0.40 meters since making rebate strips wider than this will make for more people speeding and, therefore, a lower perceived safety. (SWOV, 2023)

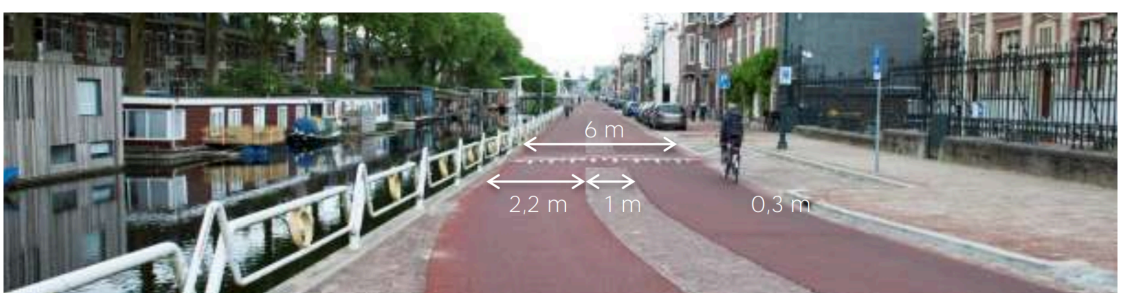

Figure 7.4: Example of cycle street with a 6.00 m width (CROW, 2019)

As can be seen in Figure 7.4, it is not simply red asphalt with more prominent cyclists. The street also incorporates a middle and rebate strip. The rebate strip made of bricks is used to push the cyclist more inward into the street. A middle strip is used to mark the road's middle, showing car drivers that they use the lane in the other direction when trying to overtake a cyclist.

The middle strip also has the use case of providing a space for faster cyclists to pass other cyclists who are cycling beside each other. A cycle road with a width of 6.00 meters and a walking path of a minimal width of 1.80 meters on both sides leaves 3.90 meters left for other purposes in the road. This allows parking to be combined with greenery on one side of the road and greenery on the other side of the road. This will be altered alongside the road to ensure variation between greenery and parking. The final design of the cross-section is provided in Figure 7.5 below.

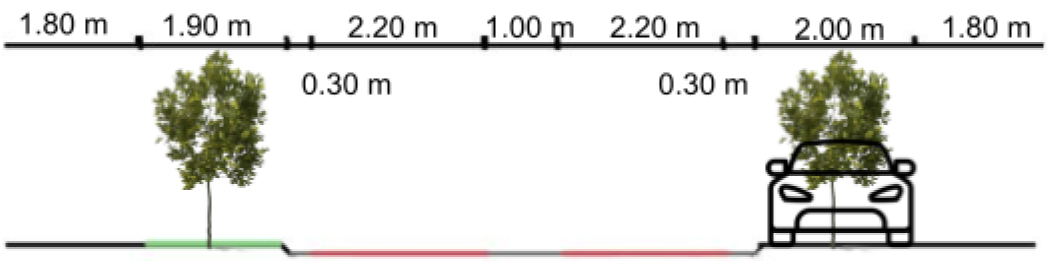

Figure 7.5: Cycle street alternative

7.1.3 Problems cycle street

The previous section calculated that the number of vehicles per hour is 196 mvt/hr. This was based on the total number of vehicles of 4.700 mvt/day in 2030. However, the municipality of Berkelland uses a different method to calculate the demand based on the total number of vehicles during the day. They perform the calculation by getting 10% of the total demand of the day, which incorporates the peak demands better. This is a traffic demand that is much larger than first anticipated, which means that the design of section 7.1.2 will not be feasible anymore based on the used literature. However, it has been decided that the option of the cycle street will still be present in the analysis since it will be a good, more radical change in the road layout and usable in combination with car-reducing measures.

7.1.4 Alternative focussing on parking

In the alternative that focuses on parking spaces, the space reserved for parking is the most important. This is to check for more extreme alternatives and to account for possible stakeholders that strongly prefer more parking. Therefore, the road will mainly focus on the residents who cannot park on their own property. However, the residents who can park on their property will likely dislike the view of the road. This alternative will use the space regulations explained in section 7.1.1. The total available road width is 13.50 meters on average for the road designed. By optimizing for the parking spaces, a row of parking spaces will be implemented alongside the road on both sides. The optimal space of 2.00 by 5.50 meters is chosen to account for more accessible parking and enough space for bigger cars. Also, walking paths must be on both sides of the road, with a minimal width of 1.80 meters. This leaves a width of 5.9 meters for the regular road. The road design that Royal Haskoning has proposed can still be used with this information. This means a road surface of 5.80 meters, with cycling lanes that are 1.70 meters inwards on the road. This cross-section type leaves no space for greenery and is solely focused on functionality. The design of the cross-section of this alternative is provided in Figure 7.6 below.

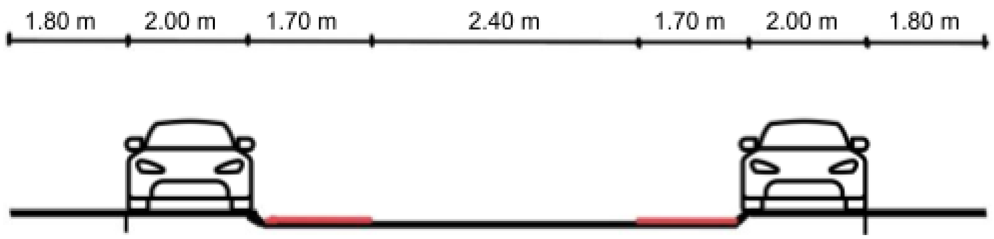

Figure 7.6: Parking focussed alternative

7.1.5 Alternative focussing on greenery

This last alternative will be the opposite of the previous section's alternative. Instead of focusing on the parking spaces, the parking spaces are removed entirely to make space for greenery alongside the road. This has been done since greenery is considered essential for the liveability of the surrounding area. By planting trees closer to each other, drivers get the feeling that they are driving quite fast. By having this, there will be less speeding on the road, reducing the average speed and, therefore, the impact of an incident in case it happens. The exact dimensions were used for the road and the walking paths, which means that the space previously reserved for the parking spaces can now account for greenery. This greenery will reduce the amount of space that is functional for the traffic but increase the liveability in the area around the road, which will likely improve the likeability of the road for the neighbouring houses. The design of this cross-section is provided in Figure 7.7 below.

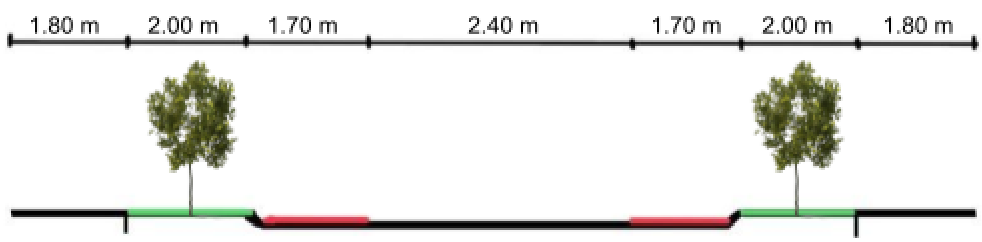

Figure 7.7: Greenery focussed alternative

7.2 Parking Borculoseweg

Parking will be an important aspect of the design of a road used frequently by the inhabitants. People want to park their cars as close to their homes as possible, which could mean high parking demands on one part of the road and low parking demand on another.

7.2.1 Current parking demand

The current parking demand has been counted in two segments at two different times during the day. The first segment is the roundabout of the N315 to the intersection with the Merelstraat. The second segment is the Merelstraat, which goes to the start of the centre of Neede. The two times are at 15:00 when most people are at work, so they do not have their cars parked in the Borculoseweg. However, shops in the centre have opened, and people can have visitors. The second time frame is at 21:00. At this time, most people are at home and will, therefore, have their cars parked in the street in case they can not park on their property. The segments of the counts are displayed in Figure 7.8 in Appendix 8.

The first segment has 13 parking spaces alongside the road. In the afternoon, 5 of these were in use, which comes down to 38%. In the evening, only two parking spaces were in use, which is only 15% of the available parking spaces. The second segment has more parked cars, of the available 20 parking spaces in this segment, 9 were in use in the afternoon. This is a percentage of 45%, which is higher than the demand in the other segment. In the afternoon, 12 parking spaces were in use, so 60%. From this information, it can be concluded that although the demand is higher in the segment close to the city centre, the demand did not exceed 60% of the available spaces. This means that in the practical analysis, the current situation is sufficient, and an alternative without parking places, with only roadside parking, will also be sufficient.

7.2.2 Theoretical parking demand

According to Allecijfers, there are 153 houses registered at the Borculoseweg. However, not all of these houses are within the city limits and, therefore, within the project's scope. Of these houses, 86 are detached houses. However, 14 of those are outside the city limits, meaning 72 houses will be accounted for. Another large portion of the houses are apartments, which 41 of the houses, but of these, there are also four outside of the city limits, which leaves 37 apartments for the parking demand calculation. The next most significant segment is the semi-detached houses, which make up 18 of the houses. The last type of house is the terraced house, which is 9 of the houses. (Allecijfers.nl, n.d.)

The theoretical parking demand for detached houses is 2 parking spaces per house; for semi-detached houses, 1.8 parking spaces per house; for terraced houses, 1.5 parking spaces per house; and for apartments, 1.3 parking spaces per house. This makes the following equation: 72*2+18*1.8+9*1.5+37*1.3=238 parking places needed for the houses based on the parking norms set by the municipality of Berkelland.

7.2.3 Parking conclusion

As calculated in the previous section, the theoretical parking demand is significantly higher than the number of parking spaces currently available. However, the highest parking demand in one of the segments was set to 60%. The municipality regards parking as a problem when the demand exceeds 80% of the available parking spaces. This means that according to the rules set by the municipality of Berkelland, the Borculoseweg does not have a parking problem.

8. Interviews

For the research of the alternatives for the Borculoseweg, interviews have been conducted to learn the criteria of the stakeholders involved in the project. This information will also be compared to the information found in the literature.

8.1 Main outcomes

The interviews were conducted with the stakeholders involved in the Borculoseweg project or those affected by the changes that will be made to the Borculoseweg. The most important thing is that safety on the road should be improved. Road users feel unsafe in the current situation, mainly because many drivers are speeding. In order to increase safety and the feeling of safety, nearly all stakeholders opted to have a speed limit of 30 km/h. However, the bus company wants to have a speed limit of 50 km/h since this is a significant factor in the schedule of Arriva. Another factor is the placement on the road since cyclists do not have a separate lane where they are supposed to cycle, which means that cyclists should simply keep on the right side of the road. However, many cyclists use the sidewalk to get to their destination. Parking is a point of interest, but not a problem currently. The residents have parking on their property and do not need many parking spaces. It is, however, preferable that parking is not allowed on the road itself since cyclists and motorists do not need to go around the parked cars. Other important factors are water and greenery. These factors are mainly of lower to middle importance. Water is not regarded as a problem by the residents. It is, however, a problem of the municipality and one of the main reasons why the Borculoseweg project started. Green is often seen to be more critical than water since green adds to the road design to be more in line with the rural styling of the area. Furthermore, it adds shade to the road, helping to achieve the municipality's goal, stating that three trees should be visible, 30% should be green, and 300 meters away from a cooler spot. Greenery in the gardens of residents also counts toward that goal.

8.2 Compared to literature

According to the literature in section 6.2, there are three different options for a type of road that can be implemented: an access road, a distributor road 30 km/h and a distributor road 50 km/h. It has been made clear that the Borculoseweg is regarded to be one of the major roads leading into the centre of Neede, with also buses and some trucks making use of the road. The Borculoseweg is a so-called 'grey road' since the road has a speed limit of 50 km/h but insufficient space to implement safety measures. For the redesign, an access road is not one of the possibilities. The bus company Arriva preferred the distributor road at 50 km/h from the other two options. This is due to the bus company's schedule, on which travellers rely. However, the 50 km/h speed limit should only be set in case this can be implemented safely. Safety is currently the primary concern of the residents and the road manager since the residents do not feel safe on the Borculoseweg. Large trucks are using the road, and the buses will try to overtake as soon as possible. Therefore, all other stakeholders have opted for a 30 km/h speed limit as the better option. This mainly increases the road's safety since the traffic flow will decrease. According to the traffic expert, it will also decrease material damage. However, this 30 km/h speed limit can only be implemented when the road is optimized for emergency vehicles and public transport. This means that the road will need to have a good traffic flow. Besides that, it should be possible for emergency vehicles to reach high speeds safely without other traffic having to make space for emergency vehicles to pass. With a speed limit of 30 km/h, it is also likely that people will be speeding. However, the driving speed will still be lower than in the current situation. In the most recent study of SWOV, it has been found that on 10 locations in Limburg with a speed limit of 30 km/h, the actual driven average speed was between 25 and 37 km/h. The amount of drivers exceeding the speed limit was between 26% and 85%. (SWOV, 2018)

According to section 6.3, the road design should incorporate functionality, biomechanics and psychologics. There are further principles of Sustainable Road Safety, but these are the operational principles of responsibility, learning and innovating. Functionality is one of the principles that play a role in the hierarchy of the road system, as said by the traffic expert. This plays a role in the speed limit and the function of the road. The function of the Borculoseweg should be exchanged since people can leave and enter the road network from their driveway. Biomechanics is something that is also pointed out implicitly by the residents of the Borculoseweg. They do not feel safe due to the cars with high speeds and large trucks that use the road. As seen in table 6.1 in Appendix 7, a 50 km/h road can only be safely implemented in case there are no conflicts with vulnerable road users, except with helmet-protected riders or motorized two-wheelers. Due to this, it would be safer if the current situation of the Borculoseweg would be a 30 km/h road. Other designs that could be implemented will also choose to be 30 km/h or 50 km/h. However, there must be no conflicts with vulnerable road users in the case of a 50 km/h road. Lastly, there is the psychlogics principle. This means that people should be able to understand the preferred behaviour well. Furthermore, the road profile should also provide information about the speed limit and the preferred behaviour.

The case of Amsterdam in section 6.4 can also be compared to the situation at the Borculoseweg. In Amsterdam, most roads were changed to 30 km/h to increase safety. It has been found that the number of incidents decreased between 24% and 64% (Academische Werkplaats Gezonde Leefomgeving, 2023). This is something that most of the stakeholders, including the residents, want to have on the Borculoseweg. Their opinion about this change can be compared to the stakeholders in Neede. A survey conducted by AT5 and filled in by nearly 2000 Amsterdammers found that 60% of the people were satisfied with the 30 km/h speed limit. Others were unsatisfied with the new speed limit since it was too slow. In Amsterdam, the enforcement of the new speed limit is flexible, especially at the start of the project, which makes people feel less affected by the new speed limit. Only 26% state that they will drive the speed limit. 54% of the respondents say that they sometimes speed but otherwise drive the speed limit, and the last 17% do not obey it. These opinions are comparable to the opinions found about the Borculoseweg. The feeling of safety was also surveyed, and 17% said that they felt safer on the road. 63% do not feel a difference, while 16% even feel more unsafe. In short, by the 60% that is still satisfied by the new speed limit, it can be concluded that there is a support base for this change, while it is also clear that sufficient speed-reducing measures should be implemented to bring the amount of speeding down. This speeding is also the main reason people feel unsafe, so it will also increase their feeling of safety. (AT5, 2024)

Furthermore, there is a parking demand at the Borculoseweg in section 7.2. According to the regulations set up by the municipality, the Borculoseweg should have at least 238 parking spaces alongside the road. The type of houses built accounts for this, but parking on one's property is not subtracted. Since there are currently 33 parking spaces in total, this should be a problem, according to the data. However, parking is not regarded as a problem by the road residents. This is because most cars are parked on their property, and not all households have the number of cars accounted for by their type of house. Furthermore, the highest parking demand was 60%, below the municipality's threshold. Parking, therefore, is not a problem currently but will remain a point of interest.

9. MAMCA

In the MAMCA analysis, the alternative will be tested against the criteria set by the stakeholders in the project. These criteria will be scored based on the indicators that are set, which means that the alternatives perform differently from each other. Using the weights, a total score can be determined on how well the alternatives perform.

9.1 Alternatives

An overview of the five alternatives and their most differentiating characteristics is provided in table 9.1 in Appendix 10.

The first alternative is the one with greenery on both sides of the road and parking on one side of the road, as proposed by Royal Haskoning and depicted in Figure 8.2 of Appendix 9. This is decided since this alternative is essentially the same as the alternatives in Figures 8.3 and 8.4 of Appendix 9. The difference is the dimension of the green strip on the left side. This alternative is more mixed-use and will likely speak to all stakeholders. However, it does not do one of the primary uses such as parking, greenery or traffic flow the best. In the case of this road profile, it has been chosen to set the speed limit to 50 km/h. This makes it possible to see the safety changes compared to other alternatives. An example of this cross-section being implemented is shown in Figure 9.1. In this case, the speed limit is 50 km/h, with parking being facilitated alongside the road. However, the cross-section was aiming for more green, so some parking spaces need to be replaced with greenery. However, the road profile will be similar to the one shown. This road does have priority over the roads connecting to it, making for a more significant traffic flow on this main road.

Figure 9.1: Regular alternative implementation (Theoriecursus.nl, n.d.)

The second alternative that will be tested is another one proposed by Royal Haskoning, shown in Figure 8.6 of Appendix 9. In this alternative, there is a separate two-way cycle path. This makes cyclists most separated from the cars on the main road. However, it also brings forward more conflicts. This alternative has been chosen over Figure 8.5 of Appendix 9 since it differentiates more from the original situation. This alternative will mainly target car users since they can drive more comfortably by not having to slow down for cyclists since they do not share the same space. An example of the cross-section of this alternative being implemented is shown in Figure 9.2. There is, however, a difference since the alternative set for the Borculoseweg will have a sidewalk on both sides of the road. The speed limit on the road is 50 km/h, but the speed is limited by the speedbumps and the road material made of clinker pavement. The road also has priority over the other roads connected to it, improving the traffic flow on the main road. The cycle path connected to the road is two-way, meaning that cyclists going in both directions will use the cycle path. In the case of the Borculoseweg, this will, however, create conflicts in the centre and at the roundabout with the N315 since cyclists need to cross to one side of the road.

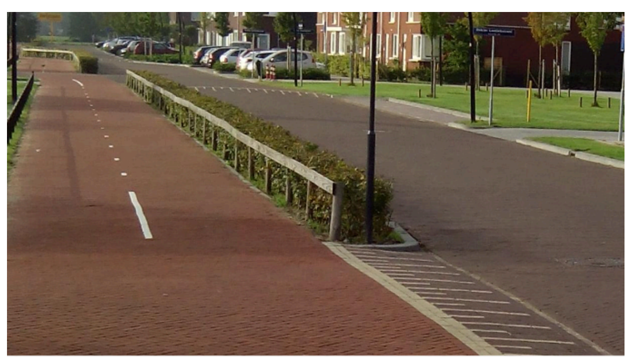

Figure 9.2: Separate cycle path alternative implementation (Wikipedia, 2014)

The third alternative is the cycle street. This alternative has the flaw that the Borculoseweg has a traffic intensity that is too high, which makes the cycle street a good alternative. However, the cycle street can be combined with car-reducing measures as suggested in section 6.1, such as a reduction in the number of parking spaces and a change to 30 km/h, a characteristic of a cycle street. The cross-section proposed for this alternative is provided in Figure 7.5 in section 7. Based on this cross-section, a real-world example of this road can also be found. This example is provided in Figure 9.3. In this example, the road is also constructed from two major asphalt parts, which are comfortable for cyclists and cars to drive. On the side are clinker pavings, which are uncomfortable for cyclists to drive on, so they are pushed more inwards on the road and will drive more prominently. This also helps slow down the traffic since drivers have to overtake the cyclists first to continue at their speed. The middle section also has clinker paving, which makes it uncomfortable for cars to cross this section. This discourages people from overtaking this road section, which, in theory, should improve the safety of this type of road. The speed limit on this road is 30 km/h. There are no speed bumps on this road, but since sufficient cyclists use the road, the traffic will be slowed down sufficiently from cyclists in front and opposite direction traffic, which makes overtaking not an option.

Figure 9.3: Cycle street implementation (Gemeente Oss, n.d.)

The fourth alternative is the street, which is highly focused on the number of parking spaces. Business owners and house owners will likely prefer this road without the possibility to park their cars in their driveway. A cross-section of this alternative is provided in Figure 7.6 in section 7. Based on this cross-section, an example of implementing this type of road has been found to give the cross-section a better understanding. This road has a speed limit of 30 km/h, enforced by the road surface made of clinker paving. This causes more vibrations to car drivers, which will slow them down since it is uncomfortable to drive on. The cycling lanes are made of asphalt to let cyclists ride comfortably. There are parking spaces alongside the road on a slight increase, with blocks of 2 or 3 parking spaces to increase the ease of parking, as seen in Figure 9.4.

Figure 9.4: Parking alternative implementation (Funda, n.d.)

The fifth and last alternative is heavily focussed on incorporating greenery to increase the liveability for the house owners along the road. This is due to the effects of greenery since it can provide shade and reduce the local temperature slightly. The cross-section of this road is provided in Figure 7.7 in section 7. In this case, the speed limit is 30 km/h, which means that some speed-decreasing measures must be implemented. Figure 9.5 shows that the road uses speed bumps, which is an option to implement on the Borculoseweg. However, these can cause house vibrations and are therefore not an optimal solution. This alternative has greenery on both sides of the road. It, therefore, focuses on a high score for greenery, which means that the alternative speaks to the residents or green manager, for example.

Figure 9.5: Greenery alternative implementation (Atlas leefomgeving, 2024)

9.2 Criteria

The criteria are set by asking stakeholders or the people representing the stakeholders. In their opinion, these aspects of the project are the main points of improvement or aspects they do not want to see changed. These criteria are viewed per stakeholder.

9.2.1 Arriva

Arriva is the public transport company that operates the bus route through the Borculoseweg in Neede. Due to the tight schedule that the bus runs on, they need to have a high-speed limit on the road, and therefore, the bus company wants to have the speed limit of 50 km/h unchanged. To quickly achieve this speed easily with a large bus, they prefer to have cyclists separated from the primary traffic and no speed bumps on the road. Lastly, they want good road safety since they do not want a bus company to get involved in a traffic accident. Criteria for Arriva are provided in Table 2.1 in Appendix 2.

9.2.2 Kisveld

The elementary school is located on a side road of the Borculoseweg. It has a path leading to the walkway of the Borculoseweg, which plays a role in road safety for the children who walk and cycle home. Their main point is the speed of driving over the road and road safety. For the children, it is difficult to cross the road safely when the cars drive fast and often do not stop for the pedestrian crossing. Furthermore, it is important to the school that the road has a friendly look for the neighbourhood, which can be translated to greenery and good use of materials. All criteria are provided in Table 2.2 in Appendix 2.

9.2.3 Police

The police are responsible for checking the behaviour using enforcement and safety of people on the road. The main point for safety is the placement of road users. This involves cycle paths and walking paths that are differentiated from the main road used for cars. Another critical part is recognisability. The road's situation and its conditions should speak for the road's image. Lastly, the right of way should be reworked into equivalent intersections at which the regular right of way applies. These factors together lead to higher safety on the road, according to the police. In Table 2.3 of Appendix 2, the criteria are shown.

9.2.4 Road manager

The road manager has a broader look at the aspects of the road that play a role, which leads to the criteria in Table 2.4 in Appendix 2. In his opinion, the current road safety is only at an average level, and the capabilities of the road to cope with high amounts of rainwater are below the municipality's expectations. However, the current amount of greenery and the bus route are positive. For the design, the road manager has green as a higher interest than parking or a wider road profile. Its criteria are shown in Table 2.4 in Appendix 2.

9.2.5 Water manager

The water manager is mainly involved with the underground water infrastructure. The underground sewage is damaged and will, therefore, need replacement, which is one of the main reasons why the road will be redeveloped. The main criteria for the road set are how the underground water infrastructure fits with the road profile and where drainages are located. Another point is the above-ground water retention and the combined use of green. The criteria are also shown in Table 2.5 in Appendix 2.

9.2.6 Green manager

The main goal of the green manager is, of course, to ensure a sufficient amount of greenery along the road, but besides this, the quality of the green that is implemented and the amount of water that can infiltrate the ground. Therefore, water and green are the criteria of the green manager. Green quality consists of several aspects: biodiversity, heat effect and visual quality. Biodiversity is about having multiple types of plants and trees. The trees also help prevent the heat by providing shade, which cools down the area. Lastly, there is visual quality, which is a more subjective criterion. All criteria that are set are shown in Table 2.6 of Appendix 2

9.2.7 Traffic expert

The traffic expert has as his most important goals the safety, reachability, traffic flow and road hierarchy compared to roads surrounding the Borculoseweg. Safety in the current situation is considered insufficient since cyclists have no facilities, and pedestrians have problems crossing the road. This is partly because a school is located close to the pedestrian crossing. Safety is sufficient for cars, but with the current speed limit, it is possible that some car mirrors will be torn off. On the other hand, parking and the driving speed are seen as good and average, respectively. Other stakeholders better represent greenery, water and public transport, but there are some conflicts with traffic. The traffic plateau leads to water not being able to flow away and vibrations in combination with the heavy electric buses. In Table 2.7 of Appendix 2, the criteria are provided.

9.2.8 Residents

The residents are also an essential stakeholder in the redesigning of the Borculoseweg. For this research, five residents were asked their opinions about the criteria they wanted to set for the road. From this, four residents made safety on the road their highest priority. The other resident put the number of vibrations caused by the heavy trucks and buses as their main point of irritation, with safety in second place. The speed and the amount of greenery are close followers since speed also plays a significant role in their feeling of safety when cycling, and greenery is essential to maintain a more green status in the village. Parking is also considered, but this is unimportant since most residents have parking facilitated on their own property. In Table 2.8 of Appendix 2, the combined criteria of the respondents can be found.

9.2.9 All stakeholders

This section aims to make it more insightful to determine which criteria an optimal solution should satisfy to obtain a maximal score. Therefore, all criteria are provided in Table 2.9 of Appendix 2. Of course, not all criteria are necessary to satisfy the needs of one stakeholder. However, these criteria are combined from all stakeholders and will be a satisfying solution.

9.3 Indicators

The indicators are the factors that will be used to score the set criteria and calculate how well the alternative fits the stakeholder. These criteria are obtained by asking the stakeholders how they can be measured. Based on this, universal indicators applicable to all stakeholders stating the criteria have been selected.

9.3.1 Safety

For safety, the placement on the road is a major factor for people to feel safe and secure. It must be clear where cyclists need to cycle and where mopeds need to drive. It is also necessary that cars do not feel that they are the primary user of the road. Recognisability is an important factor for the safety of the road since road users are familiar with the rules that apply and their location on the road. This can be improved if the 30 km/h road type of the neighbourhood north of the Borculoseweg is continued at the Borculoseweg. This also involves the speed, road layout and road materials. The safety and the support base of the Borculoseweg being set to 30 km/h will improve in case the road is no longer a priority; instead, the right of way will be regulated by the basic rules. This decreases the possibility of people speeding on the road. The road has three traffic groups: motorised traffic, cyclists and pedestrians. One of the stakeholders set cyclist and pedestrian safety separately. However, it has been chosen to set a score for the safety of the whole situation, and therefore, the score will be the same for each traffic group.

9.3.2 Speed

The speed has a clear indicator: the speed limit that will be set for the road. This will be 30 or 50 km/h, with every stakeholder except the Arriva opting for the lower 30 km/h variant since they feel safer.

9.3.3 Greenery

From the municipality, the road needs to comply with their 3/30/300 meters rule. This rule means that there need to be three trees within sight, 30% of the area needs to be green, and there should be a cooler spot within 300 meters from the house. It is important to note that this does not need to be public greenery since gardens also count towards the goals. Another indicator is the amount of green spaces alongside the road. This makes it difficult to test if the road does comply with this rule. Therefore, it has been chosen to determine the score for this criteria based on the percentage of the cross-section reserved for greenery.

9.3.4 Water

The water aspect of the road is also separated into two parts, which are the above and underground aspects of the water drainage system. The above-ground water drainage is tightly connected to the greenery alongside the road. The greenery allows the water to drain into the soil instead of having the road and gardens filled with concrete tiles that make it so that all the water needs to be drained using sewage. Furthermore, the road can be hollow to let the water flow out of Neede or a sphere to let the water flow into the drainage system. For underground infrastructure, the road profile should allow a large sewage drainage system to be installed, preferably with as few side drainage systems.

9.3.5 Public transport

The leading indicators that imply the performance of the road for public transport are the walking distance to the bus stop and the number of conflicts that the bus and the other traffic can have with each other. Furthermore, a sidewalk is needed for the passengers to safely walk to and from the bus stop. Lastly, speed is also an essential factor for the bus since it determines the travel time to the destination along the bus line.

9.3.6 Vibrations

The newly introduced electric buses on the Borculoseweg route cause some residents to experience vibrations in their houses and even damage. This is because these heavy electric buses have to go over speed bumps, which causes the mass to bounce up and down. Since people want these vibrations reduced or solved, reducing or removing the speed bumps is necessary.

9.3.7 Parking

The occupancy rate of the parking spaces alongside the road is the most important factor in parking. Therefore, an important indicator is the number of parking spaces in the design, which is dependent on the amount of space reserved in the design for the parking spaces.

9.3.8 Visibility

For this criterion, the maintenance that will be done to the road over the years also plays a significant role. The greenery must not grow too high, as this will negatively impact visibility. Furthermore, the line of sight at intersections is essential since this is not currently the case at some intersections.

9.3.9 Enforceability

The rules that will be in place on the Borculoseweg must be enforceable. This is because it will otherwise be impossible for the police to ensure that people act according to the rules and otherwise give a fine for their law violations. This ensures that the signs and the speed limit should fit the profile of the road and will also need to be measurable, for example, a weight limit on the road.

9.3.10 Biodiversity

This criterion focuses on having a wide variety of plants and trees in the road's design. This variety will help to have a wide variety of insects in the neighbourhood, which will likely boost the ecosystem. For example, the road's design can help by implementing trees, different grasses, and flowers.

9.3.11 Heat

In more urban areas, heat can become a problem. Therefore, solutions that can help to reduce this heat are preferred. These solutions can be implemented in the road design by having large trees with many leaves, providing a lot of shade. This means that there should be sufficient space in the design to let a large tree grow.

9.3.12 Visual quality

This is a more subjective criterion and, therefore, difficult to measure. It depends on the maintenance of the road and, therefore, not on its design. An example of the visual quality of the road is that grass does not grow onto the road.

9.4 Weights

In the weights section, the criteria set in section 9.2 will get a weight assigned to them to show which of the criteria are the most important to be well represented in the alternative that will be chosen. These weights are based on a value between 1 and 10, in which each number can only be chosen once, which will be translated into a factor.

9.4.1 Arriva

The public transport company has three criteria: public transport on the road, speed, and safety on the road. Public transport is, of course, the most important since it is what Arriva offers to the public and, therefore, needs to be profitable. The weights based on the scores are provided in Table 3.1 of Appendix 3.

9.4.2 Kisveld

This is the elementary school close to the Borculoseweg, with a path leading to the pedestrian crossing at the Borculoseweg close to the bus stop. This school represents the safety of the children and the parents that go to the school. Therefore, the safety of the children who cycle and walk is essential. However, they also value a friendly look of the road, which can be obtained by having sufficient greenery, for example. Other factors are the speed on the road and the visibility at intersections. The weights for the criteria are provided in Table 3.2 of Appendix 3.

9.4.3 Police

The police have as their goals that the Borculoseweg becomes safer and that rules set on the road are enforceable, for which the weights are shown in Table 3.3 of Appendix 3. Safety can be increased by having the road more in line with the roads connected to it, increasing recognisability. Furthermore, the goal is to have clear placement on the road for road users. This contradicts the old way of thinking, which had motorized traffic as their most important aspect. Another safety factor is the right of way on the road, which could help slow down the traffic. Another primary goal is enforceability on the road, which means bad behaviour can be punished to maintain a safe and predictable situation. However, the police representative did not have a significantly more important goal than the others since they all helped make the road safer. This makes sure that the weights are evenly distributed.

9.4.4 Road manager

The road manager has set up three criteria for the Borculoseweg: safety and speed, water, greenery, public transport and parking. Since the road manager is involved in the maintenance and development of the road, he needs to consider many different aspects. However, safety is the primary concern, closely followed by the water since this problem currently affects the Borculoseweg. Green follows in third place, with public transport and parking taking fourth and fifth place respectively. The exact weights are shown in Table 3.4 of Appendix 3.

9.4.5 Water manager

The water manager is more closely focused on the water goals and, therefore, does not play a role in the safety and the speed, for example, on the road. The main goal is to have good underground water infrastructure since, in the current situation, the sewage sometimes can not cope with the rainfall, mainly since the Borculoseweg is located at the lowest point in Neede, so water flows towards the road. This reduction of water problems can be helped with water infrastructure above ground, which is the number of drainages or the water retaining use of greenery. Greenery is also a criterion since it helps drain the road if implemented correctly. Weights are provided in Table 3.5 of Appendix 3.

9.4.6 Green manager

The green manager's highest-weight criterion is the road's visual quality. This is also the criterion in which parts of other criteria come together into one goal. The second-highest criterion is water infiltration, which helps reduce the water problems in the current situation. After this, the next highest weight is biodiversity, the different vegetation that could be planted. A lower weight is for the heat effect, with the lowest being for the greenery percentage. The exact weights are provided in Table 3.6 of Appendix 3.

9.4.7 Traffic expert

The traffic expert has the highest priority of making the road safe for all road users, closely followed by public transport. The traffic expert wants good reachability for all destinations, including bus routes. Speed is another major factor, but it is double-sided. The higher speed makes for faster travel and a better hierarchy in the road system, but on the other hand, a lower speed is safer. Parking, greenery, and water are the less important factors and are not considered problems in the current situation. All calculated weights are provided in Table 3.7 of Appendix 3.

9.4.8 Residents

For the residents, the weights are calculated from a sample of 5 residents at various places alongside the road. The weights that each of the residents has set up are collected and summed to calculate the overall weight of the residents. The most important thing is the road's safety since some residents do not feel safe when cycling at the Borculoseweg. Another critical factor is the speed of the vehicles driven at the Borculoseweg since most residents think there are many speeders on the road. Most residents support changing to a 30 km/h road. Greenery is also essential since it contributes to the town's look and makes it feel more rural. Parking is more of a concern for visitors since the residents have parking on their property. The vibrations caused by the buses and public transport are factors that are only set by one resident and, therefore, do not score a high weight. All scores and combined weights are shown in Table 3.8 of Appendix 3.

9.4.9 All stakeholders

Table 3.9 of Appendix 3 shows the system weights with all the stakeholders. In order to set this up, some assumptions had to be made. The safety of cyclists and pedestrians is counted towards the overall safety of the road since these would otherwise obtain a substantial score, which is not representative of the situation. Furthermore, if a score is set up from multiple aspects or respondents, then the score is averaged. This prevents these criteria from obtaining a high weight, which would not be representative.

9.5 Scoring

In the scoring part, the criteria get a score based on the alternative's performance. This score is based on the SMART method and ranges between 0 and 10 points.

9.5.1 Safety

The scores for safety are set with help from the traffic expert. It has been found that the first alternative is a grey road since there are not sufficient speed-reducing measures placed on the road. However, there are wide cycle suggestion lanes that ensure a clear separation between traffic. Since it is a grey road, the function is compatible with the Borculoseweg. The alternative gets a score of 5. The second alternative's main point is that there is a separate cycling path. However, the road material causes much noise, and since the road profile is wide, there is no space left to make safer crossings. This also means that the bus stop needs to be relocated. This gives the alternative a score of 6. Alternative 3 is ideal for a 30 km/h cycle road; however, in the case of the Borculoseweg, there is too much motorised traffic with too few cyclists, decreasing safety. The Borculoseweg has a high traffic function, which does not fit the cycle road. In total, the third alternative gets a score of 5. The fourth alternative is considered nearly ideal for safety due to its profile and material. However, it would be better to make it a priority road and implement speed-reducing measures to make sure people will drive 30 km/h. In short, the alternative gets a score of 9. Alternative 5 has a good road profile, wide cycle suggestion lanes, and good livability. However, parking is done on the road itself, making it so that cyclists have to go around, therefore decreasing safety. The score for this is 8. It has been decided that the scores for pedestrians and cyclists separately do not differ substantially from the total; therefore, these scores are based on the total.

9.5.2 Speed

The speed that is driven on the road is a significant factor and is also connected to the safety of the road and the feeling of safety for the road users. The speed limit that will be set will be 30 km/h or 50 km/h. All stakeholders except the Arriva prefer a 30 km/h speed limit. Arriva prefers 50 km/h due to the bus schedule. The scores for this criterion can be found in Tables 4.2.1 and 4.2.2 in Appendix 4.

9.5.3 Greenery

The score for greenery will be obtained from the area reserved for planting greenery. This is based on the width of the reserved space for green and the possibility of shared use of parking on the side of the road. It is assumed that if greenery is shared with parking, the space will be divided equally. This means that 50% of the space available after subtracting space for other uses, such as entrances, is for greenery. Using this information, it becomes possible to calculate the score for greenery, rounding them to whole numbers. This makes the scores as provided in table 4.3 in Appendix 4.

9.5.4 Water

For water, two different aspects can be regarded. These are the above-ground infrastructure, such as how water flows away or into the ground, and underground infrastructure, such as sewage. The above-ground infrastructure can help in two different ways. Water can be stored underground or flow to a location where it will be stored. Greenery plays a vital role in the storage of water underground. Therefore, the greenery scores will be used as a basis for the water scores. Furthermore, road materials can also play a role. When the road is made out of clinkers, the speed at which it can be chosen to implement porous clinkers is reduced. These can let water flow through. Besides, it can also be chosen to place them in a way that lets more water through. Therefore, it has been decided that the roads made of clinkers instead of asphalt obtain three extra points. This is because the type of road material has a large surface, but the effects are still less than water directly flowing into the ground. This gives the following scores in

Table 4.4 in Appendix 4. Underground infrastructure does not play a significant role in the design and functioning of infrastructure above ground. Underground infrastructure follows the infrastructure that is needed above ground, which makes it less important for the road design chosen. This makes it so that it has been chosen to leave this criterion out of the analysis. For stakeholders who follow these criteria, weights will be altered appropriately.

9.5.5 Public transport

For public transport, there are four important factors, namely the walking distance to and from the bus stop, the number of bus stops, the amount of conflicts that the bus will have from other traffic which slows it down, the need for a sidewalk along the road connecting to the bus stop, and lastly the speed that can be driven on the road. The distance to the bus stops and the number of bus stops on the road will remain unchanged, making these the same for all alternatives and therefore left out of the equation. The first alternative receives full points for the 50 km/h speed limit. Half of the points for the conflicts are because it has cycle lanes, which results in more conflicts than on a cycle path but less than on a cycle street. The sidewalk is connected to the bus stop, receiving full points. The second alternative gets full points for speed and conflicts since the speed limit is 50 km/h, and the cyclists must use a separate cycle path. However, the sidewalk is not connected to the bus stop due to the separate cycling path. The sidewalk is still on both sides of the road, resulting in half of the points. The third alternative has no points for speed since the speed limit is 30 km/h. Furthermore, it also receives no points for conflicts since cyclists are more prominent on the road on the cycle street and, therefore, on the way of buses. The alternative has full points for the sidewalk, connected to the bus stop and on both sides of the road. The fourth and fifth alternatives receive no points for speed but get half the points for conflicts since cyclists use a cycle lane on the road. Both alternatives receive full points for their sidewalks. These points are translated into the following scores in Table 4.5 in Appendix 4.

9.5.6 Vibrations

It is difficult to determine the number of vibrations the road will cause from the cross-section. This is because the vibrations mainly occur around speed bumps or plateaus, in combination with houses with a weaker foundation. It is, therefore, chosen to score vibrations based on the need for speed-reducing measures. Therefore, the best alternative for this is a cycle street, since the speed limit is lower and the speed is already more limited by the road profile and materials, as well as cyclists that drive in front of the cars, which slows them down. A shared second place is for alternatives 1 and 2, which have a speed limit of 50 km/h and therefore less need to implement speed-reducing measures. However, plateaus on more prominent intersections are likely still needed, and this can cause vibrations. At the last place, alternatives 4 and 5 have a speed limit of 30 km/h. However, the road profile is similar to alternative 1, meaning that speed-reducing measures must be in place. More of these speed-reducing measures will likely make more speed bumps necessary since buses also need to pass, which is difficult if the road is narrowed. These rankings are translated into scores, provided in Table 7 in Appendix 4.

9.5.7 Parking

The scores that will be set for parking will also be based on the surface area reserved for parking. As stated in section 9.5.3, the profiles with shared use of parking and greenery will divide the space equally. This makes it possible to set up the following scores in Table 4.7 in Appendix 4

9.5.8 Visibility

This criterion is a part of the safety regulations that must be complied with to implement the road. Furthermore, the area outside of the privately owned road is often where large hedges are located. These hedges are on the Borculoseweg, so this criterion is brought up. However, since the road design does not influence the hedges or items people place on their property, it has been chosen to leave this out of the equation.

9.5.9 Enforceability

The enforceability mainly depends on the rules set on the road and how the road drives and looks. Since the rules on the road are the same, except for the speed limit, it is chosen to score the cross sections based on how well the road indicates the speed limit on the road. This is done by ranking. The best scoring for enforceability is the alternative 1 since it has a speed limit of 50 km/h, which is well indicated by the road profile. There are cycle lanes along the road, and the greenery makes it feel like drivers are going faster. The second best option is alternative 2, which has a speed limit of 50 km/h, but it is just asphalt with separated cycle paths. This makes traffic slow down less. Third is alternative 3. Since this is a cycle street, it is clear that the speed limit on that road is set to 30 km/h. Furthermore, cyclists are more prominent road users, which means motorized traffic needs to slow down more. Second to last is the fifth alternative, which has the same road profile as the first but has a speed limit of 30 km/h. This makes this speed limit less enforceable since when the road is compared to other roads, drivers can think that the speed limit should be 50 km/h. The fourth alternative is last because, alongside the fourth alternative, there are only parking spots, while along the fifth alternative, there are trees and greenery. Due to the trees, people tend to feel they drive faster, creating less desire to speed. The ranked scores are provided in Table 4.8 in Appendix 4.

9.5.10 Biodiversity

Biodiversity is an important factor in the area's vegetation types and the types of insects that are attracted by it. This leads to a boost for the whole green system. However, biodiversity can only be planned to a certain extent since it mainly develops naturally. Furthermore, the design only takes into account the location of the greenery. Biodiversity, as far as it can be planned, depends too much on the specific final design. Therefore, it has been chosen to leave this criterion out. Weights are accounted for accordingly.

9.5.11 Heat

Regarding the heat effect of the road, two different aspects are of main importance, namely the number of large trees and the material of the road surface. It has been found that a road surface made of clinkers is cooler than an asphalt road (Hogeschool Amsterdam, 2022). If the road is made out of clinkers, 3 points will be awarded. The other 7 points will be scored according to the large trees in the design. In Alternative 1, there are trees on the example road. However, these are just planted and, therefore, not well visible. Alternative 3 has nearly as many trees and greens as alternative 5, hence the scores. Alternatives 2 and 4 have no trees; however, they have clinker roads. This leads to the scores of Table 4.9 in Appendix 4.

9.5.12 Visual quality

Since the visual quality depends on the maintenance of the road and not the design, it is outside the scope of the scoring for this project. It is important that the design that will be implemented is well maintained to keep the visual quality high. Therefore, it is not scored in this analysis; weights are adjusted accordingly.

9.6 Results MAMCA

After putting all the criteria, weights and scores for each stakeholder in the MAMCA software, the following Figure 9.6 is obtained. This Figure shows each alternative fits with the stakeholders.

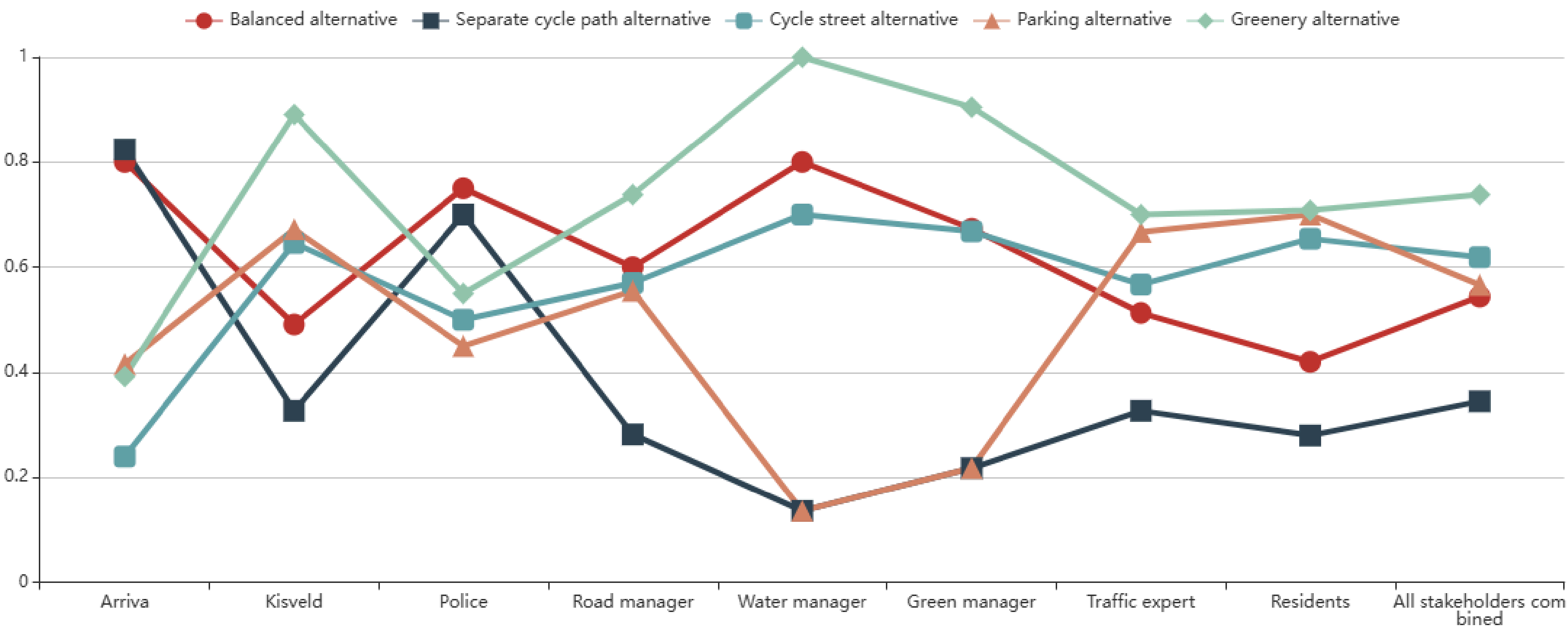

Figure 9.6: Results MAMCA

Clearly, the greenery alternative, represented by the green line, comes on top for nearly all the stakeholders. There are only two cases in which it does not, namely for Arriva due to its low speed and the police since the road does not score high on enforceability. It is also at the top of the category, combining all stakeholders. This alternative is closely followed by the balanced alternative, represented by the red line. It scores higher for the police since it has much higher enforceability since it is more clear which behaviour is intended. It scores, however, less on other stakeholders. On the other hand, an alternative that scores relatively low is the alternative with the separated cycle path, represented by the dark line. This is mainly because this alternative does not incorporate parking or greenery while scoring low on the safety criterion. It is, however, placed highest for the Arriva since it has a speed limit of 50 km/h and the bus has less trouble with other road users. Then, there are the two middle alternatives: the cycle street alternative and the parking alternative. These end up in the middle since, in the opinion of the stakeholders, they do not excel in specific cases. The balanced alternative scores are high for enforceability since it is a well-recognisable cycle street with a 30 km/h speed limit. The parking alternative scores best on the criteria of safety and parking, but due to the weights, it does not come up on top for one of the stakeholders. Sensitivity analysis for these results is provided in Appendix 5.

10. Discussion

As can be seen in the results of section 9.6, the lower speed limit proposed in the distributor road, 30 km/h, affects the driving speed and safety and causes other positive side effects. Due to the lower speed, it is possible to implement a road that has a smaller width and, therefore, leaves more space for other purposes alongside the road. This positively affects the amount of greenery, water retention, and parking that can be implemented. Especially the greenery, in combination with the water retention, increases the liveability significantly and reduces the problem of much water during storms since the Borculoseweg is the lowest point in Neede. In order to incorporate these factors into the decision, the MAMCA tool has proved to be a well-functioning tool. By having stakeholders that represent the criteria, such as greenery and water, these were able to make a change in the decision process. Due to this broader approach to a road choice, an alternative incorporating safety, speed, greenery, and water well has been selected.

A possible limitation is that the weights set for the MAMCA are based on a scale between 1 and 10, of which each number can only be selected once. This is intended to force stakeholders to select which criteria they find more important over the other. As seen in Appendix 3, in nearly all cases, the weights are counted from 10 directly downwards. This means that the weights are all relatively high since no weights are significantly lower. It would have been an option to reduce the number of possible values. However, this would also limit the number of criteria set up. Furthermore, it would be preferred to have the scores set for the alternatives based more on the knowledge of experts. This way, the scores would become more representative of the situation and give clear insights instead of having these based on comparisons. However, the scores will also be based on knowledge and experience and, therefore, still not factual. Remarkable findings in the data can be seen in Figure 9.6 of section 9.6; a dip occurs in the middle of the graph, especially at the water and green manager. These are stakeholders that do not depend on the safety of the road. Due to the highest weight that other stakeholders give to the safety criterion, the rest of the scores are considerably higher for other alternatives. This shows the stakeholder scores' dependency on the scores set for safety.

11. Conclusion

The first research question is: What alternative road profiles are possible on the Borculoseweg? These were the alternatives that were set for the MAMCA analysis. The first of the five is the balanced alternative, which has a road profile with a speed limit of 50 km/h and cycle lanes. On one side, the road has greenery and a sidewalk; on the other, there is a sidewalk and greenery, which is altered with parking. The second alternative is a road with a speed limit of 50 km/h and a separate two-way cycle path and walking paths on both sides. The third alternative is a cycle street, with two cycle lanes of 2.20 metres wide. On one side, there is greenery and a walking path; on the other, the greenery is altered with parking. The fourth and fifth alternatives have a road profile with a 30 km/h speed limit and cycle lanes. The difference between the two is what is beside the road. Alternative four has parking and a walking path on both sides, while alternative five has greenery and a walking path on both sides.

The second research question is: What are the criteria and assigned weights for the alternatives of the Borculoseweg according to the stakeholders? These are the criteria and the weights that have been obtained by having the interviews with the stakeholders of the project. Their input was crucial in shaping the research process. During these interviews, the stakeholders could select criteria from the set ones and add some themselves. The primary outcome is that most stakeholders, besides the bus company, selected safety as their primary criterion, which made speed their top priority. The second most important criterion is greenery, closely followed by the speed. Water and parking are also among the higher weighting criteria. The lower weighting criteria are vibrations, visibility, public transport, enforceability, visual quality, biodiversity and heat. The results are used in the MAMCA analysis to select the best alternative based on the scores.

The last research question is: What is the best scoring alternative to implement on the Borculoseweg? From the data collected during the research, two alternatives scored the highest on average. These are the greenery-focused and balanced alternatives, which is a variation of the current situation. To start with, the greenery-focused alternative is an alternative that has only one main downside for the stakeholders, namely, the speed limit. It is strongly recommended that Arriva has a speed limit of 50 km/h on the road since this makes their bus travel quicker. For public transport companies, the 30 km/h distributor road is a threat since a lower speed means fewer trips per hour, leading to fewer travellers and, therefore, less revenue. The CROW wants to implement more distributor troads at 30 km/h; if not otherwise possible, 50 km/h can be implemented. A public transport line could mean that 50 km/h needs to be implemented, or the road needs other measures to ensure that the bus has as little delay as possible due to the lower speed limit. Furthermore, cars have to park on the road, which slows traffic down and, therefore, increases safety on the road. However, cyclists need to go around the parked cars; therefore, they are likely to feel less safe when using the road. On the other hand, it has been found that there is a low parking demand on the road due to most houses having parking on their property or finding a parking space in the neighbourhood surrounding the Borculoseweg. The main reason that the greenery alternative scores so high is that it scores high for safety, greenery and water. The balanced alternative is comparable to the current situation. However, the road profile has been altered to incorporate cycle lanes to improve safety. Since this alternative keeps the speed limit of 50 km/h, the alternative is nearly on top for Arriva since they can keep the schedule they set up for the route. Furthermore, the alternative also scores higher for the police since the enforceability of the road is higher due to a more recognisable road and hierarchical position in the road network. However, The road scores lower for the safety criterion, therefore having lower scores in nearly all cases compared to the greenery-focused alternative.

12. Recommendations

As is concluded, the best alternative to implement is the greenery-focused alternative, followed by the balanced alternative. The greenery-focused alternative scores the highest for greenery and, therefore, also scores high on the water criterion. The balanced alternative scores lower on those two criteria but does include parking and, therefore, scores some points. If cars do not park in the Borculoseweg, they need to park in the neighbourhood surrounding it, leading to a higher parking demand there. However, since the parking demand is currently low on the Borculoseweg, this will not likely become a problem. The greenery-focused alternative scores higher on safety, mainly due to the speed limit being set at 30 km/h. A downside of this speed limit is that the bus would have difficulty keeping its schedule, which means it must be altered. Another option is to alter the route to have less distance to travel. The regular alternative has a comparable road profile but allows for 50 km/h speeds.

Suggestions for further research are mainly about the costs to implement such alternatives. The costs of implementation are an essential factor in the municipality's decision-making. Suppose one of the alternatives is significantly more expensive than the other. In that case, the municipality likely chooses the cheaper alternative over the alternative that has been found to score the best in the MAMCA, making the balanced alternative possible over the greenery alternative. Then, there are the planning and preparation of a project. For research like this, making a plan that leaves sufficient time for tasks is essential. This is because such a project depends on planning meetings with stakeholders and experts to get to know their criteria and weights. Since these stakeholders all need time to plan, it is necessary to plan this broadly. Another part is the preparation of the MAMCA. It would have been clearer if the stakeholders could only select out of a set of criteria, such as safety and greenery, instead of being able to select their criteria to be added as well. These extra criteria will eventually make the research more complete, but it will make scoring the alternatives more difficult.

13. References

Academische Werkplaats Gezonde Leefomgeving. (2023). De impact van verlagen maximum snelheid in de bebouwde kom. Accessed on 8-4-2024.
https://awgl.nl/projecten/50km-u

Allecijfers.nl. (n.d.). Borculoseweg in Neede. Accessed on 4-6-2024.
https://allecijfers.nl/weg/borculoseweg-neede/#soorten_woningen

Atlas leefomgeving. (2024). Pak de fiets en vind de spelende mens in jezelf terug. Accessed on 2-7-2024.
https://www.atlasleefomgeving.nl/nieuws/pak-fiets-en-vind-spelende-mens-in-jezelf-terug

AT5. (2024). Tevredenheid over maximaal 30 km in de stad, maar lang niet iedereen houdt zich eraan. Accessed on 1-7-2024.
https://www.at5.nl/artikelen/224886/tevredenheid-over-maximaal-30-km-amsterdam

Boveldt, G. ter. (2023). 7. Multi-Actor Multi-Criteria Analysis. Accessed on 11-4-2024.
https://sshcentre.eu/wp-content/uploads/2023/05/Infosheets-7-SSH-CENTRE-Multi-Actor-Multi-Criteria-Analysis.pdf

CROW. (2021). Afwegingskader 30 km/h. Accessed on 14-3-2024.
https://www.crow.nl/downloads/pdf/verkeer-en-vervoer/wegontwerp/afwegingskader-30-km-per-uur.aspx

CROW. (2019). Fietsberaadnotatie: Aanbevelingen fietsstraten binnen de kom. Accessed on 2-5-2024.
https://www.fietsberaad.nl/getmedia/6093c405-2ad0-46f3-a61c-33bdc9cda964/Fietsberaadnotitie-Aanbevelingen-Fietsstraten-binnen-de-bebouwde-kom-2018-versie3.pdf.aspx?ext=.pdf

Fietsberaad. (2004). Over breedtes van fietspaden. Accessed on 2-5-2024.
https://www.fietsberaad.nl/CROWFietsberaad/media/Kennis/Bestanden/document000172.pdf?ext=.pdf

Funda. (n.d.). Dijkstraat 28 28a. Accessed on 2-7-2024.
https://www.funda.nl/detail/koop/aalten/huis-dijkstraat-28-28a/43403560/

Fietsen123. (2020). Fietspaden en -stroken: waar mag/moet je fietsen?. Accessed on 2-5-2024.
https://www.fietsen123.nl/fietsnieuws/fietspaden-en-stroken-waar-mag-moet-je-fietsen

Gemeente Amsterdam. (n.d.). 30 km/u in de stad. Accessed on 8-4-2024.
https://www.amsterdam.nl/30-km-u-in-de-stad/#h2a05b84c-1837-4d70-9ef3-fc51d3008415

Gemeente Oss. (n.d.). 1.1.4.2 Fietsstraat. Accessed on 2-7-2024.
https://www.oss.nl/RIBOR/1_verkeer_en_verharding/1_1_mobiliteit/1_1_4_fiets_en_voetpaden/1_1_4_2_fietsstraat.htm

Goudappel. (2022). Het nieuwe 30 en OV. Accessed on 3-7-2024.
https://www.goudappel.nl/sites/default/files/2022-06/011554.20220415.R1.01%20Brochure%20Nieuwe%2030%20en%20OV%20-%20digitaal.pdf

Hogeschool Amsterdam. (2022). Koele bestratingsmaterialen. Accessed on 10-7-2024.
https://www.hva.nl/kc-techniek/gedeelde-content/contentgroep/klimaatbestendige-stad/resultaten/efc-bestrating.html#anker-welke-vormen-van-koele-bestratingsmaterialen-zijn-er-

Jorritsma, P., Arendsen, K., & Faber, R. (2023). Autoluw beleid gemeenten: Doelen, effecten en rollen. Accessed on 12-3-2024.
https://www.kimnet.nl/publicaties/publicaties/2023/09/26/autoluw-beleid-gemeenten-doelen-effecten-en-rollen

Klein, C. (2023). 30 km/u in bijna heel Amsterdam is veiliger en bespaart geld. NOS Nieuws. Accessed on 8-4-2024.
30 km/u in bijna heel Amsterdam is veiliger en bespaart geld (nos.nl)

Martinez Ramirez, L., Pappers, J., Keserü, I., & te Boveldt, G. (2022) SmartHubs Appraisal Tool for sustainability and stakeholder assessment. Vrije Universiteit Brussel (VUB). Accessed on 19-4-2024.
c54b12_8c0d1dd1b7ea4ef2b27db027a1f5ff74.pdf (smartmobilityhubs.eu)

Public Space Info. (2013). Handboek kwaliteit openbare ruimte. Accessed on 2-5-2024.
https://www.publicspaceinfo.nl/media/uploads/files/LEIDEN_2013_0002.pdf

Royal HaskoningDHV. (2021). Borculoseweg Neede [Not published]. File obtained by the municipality of Berkelland.

SWOV. (2023). Principles for a safe road network. SWOV fact sheet, April 2023. SWOV, The Hague. Accessed on 14-3-2024.
https://swov.nl/en/fact/road-network-2-which-road-categories-are-distinguished-netherlands

SWOV. (2023). Veiligheid van fietsstraten. Accessed on 23-5-2024.
https://swov.nl/nl/publicatie/veiligheid-van-fietsstraten#:~:text=Definitie%20fietsstraat&text=De%20definities%20van%20fietsstraten%20(of,van%20lagere%20intensiteiten%20en%20snelheden

SWOV. (2018). 30km/uur-gebieden. SWOV-factsheet, mei 2018. SWOV, Den Haag. Accessed on 1-7-2024.
https://swov.nl/nl/fact/30kmuur-gebieden-hoe-snel-wordt-er-de-praktijk-gereden-op-30kmuur-wegen

SWOV (2019). Sustainable Road Safety. SWOV fact sheet, March 2019. SWOV, The Hague. Accessed on 5-7-2024.
https://swov.nl/en/fact-sheet/sustainable-road-safety

Theoriecursus.nl. (n.d.). Fietsstroken. Accessed on 2-7-2024.
https://theoriecursus.nl/Cursus/theoriecursus-auto/Hoofdstuk/verkeerstekens-en-aanwijzingen-verkeerstekens-op-het-wegdek/Paragraaf/fietsstroken/

Wageningen University & Research. (2019). Groen: goed voor de gezondheid. Accessed on 3-5-2024.
https://www.wur.nl/nl/en/show-13/show-longread/groen-goed-voor-de-gezondheid.htm

Wikipedia. (2014). Fietspad. Accessed on 2-7-2024.
https://vi.m.wikipedia.org/wiki/T%E1%BA%ADp_tin:Fietspad_PeeWee32.jpg

1000minds. (n.d.). Multi-Criteria Decision Analysis (MCDA/MCDM). Accessed on 12-3-2024.
https://www.1000minds.com/decision-making/what-is-mcdm-mcda#overview-mcda-process

Appendix 1: Interviewvragen Borculoseweg

De gemeente Berkelland overweegt de Borculoseweg in Neede aan te gaan passen en hierbij eventueel de snelheidslimiet aan te passen. Voor het onderzoek worden belanghebbenden gevraagd om hun voorkeuren, om op deze manier uit te komen op een wegprofiel die het beste bij hun voorkeuren zou passen. Dit betekent niet dat besproken aanpassingen definitief toegepast gaan worden.

Criteria

In het criteria gedeelte worden de vragen gesteld om een beeld te krijgen van de doelen en daarmee de criteria die een stakeholder heeft om het project tot zijn/haar tevredenheid te laten verlopen. Niet alle vragen zijn definitief een criteria in het project, dit is afhankelijk van de ontvangen antwoorden.

1. Wat zijn voor u belangrijke aandachtspunten bij een eventuele aanpassing van de Borculoseweg?
2. Wat is uw mening over de snelheid van gemotoriseerd verkeer op de Borculoseweg?

Heel ontevreden	ontevreden	Gemiddeld	Tevreden	Heel tevreden
1	2	3	4	5

   a. Komt dit door een te hoge toegestane snelheid of door het overschrijden hiervan?
   b. Wat is uw mening over een aanpassing naar een snelheidslimiet van 30 km/h?

3. Is de verkeersveiligheid voldoende op de Borculoseweg?

Heel onveilig	onveilig	Gemiddeld	Veilig	Heel veilig
1	2	3	4	5

   a. Als (brom)fietser?
   b. Als auto bestuurder?
   c. Als voetganger?

4. Is er voldoende parkeergelegenheid aan de Borculoseweg?

Te weinig	Beperkt	Gemiddeld	Voldoende	Ruim voldoende
1	2	3	4	5

5. Wat is uw mening over de hoeveelheid groenvoorziening aan de Borculoseweg?

Heel ontevreden	ontevreden	Gemiddeld	Tevreden	Heel tevreden
1	2	3	4	5

   a. Wat vindt u het belangrijkst, meer groenvoorziening of meer parkeerplaatsen?
   b. Wat vindt u het belangrijkst, meer groenvoorziening of meer ruimte voor de weg en hiermee een hogere verkeersveiligheid?

6. De Borculoseweg is het laagste punt van Neede, waardoor water richting de weg stroomt. Wat is uw mening over de afwatering tijdens een storm?

Heel ontevreden	ontevreden	Gemiddeld	Tevreden	Heel tevreden
1	2	3	4	5

7. Wat is uw mening over de busroute door de Borculoseweg?

Heel ontevreden	ontevreden	Gemiddeld	Tevreden	Heel tevreden
1	2	3	4	5

   a. Indien u de bus gebruikt, rijdt deze regelmatig genoeg?
      i. Rijdt de bus zijn route op tijd?
   b. Zorgt de bus voor hinder in uw optiek?

8. Zou u de hiervoor genoemde onderwerpen, waaronder water, groen, OV, parkeren, verkeersveiligheid en snelheid, kunnen rangschikken van meest naar minst belangrijk voor u?
9. Kunt u aangeven welke van deze onderwerpen, waaronder water, groen, OV, parkeren, verkeersveiligheid en snelheid, belangrijk zijn in het ontwerp voor u?
10. Zijn er nog andere aandachtspunten belangrijk voor u met betrekking tot de Borculoseweg?
11. Wat zou u graag verbeterd willen zien aan de Borculoseweg?

Door deze vragen worden uiteindelijk de criteria opgezet. Deze zijn afhankelijk van de stakeholders verkeersveiligheid, parkeergelegenheid, groenvoorziening, waterafvoer, busverbinding en eventuele verdere criteria. De criteria kunnen hieronder ingevuld worden zodat volgende secties hierop gebaseerd kunnen worden.

Deze criteria komen voort uit het gesprek met de stakeholder. Deze zijn afhankelijk van welke van de voorgelegde onderwerpen belangrijk zijn in de ogen van de stakeholder. Daarnaast kan de stakeholder nog andere criteria toevoegen. Het is niet verplicht dat het aantal criteria 10 moet zijn, dit is enkel het maximale aantal wat gesteld is door de bepaling van de weging later in het interview.

Criteria 1: ………………………………………………………………………………………
Criteria 2: ………………………………………………………………………………………
Criteria 3: ………………………………………………………………………………………
Criteria 4: ………………………………………………………………………………………
Criteria 5: ………………………………………………………………………………………
Criteria 6: ………………………………………………………………………………………
Criteria 7: ………………………………………………………………………………………
Criteria 8: ………………………………………………………………………………………
Criteria 9: ………………………………………………………………………………………
Criteria 10: ………………………………………………………………………………………

Indicatoren

Bij de indicatoren wordt per criteria gevraagd wat nodig is om dit doel te bereiken. Denk hierbij bijvoorbeeld aan criteria groenvoorziening, om hierop hoog te scoren kan de indicator zijn dat er 20 bomen nodig zijn. Een lager aantal leidt dan tot een lagere score.

Criteria 1: ……………………………………………………………………………………
Criteria 2: ……………………………………………………………………………………
Criteria 3: ……………………………………………………………………………………
Criteria 4: ……………………………………………………………………………………
Criteria 5: ……………………………………………………………………………………
Criteria 6: ……………………………………………………………………………………
Criteria 7: ……………………………………………………………………………………
Criteria 8: ……………………………………………………………………………………
Criteria 9: ……………………………………………………………………………………
Criteria 10: ……………………………………………………………………………………

Weging

Hierbij wordt een weging opgezet op basis van de criteria die zijn opgesteld in het eerste gedeelte. Deze criteria krijgen een weging tussen 1 en 10, waarvoor figuur 1 gebruikt wordt. Om te voorkomen dat alle criteria op de hoogste schaal komen, mag iedere weging slechts een enkele keer gegeven worden. Er hoeft geen volgorde in te zitten. Bijvoorbeeld, er zijn vier criteria opgesteld, in dit geval kunnen de wegingen bijvoorbeeld 2,4,7 en 9 zijn.

Tabel 1: Weging

	Weging									
Crit. 1	1	2	3	4	5	6	7	8	9	10
Crit. 2	1	2	3	4	5	6	7	8	9	10
Crit. 3	1	2	3	4	5	6	7	8	9	10
Crit. 4	1	2	3	4	5	6	7	8	9	10
Crit. 5	1	2	3	4	5	6	7	8	9	10
Crit. 6	1	2	3	4	5	6	7	8	9	10
Crit. 7	1	2	3	4	5	6	7	8	9	10
Crit. 8	1	2	3	4	5	6	7	8	9	10
Crit. 9	1	2	3	4	5	6	7	8	9	10
Crit. 10	1	2	3	4	5	6	7	8	9	10

Appendix 2: Criteria tables

Table 2.1: Criteria Arriva

Criteria	
1	Public transport
2	Speed
3	Safety

Table 2.2: Criteria Kisveld

Criteria	
1	Safety cyclists
2	Safety pedestrians
3	Friendly look of the road
4	Speed
5	Visibility on intersections

Table 2.3: Criteria police

Criteria	
1	Safety
2	Enforceability

Table 2.4: Criteria road manager

Criteria	
1	Safety and speed
2	Water
3	Greenery
4	Public transport
5	Parking

Table 2.5: Criteria water manager

Criteria	
1	Underground water infrastructure
2	Above ground infrastructure
3	Greenery

Table 2.6: Criteria green manager

Criteria	
1	Greenery
2	Biodiversity
3	Heat
4	Visual quality
5	Water

Table 2.7: Traffic expert

Criteria	
1	Safety
2	Public transport
3	Speed
4	Parking
5	Greenery
6	Water

Table 2.8: Criteria residents

Criteria	
1	Safety

2	Speed
3	Greenery
4	Parking
5	Vibrations
6	Public transport

Table 2.9: All stakeholders

Criteria	
1	Safety
2	Speed
3	Greenery
4	Parking
5	Vibrations
6	Visibility
7	Public transport
8	Enforceability
9	Water
10	Visual quality
11	Biodiversity
12	Heat

Appendix 3: Weight tables

Table 3.1: Weights Arriva

	Criteria	Obtained score	Weight
1	Public transport	10	0.40
2	Speed	9	0.36
3	Safety	6	0.24

Table 3.2: Weights Kisveld

	Criteria	Obtained score	Weight
1	Safety cyclists	10	0.25
2	Greenery	9	0.225
3	Visability	7	0.175
4	Safety pedestrians	8	0.2
5	Speed	6	0.15

Table 3.3: Weights police

	Criteria	Obtained score	Weight
1	Safety	x	0.5
2	Enforceability	x	0.5

Table 3.4: Weights road manager

	Criteria	Obtained score	Weight
1	Safety and speed	10	0.25
2	Water	9	0.225
3	Greenery	8	0.2
4	Public transport	7	0.175
5	Parking	6	0.15

Table 3.5: Weights water manager

	Criteria	Obtained score	Weight
1	Underground infrastructure	8.5	0.436
2	Above ground infrastructure	5	0.256
3	Greenery	6	0.308

Table 3.6: Weights green manager

	Criteria	Obtained score	Weight
1	Visual quality	10	0.25
2	Water	9	0.225
3	Biodiversity	8	0.2
4	Heat	7	0.175
5	Greenery	6	0.15

Table 3.7: Weights traffic expert

	Criteria	Obtained score	Weight
1	Safety	10	0.222
2	Public transport	9	0.2
3	Speed	8	0.178
4	Parking	7	0.156
5	Greenery	6	0.133
6	Water	5	0.111

Table 3.8: Weights residents

	Criteria	Obtained score	Weight
1	Safety	9, 9, 10, 10, 10	0.340

2	Speed	8, 8, 9, 9	0.241
3	Greenery	8, 8, 8	0.170
4	Parking	6, 5, 7	0.128
5	Vibrations	10	0.071
6	Public transport	7	0.050

Table 3.9: Weights all stakeholders

	Criteria	**Obtained score**	**Weight**
1	Safety	6, 10, 8, 10, 10, 10, 9.6	0.2257
2	Speed	9, 6, 10, 8, 8.5	0.1472
3	Greenery	9, 8, 6, 6, 6, 8	0.1526
4	Parking	6, 7, 6	0.0674
5	Vibrations	10	0.0355
6	Visibility	7	0.0248
7	Public transport	10, 7, 9, 7	0.1171
8	Enforceability	10	0.0355
9	Water	9, 6.75, 9, 5	0.1056
10	Visual quality	10	0.0355
11	Biodiversity	8	0.0284
12	Heat	7	0.0248

Appendix 4: Score tables

Table 4.1.1: Scores safety motorized traffic

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
5	6	5	9	8

Table 4.1.2: Scores safety cyclists

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
5	6	5	9	8

Table 4.1.3: Scores safety pedestrians

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
5	6	5	9	8

Table 4.1.4: Scores safety - total

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
5	6	5	9	8

Table 4.2.1: Scores speed - General

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
0	0	10	10	10

Table 4.2.2: Scores speed - Arriva

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
10	10	0	0	0

Table 4.3: Scores greenery

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
8	0	7	0	10

Table 4.4: Scores water above ground

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
8	3	7	3	10

Table 4.5: Scores public transport

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
8	8	3	5	5

Table 7: Scores vibrations

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
5	5	10	0	0

Table 4.7: Scores parking

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
3	0	3	10	0

Table 4.8: Scores enforceability

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
10	8	5	0	3

Table 4.9: Scores heat

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
4	3	6	3	7

Appendix 5: Sensitivity MAMCA

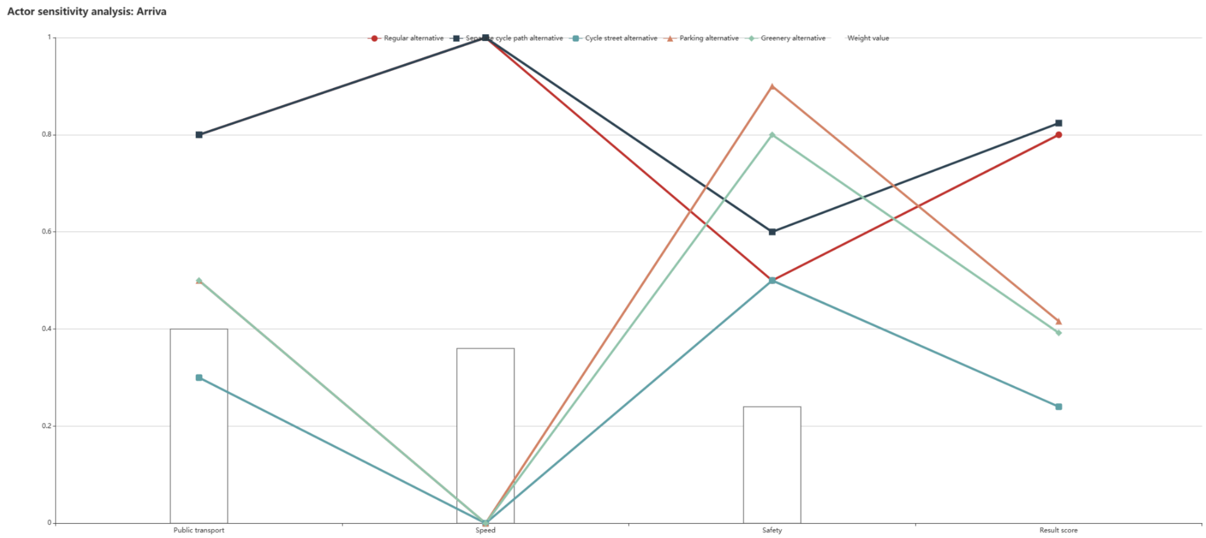

Figure 5.1: Sensitivity analysis Arriva

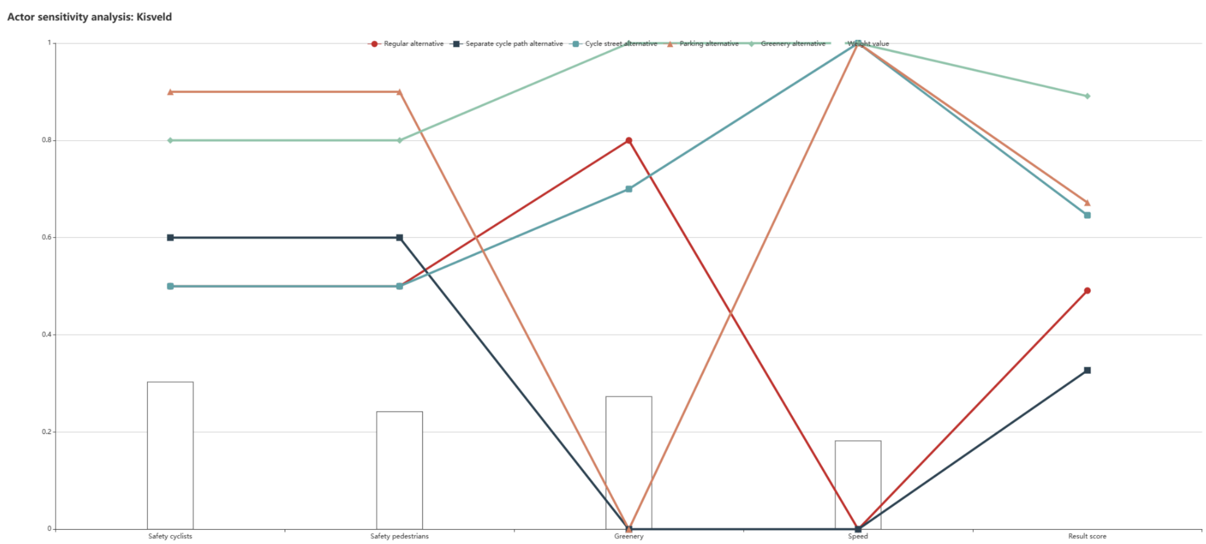

Figure 5.2: Sensitivity analysis Kisveld

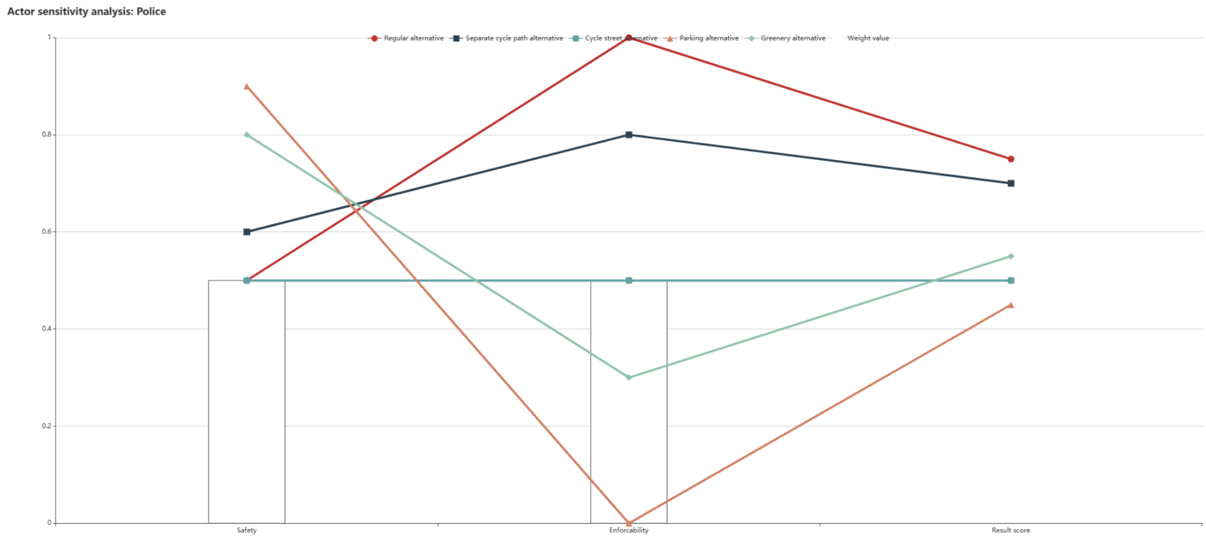

Figure 5.3: Sensitivity analysis Police

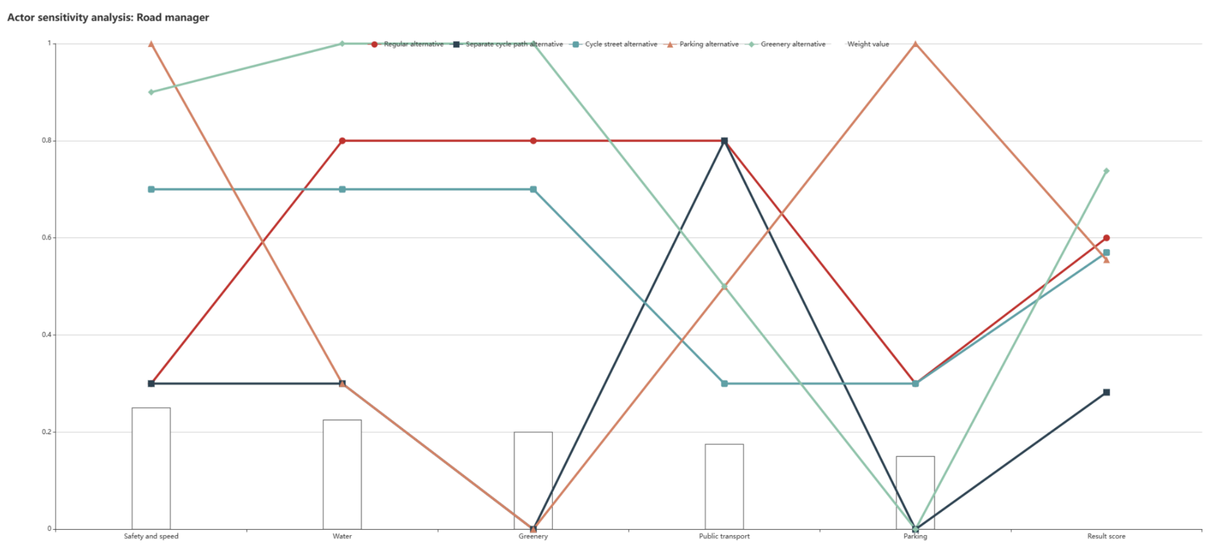

Figure 5.4: Sensitivity analysis Road manager

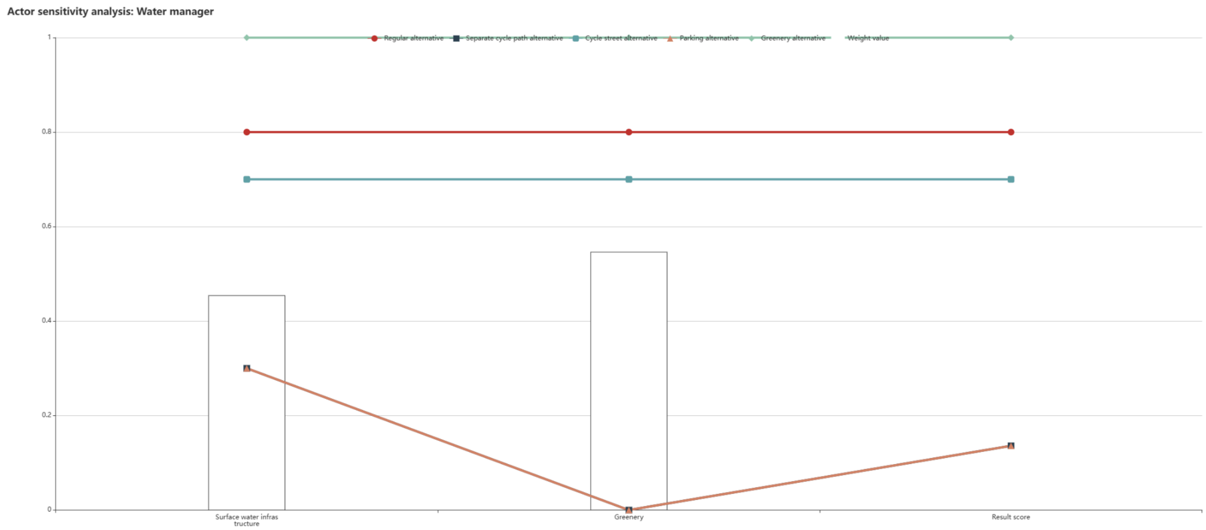

Figure 5.5: Sensitivity analysis Water manager

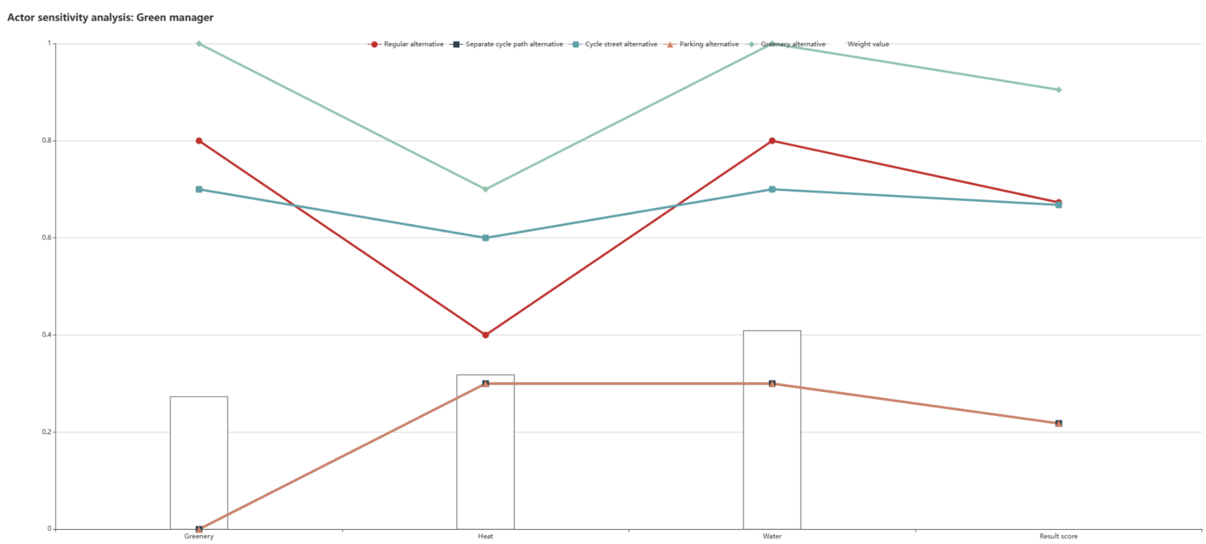

Figure 5.6: Sensitivity analysis Green manager

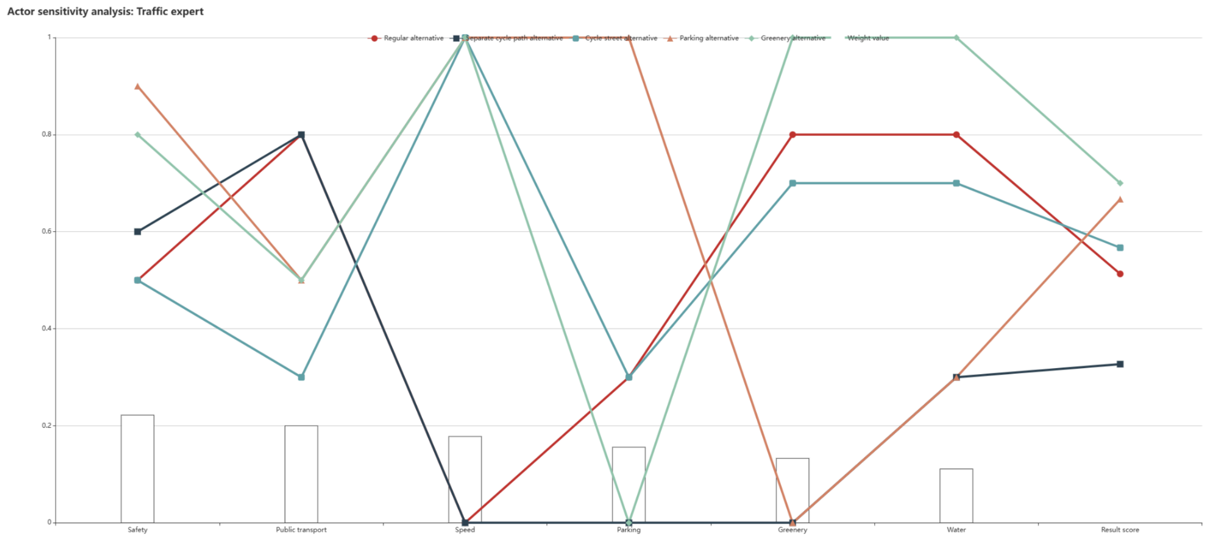

Figure 5.7: Sensitivity analysis Traffic expert

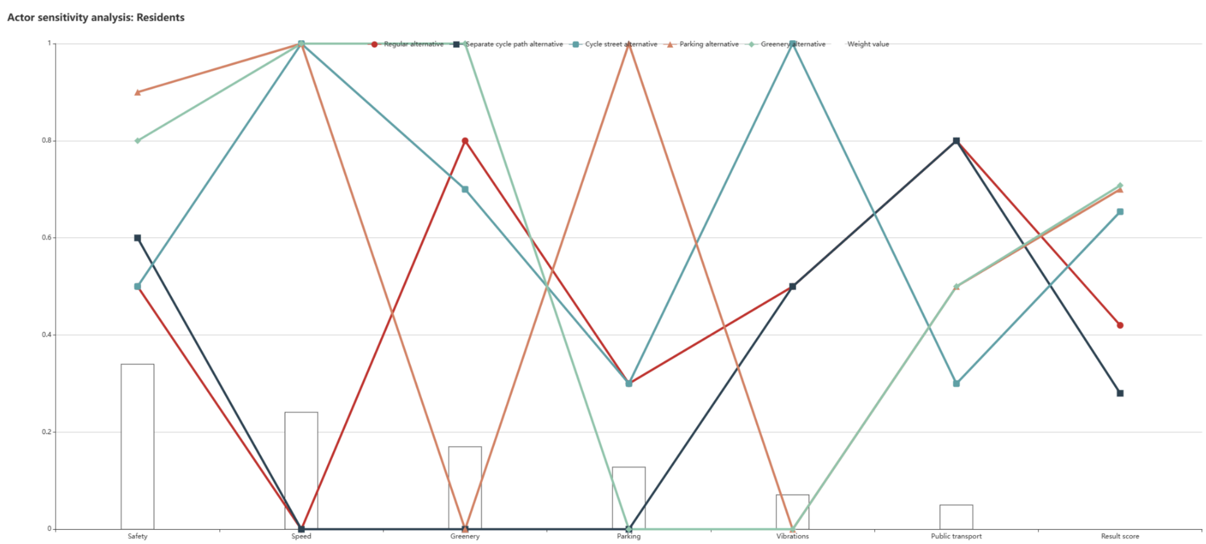

Figure 5.8: Sensitivity analysis Residents

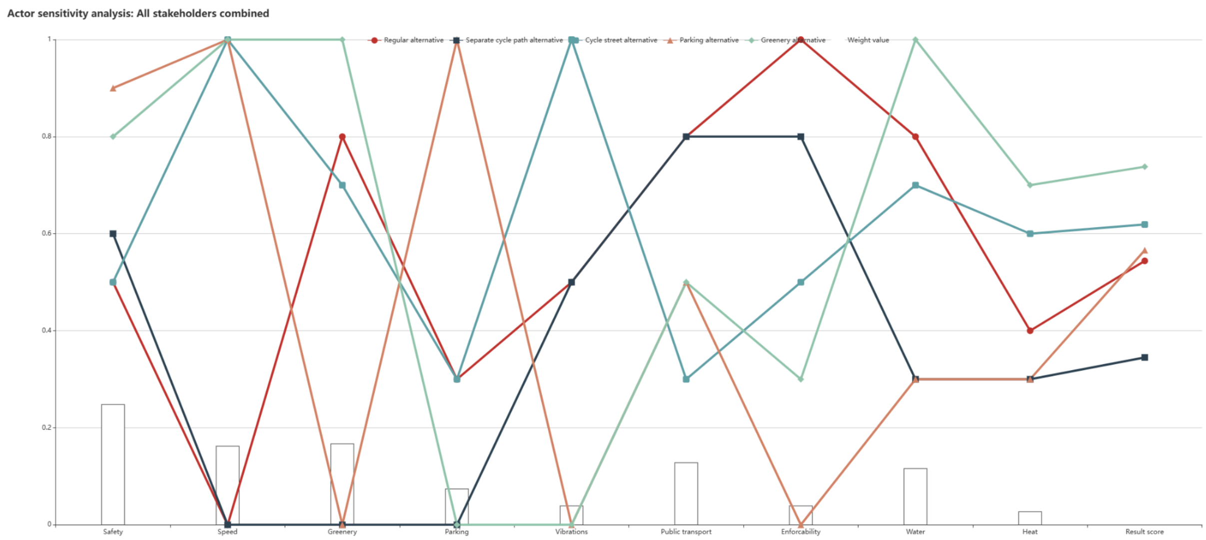

Figure 5.9: Sensitivity analysis All stakeholders combined

Appendix 6: Figures and tables of Methodology

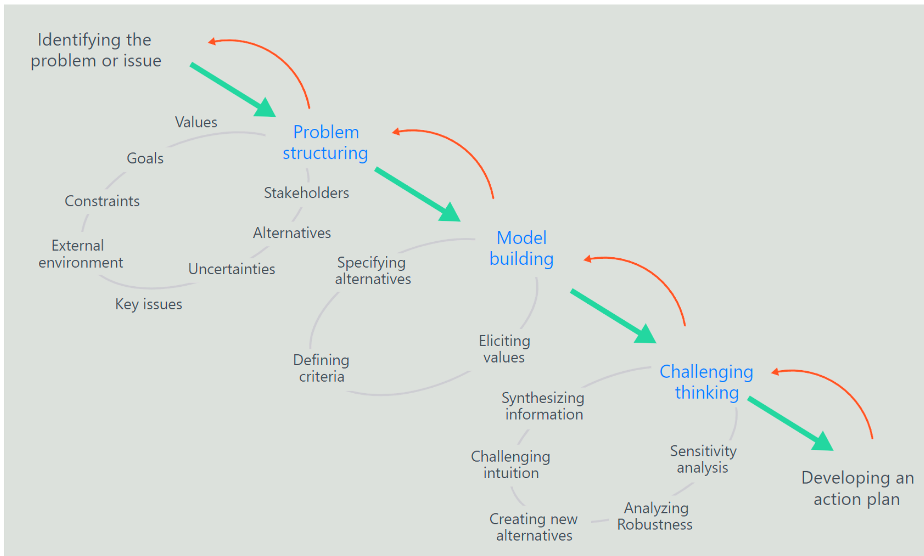

Figure 5.1: MCA process (1000minds, n.d.)

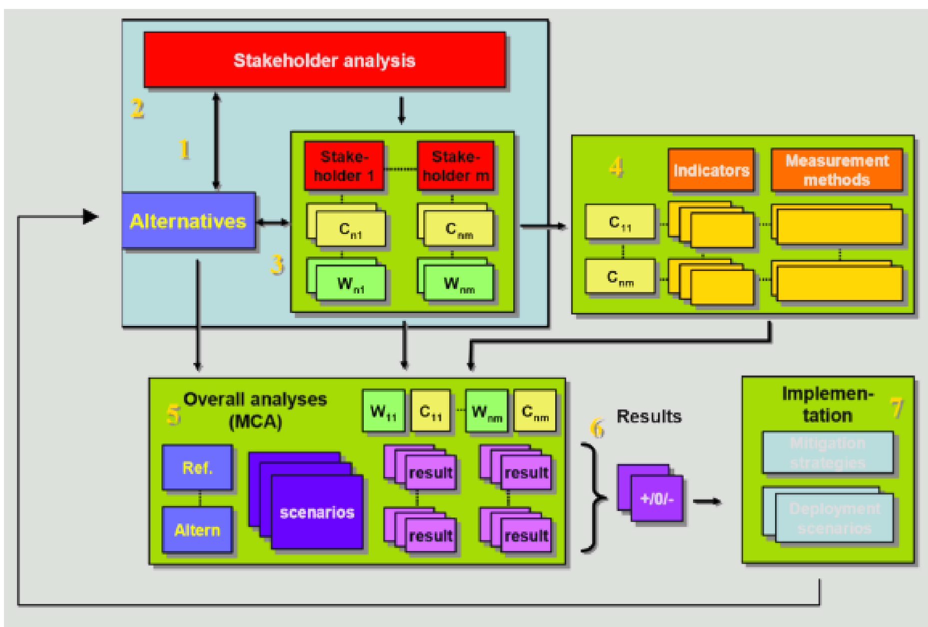

Figure 5.2: MAMCA

Appendix 7: Figures and tables of Literature overview

	Effect op autobezit	Effect op autogebruik
Bebouwde omgeving		
Verdichting	↓	↓
Functiemenging	↓	↓
Parkeren		
Verwijderen van bestaande parkeerplaatsen	?	↓
Stringente parkeernormen nieuwbouw	↓	↓
Parkerenvergunningen	↓	?
Verhogen parkeertarieven	↓	?
Parkeren op afstand	?	?
Wegen en straten		
Wegafsluiting/ 'Knip'	↘	?
Autlow centrum	?	?
30 km/ u straten	↘	?
Herinrichting straten	↘	?

Figure 6.1: Effects of car reducing measures (Dutch) (Jorritsma et al, 2023)

	Bereikbaarheid	Leefbaarheid	Veiligheid	Gezondheid
Bebouwde omgeving				
Verdichting	●●●	●●	●●	●●
Functiemenging	●●●	●●●	●●●	●●●
Parkeren				
Verwijderen van bestaande parkeerplaatsen	●●	●●	●●	●●●
Stringente parkeernormen nieuwbouw	●●●	●●●	●	●●●
Parkeervergunningen	●●●	●●●	●	●
Verhogen parkeertarieven	●●●	●●●	●	●●
Parkeren op afstand	●	●●	●●	●●●
Wegen en straten				
Wegafsluiting/ 'Knip'	●●	●●	●●●	●●●
Autlow centrum	●●	●●	●●●	●●
30 km/ u straten	●	●	●●●	●
Herinrichting straten	●●●	●●●	●●●	●●●
Investeringen in fietnetwerk	●●●	●●●	●●●	●●●

Figure 6.2: Impact levels of car-reducing measures (Dutch) (Jorritsma et al, 2023)

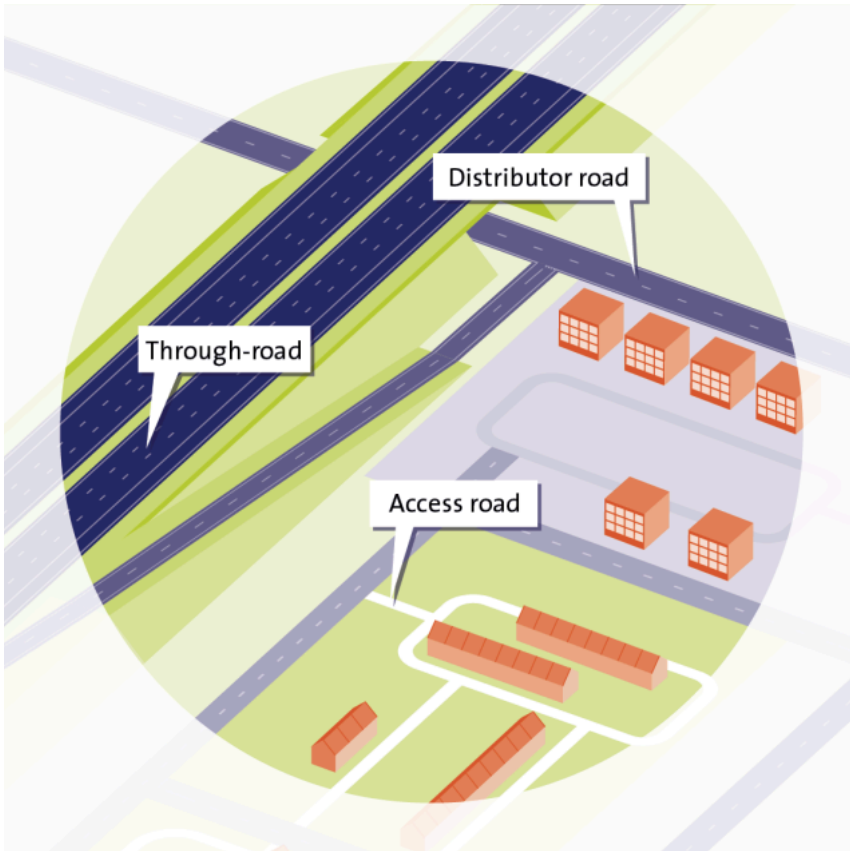

Figure 6.3: Different road categories (SWOV, 2023)

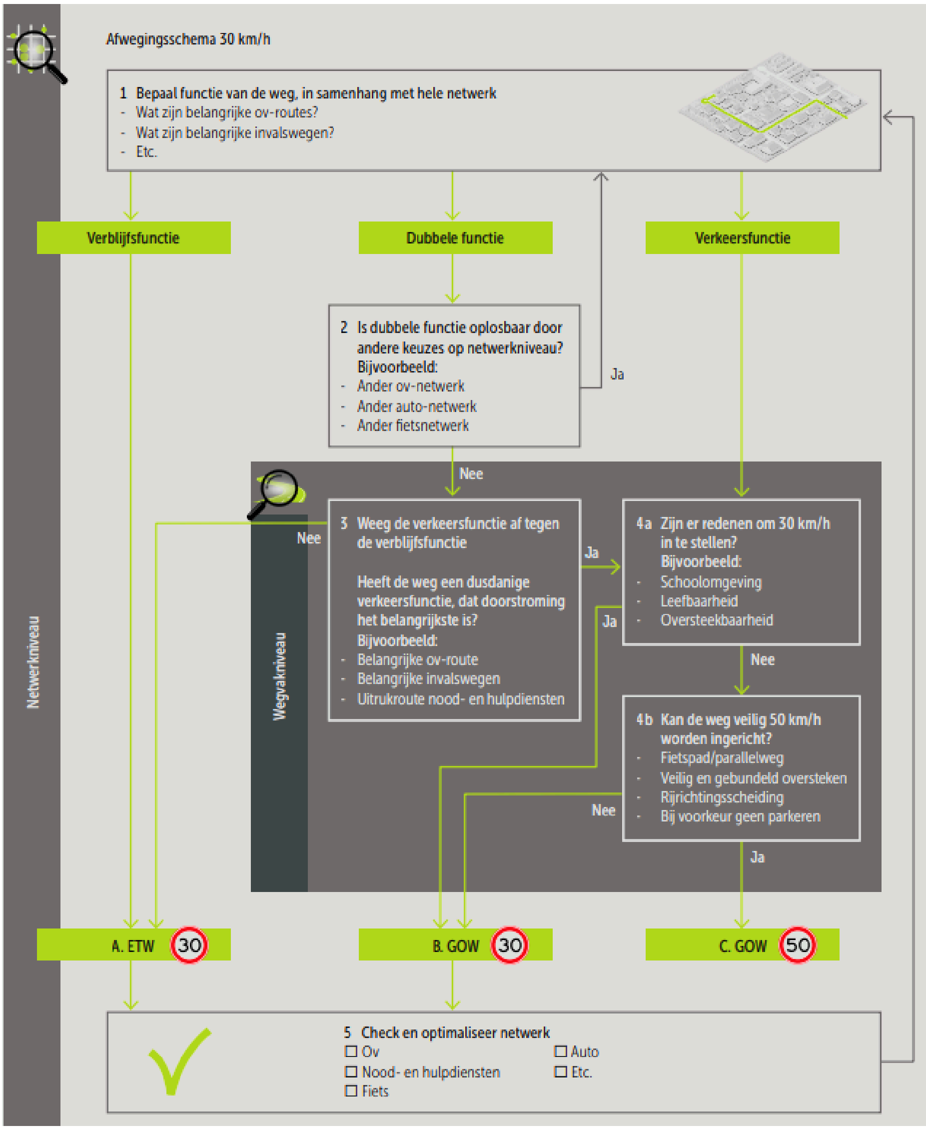

Figure 6.4: Assessment scheme road class (Dutch) (CROW, 2021)

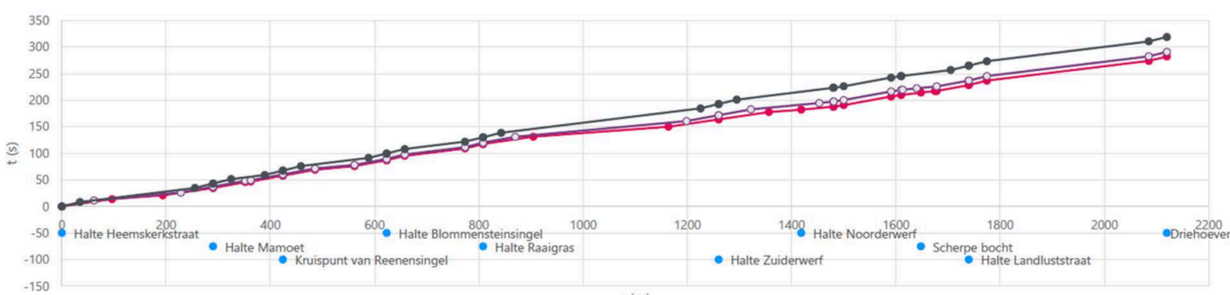

Figure 6.5: Time it takes bus to drive route in 30/40/50 km/h (Goudappel, 2022)

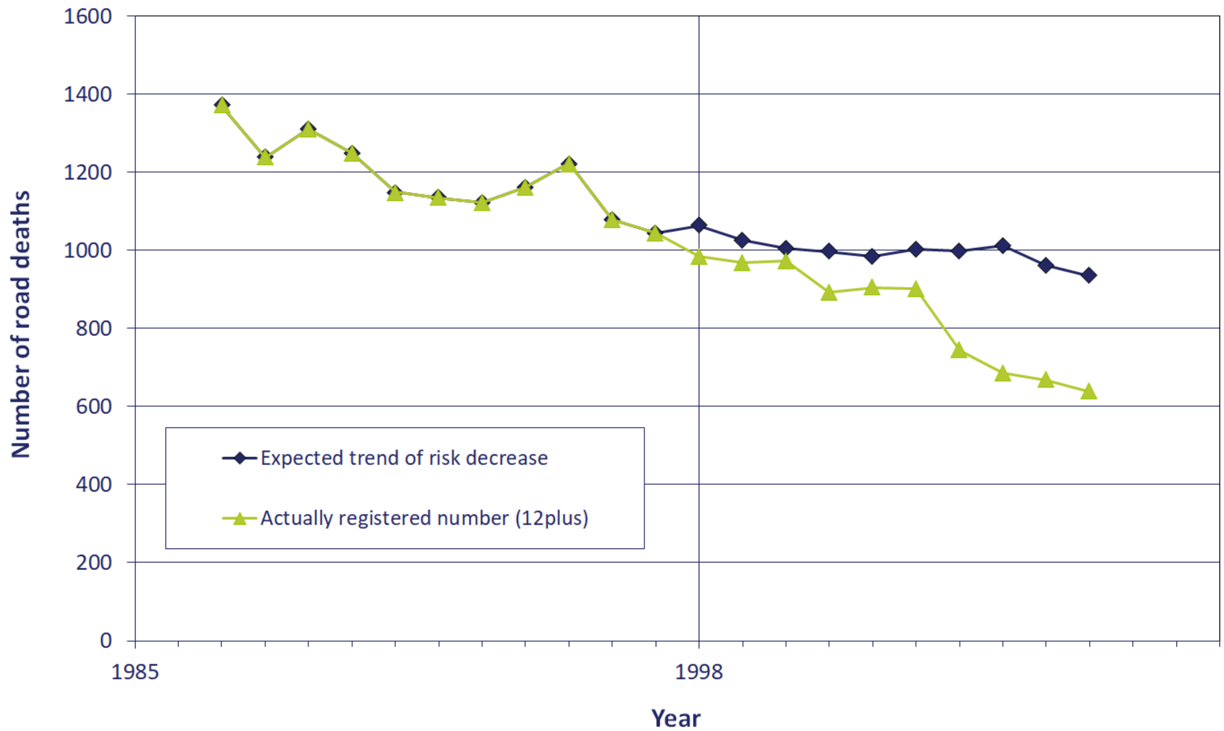

Figure 6.6: Number or road deaths with and without Sustainable Road Safety (SWOV, 2019)

Table 6.1: Safe speed limits (SWOV, 2019)

Potential conflicts and requirements associated with	**Safe speed (km/h)**
Possible conflicts with vulnerable road users in home zones (no foot paths and pedestrians using the carriageway)	**15**
Possible conflicts with vulnerable road users **on roads and at intersections, including situations with bike lanes or advisory bike lanes**	**30**
No conflicts with vulnerable road users, except with helmet-protected riders of motorised two-wheelers (mopeds on the carriageway). Possible right-angle conflicts between motorised vehicles, possible frontal conflicts between motorised vehicles. **Stopping sight distance ≥ 47 m**	**50**
No conflicts with vulnerable road users **No right-angle conflicts between motorised vehicles,** possible frontal conflicts between motorised vehicles **Obstacles shielded or obstacle-free zone ≥ 2.5 m, (semi)hard shoulder** **Stopping sight distance ≥ 64 m**	**60**
No conflicts with vulnerable road users No right-angle conflicts between motorised vehicles, possible frontal conflicts between motorised vehicles Obstacles shielded or **obstacle-free zone ≥ 4.5 m,** (semi)hard shoulder **Stopping sight distance ≥ 82 m**	**70**
No conflicts with vulnerable road users **No right-angle or frontal conflicts between motorised vehicles** Obstacles shielded or **obstacle-free zone ≥ 6 m,** (semi)hard shoulder **Stopping sight distance ≥ 105 m**	**80**
No conflicts with vulnerable road users No right-angle or frontal conflicts between motorised vehicles Obstacles shielded or **obstacle-free zone ≥ 10 m, hard shoulder** **Stopping sight distance ≥ 170 m**	**100**
No conflicts with vulnerable road users No right-angle or frontal conflicts between motorised vehicles Obstacles shielded or **obstacle-free zone ≥ 13 m**, hard shoulder **Stopping sight distance ≥ 260 m**	**120**
No conflicts with vulnerable road users No right-angle or frontal conflicts between motorised vehicles Obstacles shielded or **obstacle-free zone ≥ 14.5 m**, hard shoulder **Stopping sight distance ≥ 315 m**	**130**

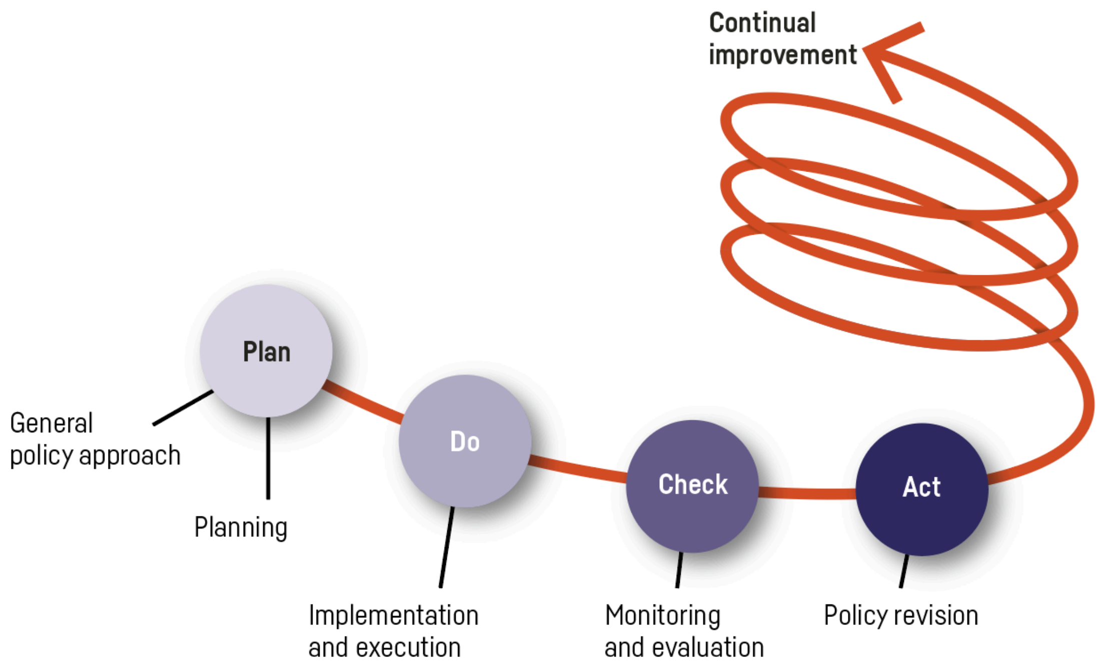

Figure 6.7: Cycle of improvement in the Sustainable Road Safety (SWOV, 2019)

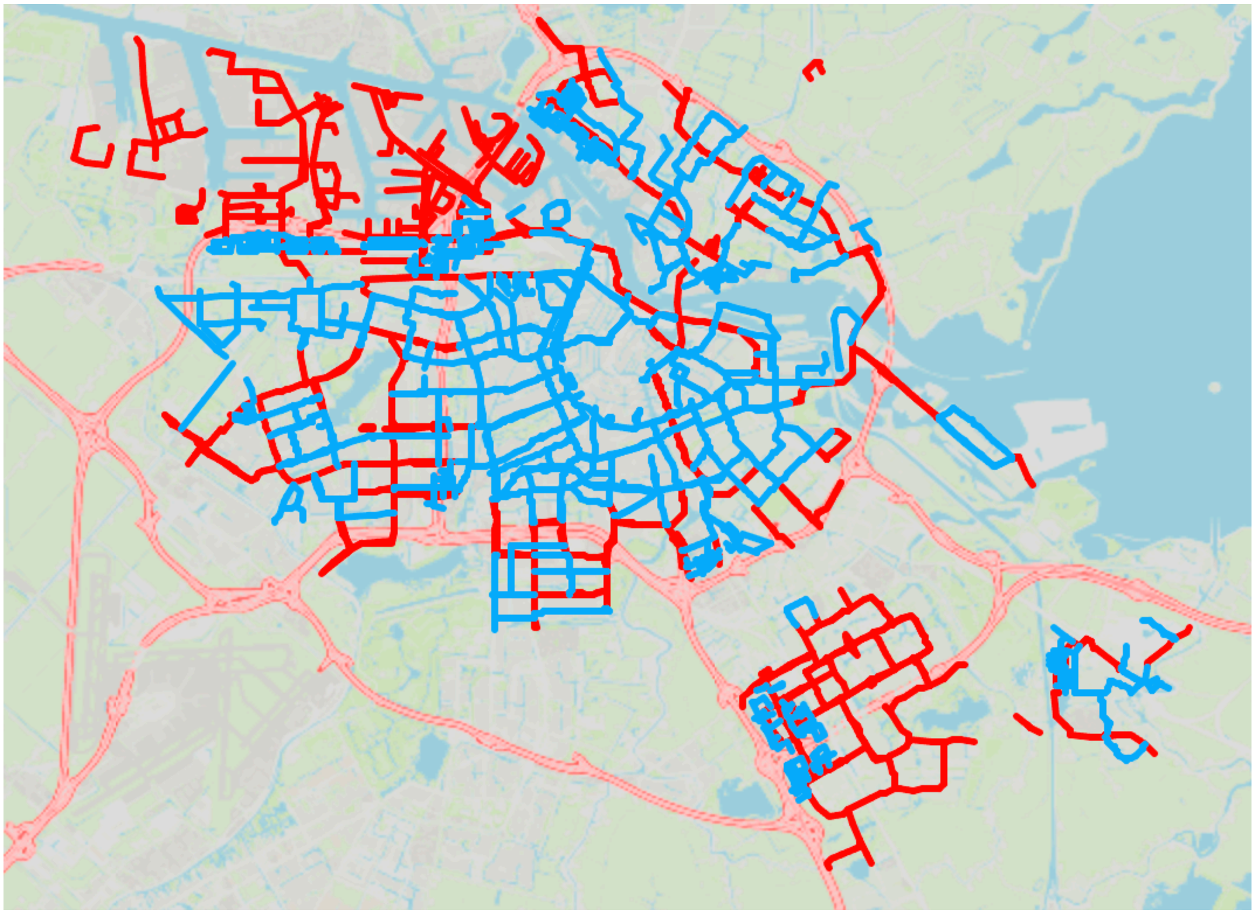

Figure 6.8: Road network of Amsterdam, blue will change, red will not change (Gemeente Amsterdam, n.d.)

Appendix 8: Figures and tables of Research to the Borculoseweg

FIETSPADEN			
Eenrichtingverkeer		**Tweerichtingverkeer**	
Spitsuurintensiteit (1 r.)	Breedte (m)	Spitsuurintensiteit (2 r.)	Breedte (m)
0 – 150 (13)	2,00	0 – 50 (12)	2,00
150 – 750 (14)	2,50 – 3,00	50 – 150 (13)	2,50 – 3,00
> 750	3,50 – 4,00	> 150	3,50 – 4,00
(BROM)FIETSPADEN			
Eenrichtingverkeer		**Tweerichtingverkeer**	
Spitsuurintensiteit (1 r.)	Breedte (m)	Spitsuurintensiteit (2 r.)	Breedte (m)
0 – 75	2,50	0 – 50	2,50
75 – 375	3,00 – 3,50	50 – 100	3,00 – 3,50
> 375	4,00 – 4,50	> 100	4,00 – 4,50

Figure 7.1: Cycle path width (Fietsberaad, 2004)

<table>
<tr><th>Functie</th><th colspan="3">Erftoegangsfunctie voor motorvoertuigen (ETW, 30 km/uur)</th></tr>
<tr><td>Hoofdfietsroute</td><td rowspan="2">Fietspad
- Geen autoverkeer
Solitair of vrijliggend</td><td>Fietsstraat
✓ Gemengde verkeersafwikkeling
✓ Kwaliteitseisen hoofdfietsroute
✓ Herkenbaar als Fietsstraat</td><td>Fietsstroken met smalle rijloper
- Eén volwaardige strook auto
- Menging bij tegenliggers en vrachtverkeer
Kwaliteitseisen hoofdfietsroute</td></tr>
<tr><td>Geen hoofdfietsroute</td><td colspan="2">Normale woonstraat
- Basiskenmerken 'ideale inrichting ETW'
- Geen speciale maatregelen voor fietsers
- Zoveel mogelijk vormgevingselementen uit hoofdstuk 4 toepassen, behalve "rood asfalt" en "Fietsstraatbord L51"</td></tr>
</table>

Figure 7.2: Different ETW types with or without cycling facilities (CROW, 2019)

Tweerichtingsverkeer				Eenrichtingsverkeer			
I-mvt /uur	100 fietsers /uur	250 fietsers /uur	400 fietsers /uur	I-mvt /uur	100 fietsers /uur	250 fietsers /uur	400 fietsers /uur
50	450	450	450	50	420	420	450
100	500	480	480	100	420	420	450
150	590	510	480	150	510	420	450
200	630	590	480	200	510	510	450
250	geen fietsstraat, eventueel fietsstroken	630	510	250	geen fietsstraat, evt. fietsstroken met smalle rijloper	510	510
300		630	590	300		590	590
350		710	630	350		590	590
400		met smalle rijloper		400		590	590

Maatgevende voertuigcombinatie		
fiets-fiets	fiets-mvt-(fiets)	mvt-mvt

Rijbaanbreedte incl. rabatstroken van 30 cm
Percentage duofietsers 10%
Percentage bus/vrachtverkeer < 2%

Figure 7.3: Width regulation based on demand (CROW, 2021)

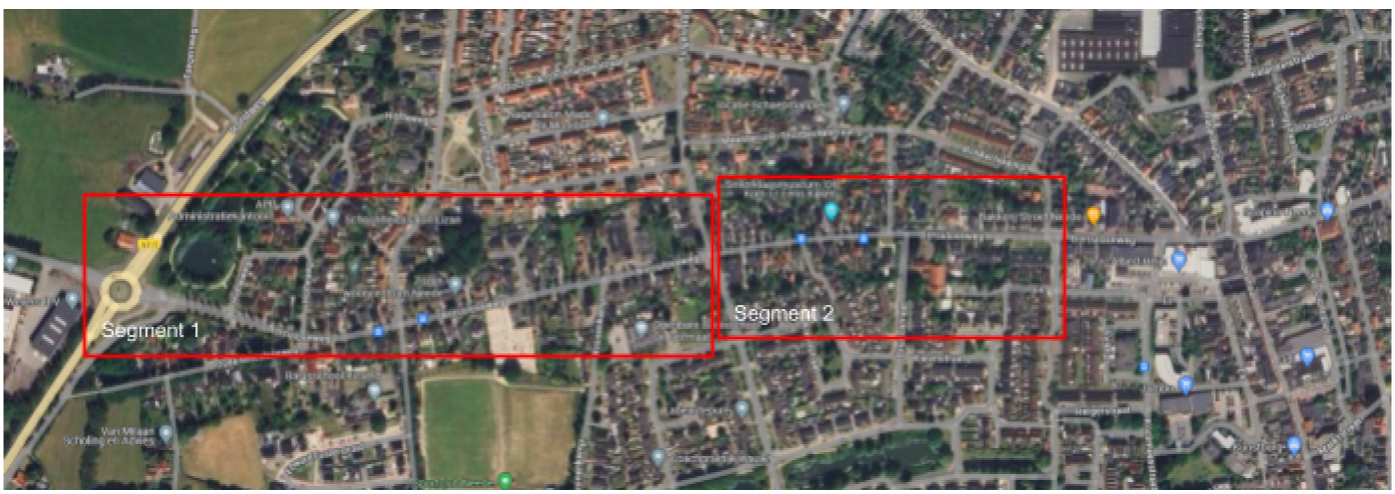

Figure 7.8: Segments of the Borculoseweg

Appendix 9: Cross-sections Royal Haskoning

The research that has been done by Royal Haskoning brought forward five possible solutions in order to improve the safety on the road.

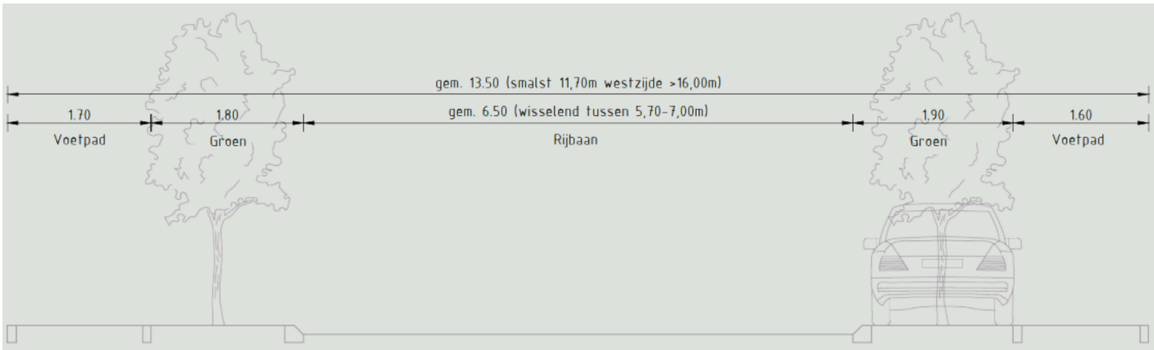

Figure 8.1: Current situation (Royal HaskoningDHV, 2021)

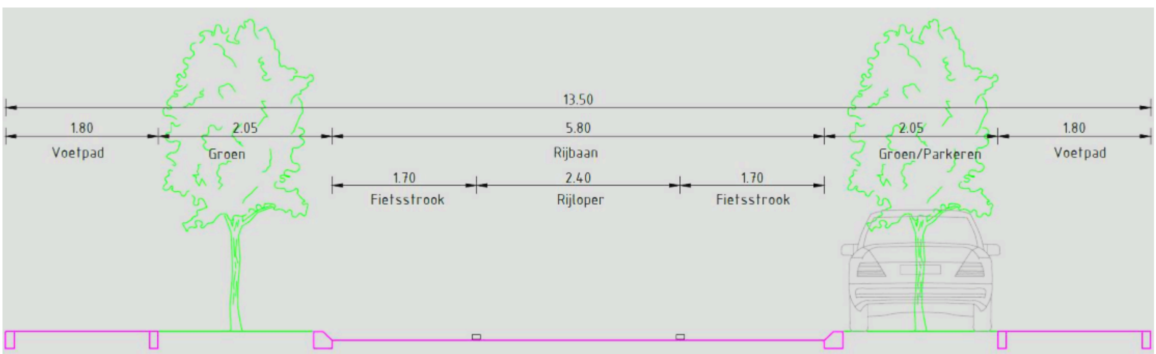

Figure 8.2: First alternative (Royal HaskoningDHV, 2021)

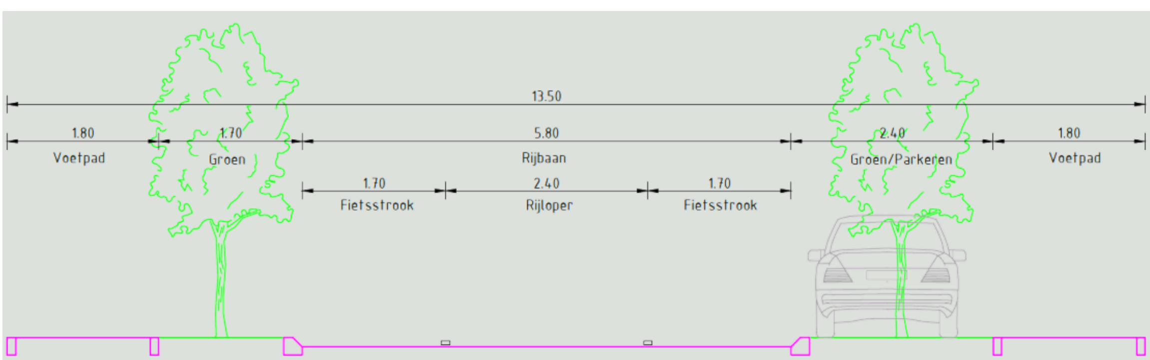

Figure 8.3: Second alternative (Royal HaskoningDHV, 2021)

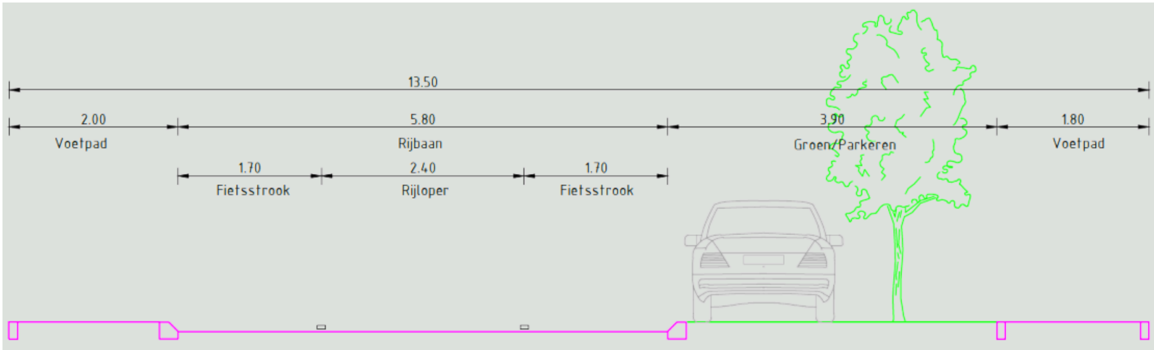

Figure 8.4: Third alternative (Royal HaskoningDHV, 2021)

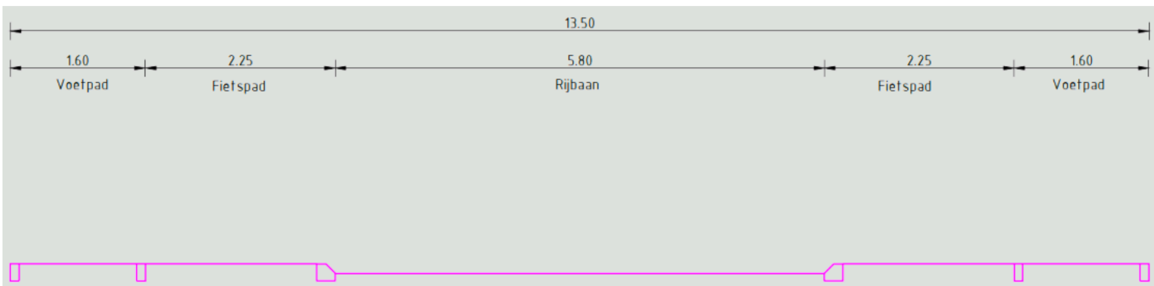

Figure 8.5: Fourth alternative (Royal HaskoningDHV, 2021)

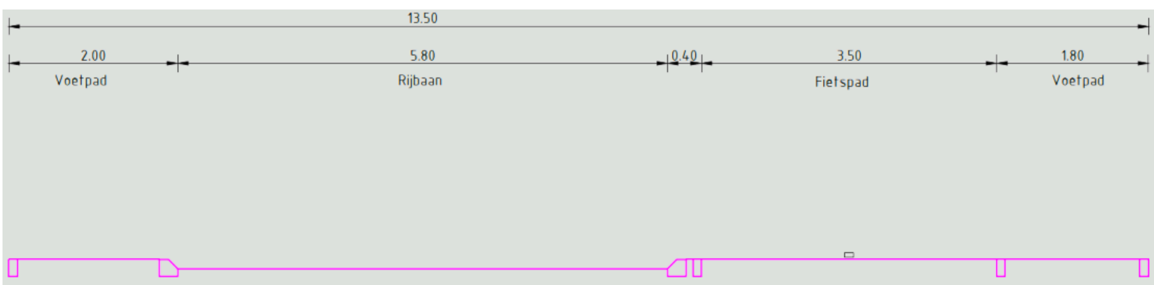

Figure 8.6: Fifth alternative (Royal HaskoningDHV, 2021)

Appendix 10: Table of alternative characteristics

Table 9.1: Differentiating characteristics alternatives

Number	Name	Situation	Characteristics
1	Balanced		The road has balanced characteristics, therefore not excelling in one criteria. It has a speed limit of 50 km/h, cycle lanes. On the sides there is alternating parking and greenery as well as a walking path.
2	Cycle path		This alternative means that there is no slow traffic making use of the road, therefore scoring points for cycle safety and with the 50 km/h speed for public transport. The road is wide, leaving no space for greenery or parking. There is a walking path on both sides.
3	Cycle street		The cycle street makes the cyclist of the highest concern. Speed limit is 30 km/h and cyclists are functioning as speed reducing measures. There is greenery alternating with parking on both sides, as well as walking paths.
4	Parking		This alternative also has a speed limit of 30 km/h and focussed on a high amount of parking, therefore there is parking alongside both sides of the road, as well as a walking path. The road has cycle lanes to increase the safety for cyclists.

5	Greenery		This road has the same road profile and 30 km/h speed limit as the parking alternative, but has greenery on both sides of the road. This increases the livability and temperature of the road.