Evaluation of proposed solutions for the Europalaan-Tuunterstraat intersection in Winterswijk

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19-06-2024

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Preface

This Bachelor Thesis is made as part of the Civil Engineering Bachelor programme at the University of Twente in Enschede. It is executed by and for the Municipality of Winterswijk. The project was executed from April 2024 to June 2024.

The Municipality was interested in investigating the effects of two proposed solutions to the safety and capacity problem at the intersection of the Tuunterstraat and Europalaan. The safety of cyclists was the main priority since several incidents did happen with cyclists, due to the layout of the intersection and the poor cycle connections, cyclists tend to use a one-way cycle path as a two-way cycle path. The effects of two proposed solutions, one by Veilig Verkeer Nederland (A Dutch organisation that promotes safety in traffic) and one by the municipality itself, can be investigated with the help of simulation. During an earlier module in the Bachelor's programme, I found traffic simulation interesting and was therefore motivated to deepen this knowledge during this Thesis.

I want to thank Ing. Ben Stockmann, my external supervisor from the Municipality of Winterswijk, and Dr. Ir. Oskar Eikenbroek, my internal supervisor from the University of Twente, for assisting me whenever I needed help or had questions.

Furthermore, I want to thank the Municipality of Winterswijk and the University of Twente itself for providing me with this opportunity and for the Bachelor's programme which helped me prepare.

Finally, I want to thank family and friends for their support during the past three years.

Jasper Piek

19-06-2024

Executive summary

This thesis concerns the safety and traffic flow problem at the intersection of the Tuunterstraat and Europalaan in Winterswijk, where cyclists use a one-way cycle path as a two-way cycle path, which leads to dangerous situations and incidents. Veilig Verkeer Nederland and the Municipality of Winterswijk have developed one possible solution to these issues. This thesis aims to investigate the effects of these solutions. Therefore, the main research question is: "What are the effects of the solutions proposed by the VVN and the Municipality of Winterswijk for the intersection of the Europalaan and Tuunterstraat in Winterswijk, on traffic flows, safety, environmental and economic effects?"

The method followed to answer this research question started with a data collection at the intersection, since a simulation program, Vissim, is used to assess the effects of the solutions. This data is then implemented into the simulation program, for each of the different designs, including the current situation. After this, the travel times, delays, and queue lengths are compared between the designs to assess the performance of the intersection on the traffic flow. To assess the safety, the number of conflict points is used, together with the angle, speed, and intensity at these conflict points. The environmental effects are assessed with a calculation of the fuel consumption and the economic effects are a relative cost-comparison.

The results of this assessment are that there are trade-offs between the different solutions. The solution of the Municipality is better for the safety and traffic flow of cyclists, while the solution of VVN is better for the traffic flow of motorised traffic, and therefore also for fuel consumption. While still improving the traffic flow for cyclists. The difference in economic effects is negligible.

The main limitation of this project was the availability of people during the data collection, which made it not possible to count all the relevant directions, which led to somewhat fewer queues in the final model than in reality. Other limitations are model-dependent, such as not being able to insert speed measurements at all the conflict points and the accumulation of cyclists who are cycling against the direction and those who are not. A recommendation is to look into the possibility of combining some elements from both solutions since both solutions have valuable elements, and the effects of this combined solution can be investigated further.

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1. Introduction

People will cycle more and more. It has many advantages, it is good for mental health and well-being, as well as cognitive functions (Leyland et al., 2019). A study from the Netherlands Institute for Transport Policy Analysis indicates that Dutch inhabitants will cycle more in 2050 because of climate change, which means that in total more cycle trips will be made compared to now (Fietsberaad CROW, 2020). Roads are not always designed to accommodate these high numbers of cyclists yet. This also became apparent in an investigation from CROW in Winterswijk (Siebenga & De Jong, 2005). In some places, cyclists have separated infrastructure, but in the city, there are numerous places where cyclists share the road with cars and other motorised vehicles. On distributor roads, this is highly undesirable in terms of safety. While on residential roads, it is safer for cyclists to share the same road with cars and other vehicles since the speed on residential roads in an urban area is most of the time lower (30 km/h) compared to distributor roads (50 km/h in the urban area)).

This undesirable situation of cyclists opposing motorised traffic was also noticed by the Winterswijk Senior Citizens Council, which reported a dangerous situation in the city of Winterswijk to Veilig Verkeer Nederland. A separated two-way cycling path transforms into a cycle lane on both sides of the road. Since this cycle lane is connected to the road for motorised traffic, this results in cyclists sharing the same infrastructure with other vehicles. This is at the point of the intersection of the Tuunterstraat and Europalaan, which can be seen in Figure 1.1. Cyclists must cross the Europalaan north of the intersection. They must cross the Europalaan again some hundred metres after the intersection to cycle to the action. However, this is not the route followed by most cyclists. The route that the cyclists follow to the Handelscentrum is also indicated in Figure 1.1, where the only two-way cycle path in the area is indicated with a black box. The yellow lines indicate other existing one-way cycle paths along the Tuunterstraat.

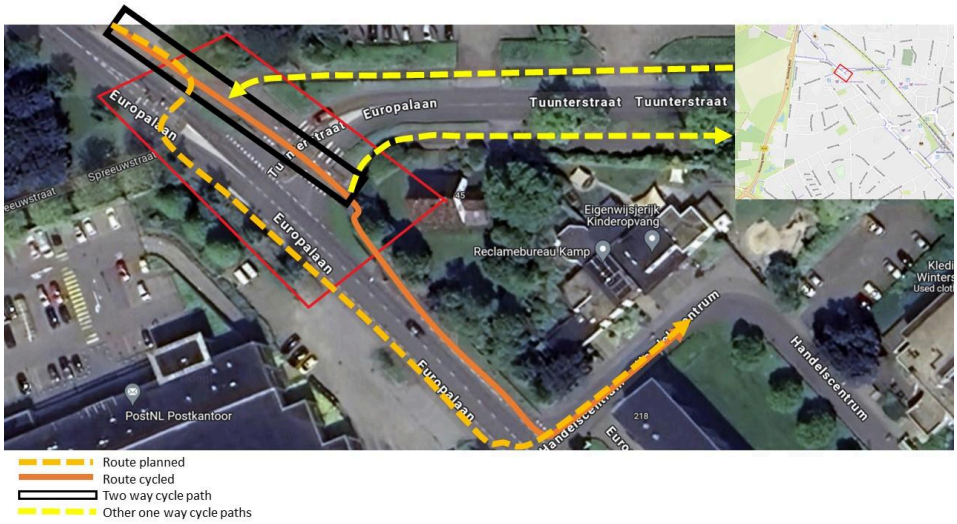


Figure 1.1: Intersection Europalaan and Tuunterstraat situation one-way cycle path used as two-way cycle path (Google Maps, 2024)

In Figure 1.1 it can be seen that instead of crossing the Europalaan twice to go to the Action/Handelscentrum, the cyclists use the one-way cycle path as a two-way cycle path, to not cross the busy road twice. Another problem and the cause of the safety problem is that the intersection is very busy during the rush hours (from 16:00 till 18:00 mainly), congestion occurs

especially when motorised vehicles are turning left from the Europalaan and the Tuunterstraat, since when turning left, there is a lot of opposing traffic, both cars and cyclists from both sides. This leads to vehicles queuing to the entrance of the Handelscentrum on one side and to the entrance of the Jumbo (and further) on the other side of the Europalaan. At the Tuunterstraat the traffic is queuing till behind the start of the bend in the road, such the end is not visible anymore when driving from the east of the Europalaan. There also have been 9 incidents at this intersection, from which 2 with injuries, in 5 years (VIA statistiek ongevallen, n.d). This is quite a high number for the Municipality of Winterswijk, as can be seen at VIA statistiek ongevallen, n.d. The accidents in the past 5 years did happen on Tuesday, Wednesday, Thursday, and Sunday, whereas the time of the day differed from morning, afternoon, and evening. The type of incident was 1 time (moped)bicycle-car, this accident did happen with an angle of 90 degrees (flank). Also, one incident did happen between a cyclist and a (moped)bicycle. This accident was frontal on the cycle path and could have been caused by using the one-way cycle path as a two-way cycle path since it did happen around that cycle path. This accident heavily injured the cyclist. Between 2014 and 2019 also 13 accidents did happen. In 2014 a cyclist was heavily injured by a flank accident with a car. These incidents display the safety problem that exists between motorised vehicles and cyclists.

The first proposed solution by VVN is to create a new crossing for cyclists of the Tuunterstraat to an existing parking place that is connected to the Handelscentrum. To realise this, on the north side of the Tuunterstraat, a two-way cycle path needs to be constructed, that starts before the intersection and is running till it crosses the Tuunterstraat to the car park at the Handelscentrum. In addition, the crossing itself has to be constructed. In this way, the cyclists only must cross the Tuunterstraat once, which is typically less busy in terms of traffic compared to the Europalaan. In Figure 1.2 the route that can be cycled as a solution is shown.

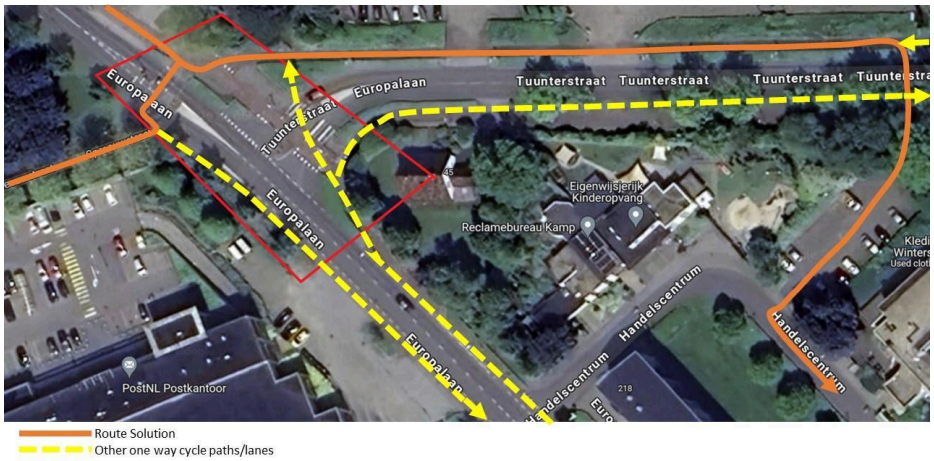


Figure 1.2: Intersection Europalaan and Tuunterstraat proposed solution VVN (Google Maps, 2024)

Another proposed solution is to construct a roundabout with separate cycle paths all around. However, this solution is indicated by the Municipality as not desirable/possible since the solution is too expensive and is therefore not considered further in this project.

A possible solution that is considered as part of this thesis research is the proposed solution of the Municipality itself. It is a bit similar to the first proposed solution of VVN with the new entrance to the Handelscentrum. However, the idea of the Municipality is to extend the two-way cycle path further along the Europalaan and to close off the entrance to the Handelscentrum at

the Europalaan. Furthermore, the cycle lane along the entrance and departure of the Jumbo is removed completely. This situation is sketched in Figure 1.3. The construction of the two-way cycling path along the Europalaan can be combined with the removal and construction of new apartments in the south of the Europalaan since this part is then already under construction. The construction of new apartment buildings is a project from the Woonplaats, a housing corporation. This project is also one of the causes for this project since it is a good coupling opportunity, to reduce costs and disturbance during the construction.

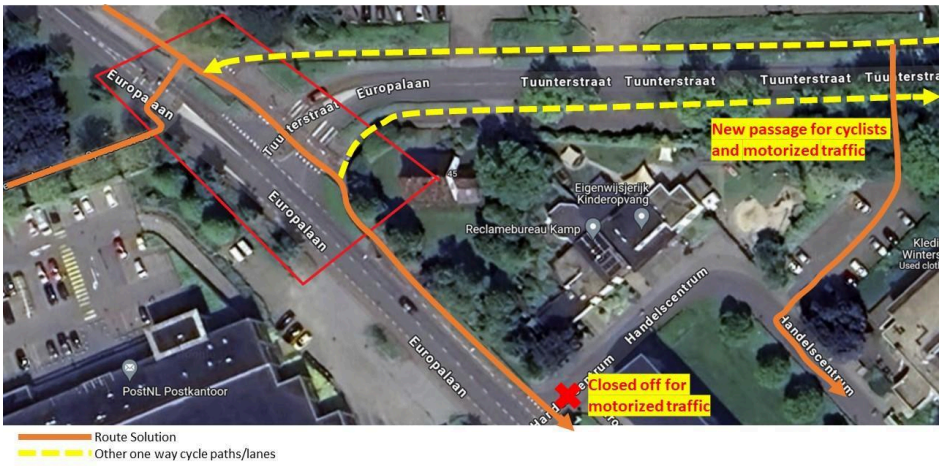


Figure 1.3: Proposed solution Municipality (Google Maps, 2024)

However, the effects of these proposed solutions on the traffic situation are not known. The effects of the solutions can be analysed with the help of simulation. The use of models has a lot of advantages, such as that it provides a risk-free environment, saves money and time, can be used for visualisation, can give an insight into difficult dynamics, can increase accuracy, and can handle uncertainty (Anylogic, n.d.). In particular in this situation, where it would be expensive for the Municipality of Winterswijk to construct the intervention to test what the effects are. A simulation model is a good solution since multiple solutions can be tried without consequences, and it is less resource-intensive compared to a real-world implementation. The effects on the traffic flows can be analysed for example with VISSIM, which is a program to simulate traffic flows.

In this report, the safety and capacity problem will be further broken down in Chapter 2. Where also a clear problem will be stated, as introduced here already, while also the objective of the research will be made clear. In Chapter 3 the research question(s) will be formulated. After that the methods that will be used to investigate these research questions will be described in Chapter 4. When these methods are clear, the data collection that is performed is analysed. In Chapter 6 the model of the current situation will be explained, and the results are shown. Then the models of the proposed solutions are shown, and the results are compared with the current situation. In Chapter 8 the safety of the current situation and the proposed solutions is analysed. In Chapter 9 the trade-offs from the different solutions are discussed and finally, in Chapter 10 the research questions are answered.

2. Project definition

In this chapter, the problem will be investigated further. First, it is important to know what the interests of the stakeholders are. These interests are needed to assess the effects of the solutions on these interests. Then the cycle paths in and around the study area are investigated, after which the traffic flow will be analysed with the help of available data. Also, a site visit is done to better understand the traffic flows at the intersection. After this, requirements will be set to be able to assess the effects of the proposed solutions. These effects need to be assessed with some indicators. Which indicators are the best for assessing these effects are investigated in a literature review, as well as the influential traffic flows and final discussion of trade-offs. Following this, the research objective and problem statement are set.

2.1 Context

First, the stakeholders in the problem are identified, the study area is also described in more detail and previous simulation studies are investigated.

2.1.1 Stakeholders

Many stakeholders are involved in this safety (9 incidents in 5 years) and capacity (congestion during rush hours) problem. It is important to have the stakeholders identified, as well as their interests, to come to the right recommendations in the end, since it could be the case that there are conflicting interests.

The Municipality of Winterswijk, since this is the client, identified the problem and communicated it to the VVN. The Municipality of Winterswijk also has a lot of different interests. The most significant interest in this problem is ensuring that the intersection becomes safer. Safety is one of the main tasks of municipalities (VNG, n.d.) Another interest from the Municipality is the accessibility of the area, since this has also a link with safety, therefore congestion should not be increased dramatically by the implementation of a solution, or the congestion needs to decrease. Furthermore, the reduction of congestion and improving the safety of the intersection are important for the satisfaction of inhabitants. Making the inhabitants satisfied is also a core task of the Municipality, as well as the satisfaction of the businesses in the area, which is important for the economic vitality of the Municipality.

VVN is also partially a stakeholder in this problem since their goal is to contribute to improving traffic safety, therefore this project is a chance for them to contribute to the traffic safety at this intersection. A study to clarify the results of their proposed solutions can be a strong argument for the Municipality to implement them, which helps to reach the goal of VVN.

Stakeholders with high interest are the users of the road and cycle path. They are the residents in the area, but also the visitors of the many points of interest in the area, such as shop owners, restaurants, and other companies and commuters. These users have a high interest since they will be affected by the implementation of safety measures. Safety is important to them, however, accessibility is also important, since users of the road may not agree with the solution if this leads to longer travel times and objections from stakeholders can occur that try to withhold the implementation of a solution. In total their interest will be a safer intersection, but also an intersection that does not have a lot of congestion.

The last group of important stakeholders are a lot of stakeholders that are situated in the area, from shop owners (Welkoop, Gamma, Jumbo, Action, Aldi) to restaurants (McDonalds), a school (Pronova) and other companies such as childcare. Their interests differ from mainly safety to mainly accessibility. For example, the childcare and Pronova interest is mainly safety, such that children can travel safely to school, while the Jumbo interest is mainly the accessibility of their shop for customers as well as suppliers (with big trucks). So, less congestion at the entrance and exit of their parking places is the biggest interest of the shops. There is no public transport going through this area. There are also some pedestrians in this area, however, way less than cyclists.

2.1.2 Study area

In Figure 2.1 an overview can be seen of the cycle paths in the area, where the red lines are cycle paths separated from the road, while the orange lines are cycle lanes connected to the road. In addition, some businesses in the area are highlighted.

Figure 2.1: Cycle paths and businesses in and around the study area (OpenStreetMap, n.d.)

In the area, besides most of the 50 km/h roads (grey and white), there is a separate cycle path, this is however not the case at the Europalaan between the roundabout in the south and the intersection with the Tuunterstraat. As said before, this means that the cyclists must cross the road two times to go to the Handelscentrum (and the shops located there). It can also be seen that the cycling infrastructure is neither homogeneous over the whole area nor very well-connected. Cycling paths in and around the study area consist of cycle paths separated from infrastructure for motorised vehicles. One-way cycle paths on both sides of the road are separated from the infrastructure for motorised vehicles, cycle paths that are two-way on one side of the road, and cycling lanes connected to the road on both sides. Furthermore, on the light blue roads in Figure 2.1, there is no cycling path or lane at all, the cyclists share the complete road with the other traffic. This all means that the cycling infrastructure is very disconnected from each other and consists of a lot of different forms of cycling infrastructure (two-way, one-way, separated or not). This all results in cyclists using one-way cycle paths as

two-way cycle paths, just because the alternative (cycle path on the other side of the road) is slower, or they need to cross a busy road just to end up at the same place at the end of the cycle path, which is most of the time a road without cycle paths or lanes at all.

Road characteristics
On both the Europalaan and the Tuunterstraat the maximum speed is 50 km/h, while the V85 (85% of the cars go slower than this and 15% faster) is on both roads 52 km/h and the average speed is 44 km/h, as measured by Basec in 2019. Furthermore, the volume and vehicle composition on both roads were measured. The results of these measurements, together with the intensities on both roads, are added in Appendix A. As can be seen, the Europalaan is most of the time a lot busier (5 times or more) than the Tuunterstraat. One remarkable thing is that on both roads the evening rush hour (16-18h) is almost twice as busy as the morning rush hour (7-9h). On both roads, the vehicle composition is mainly light vehicle traffic

Another characteristic of the intersection is that the traffic on the Europalaan has priority over the traffic from the Tuunterstraat. The cyclists and pedestrians have priority over the other traffic when crossing the Tuunterstraat at the intersection with the Europalaan. While this is not the case when crossing the Europalaan, then the traffic on the Europalaan has priority over the cyclists and pedestrians. This is also the reason cyclists instead of crossing the Europalaan twice to go to the Action/Handelscentrum, the cyclists use the one-way cycle path as a two-way cycle path. This is to not cross the busy road twice, where they also do not have priority, while they do have priority when using the one-way cycle path crossing the Tuunterstraat.

From personal experience and in talks with the traffic engineer of the Municipality, the traffic at the intersection seems to be very diverse. In the evening peak, the traffic consists of commuters coming from the N319 back from work. Visitors of shops in the area, which are located on all sides of the intersection, visitors of shops in the inner city, visitors of the neighbourhoods in the area, children that are done at their high school at 16:15 or people that have an evening shift at work and are going out of the city.

Site visit
During the site visit it became clear that the pattern that was seen in the available data was also the case during the site visit. It became clear that this is also the case for cyclists, during the evening peak there were also around twice as many cyclists. In the evening peak, a lot more cyclists were using the one-way cycle lane as a two-way cycle lane, possibly because crossing the road would take more time since there was more opposing traffic. The Action and other shops also open from 8:30, so when the morning peak is already running towards the end. Furthermore, the secondary school that is nearby opens at 9:00 and closes at 16:15, already in the evening peak, therefore also children from school can be seen in the evening peak.

2.1.3 Requirements

To indicate what the stakeholders want as a result of the solutions a program of requirements is set up, to know on what the solutions should be assessed. The requirements are:

- Visitors of the shops/restaurants and commuters want to be able to cycle safe(r) to their destinations
- Shop/restaurant owners want to be well accessible, so travel times may not increase largely
- Pronova, a secondary school, wants its scholars to be able to come to school safely
- Municipality has a limited budget, solution may not be too expensive

- The Municipality wants to be sustainable, so the impact on the environment should be as low as possible or should have a positive impact

As can be seen, safety, traffic flow, economic and environmental factors are important. At the same time, not always these requirements go along well with each other since it could be the case that one solution makes the situation safer (and maybe faster as well) for cyclists. At the same time, it affects the traffic flow of motorised traffic negatively. These indicators will be further investigated in the literature study, to know what indicators can be used to assess the effects of the solutions.

2.2 Literature study

In the literature, the focus will be on the assessment of the simulation model, which indicators are used in other studies to assess traffic performance measures of effectiveness (MOEs), both for traffic flow and safety? And which traffic flows are compared with each other at which time of the day? Only during peak hours or also during the whole day? Finally, the results incorporated by these factors must be compared with the current situation and the proposed solutions, to discuss trade-offs.

2.2.1 Indicators performance intersection

There are many indicators possible to assess the performance of an intersection. In a paper by Otković et al. (2021), these indicators are split into different categories: Functional, safety, economic, environmental, and spatial-urban criteria. In this Thesis, some indicators in the category functional, indicated in the paper, will be used to assess the throughput. Also, the safety, economic, and environmental effects will be considered in the final evaluation of the performance of the models.

Traffic flow indicators

As said before, many traffic flow indicators exist. According to an article from the US Department of Transportation (2021), travel time, queue length and vehicle delay are the main MOEs to assess traffic flow. These indicators are also used in the paper of Alemdar et al. (2021) and queue length and vehicle delay are also part of the functional criteria 1 in the paper of Otković et al. (2021). According to the US Department of Transportation (2021), travel time is used to assess the traveller's benefits, this can be assessed when travel times for different solutions are compared. Queue length is, according to Otković et al. (2021), “the longest line that appears within the traffic simulation”. And is according to Alemdar et al. (2021), “one of the indicators that best shows the operation quality and condition of the intersection/corridor.” Furthermore, the queue length is important for the Jumbo for example, since their entrance can be blocked if there is a long queue. Vehicle delay is “one of the most important performance indicators used in the evaluation of intersection/corridor design.”, according to Alemdar et al. (2021). Vehicle delay is important for almost all stakeholders since almost all stakeholders are interested in the accessibility of the area.

These factors together make it possible to assess the performance of the intersection in terms of traffic flow, since travel time is used to assess travellers’ benefits. This is the travel time from where cars enter the model to their destination, while these measure points must start before the queues will start. The queue length can indicate possible operation problems of the intersection and vehicle delay is an important indicator of the overall performance of the intersection in terms of traffic flow. The indicators will be assessed for all directions and compared between the models for the same directions, however, cars and trucks will be analysed together since there are not many trucks at all at the intersection. Cyclists will be

analysed separately. It could be the case that one solution is very beneficial for one direction or transport mode, while the other direction is congested completely. Since there is a very limited amount of pedestrians observed, these pedestrians are not taken into account.

Safety indicators

According to Mullakkal-Babu et al. (2017), safety assessment of intersections is always a challenging issue. This is especially the case in a simulation model since no accidents are simulated within the model. However, there do exist some indicators for safety within simulation models.

Some safety indicators are stated in the criteria of the paper by Otković et al. (2021), where the first criterion is speed since this is directly correlated with safety and with that mainly the severity of accidents, according to this paper “The increase in speed from 30 km/h to 50 km/h increases the likelihood of fatal and severe outcomes for pedestrians from the range of 5–22% to the range of 45–85%”. It is assumed that this trend is the same for cyclists. That speed, a good indicator is, is described by an article from the US Department of Transportation (2022), which states that higher speeds lead to a decrease in safety, which is also stated by the Dutch institute SWOV (2023). The SWOV (2023a) states that indicators such as the number of potential conflict points, as described by both Otković et al. (2021) and SWOV (2023b) are good indicators for safety. The SWOV (2023b) also indicates that the impact angle is an important indicator of safety; there are three conflict groups important in this study, which are lateral conflicts (90°), rear-end conflicts (0°) and frontal conflicts (180°), also the amount of opposed traffic is stated as an indicator for safety.

Therefore, three indicators will be used to assess safety, the speed at the intersection, the number of potential conflict points, and the impact angle of these conflict points. The speed is the only factor that is integrated within the Vissim simulation. The speed of cars is the most important factor, since the difference from 50 km/h to 30 km/h leads to 3.5 times fewer deaths for cyclists, but since it is all about the speed difference, also the speed of the cyclists matters a bit. The speed of cars is the most important at the conflict points with the cyclists, thus where the flow of cars and cyclists interfere at the crossings. This can be measured within Vissim with the use of data collection points at these conflict points. The number of these potential conflict points between cars and cyclists and the impact angle attached need to be indicated manually. So, when the term safety is coming up, these three factors combined are meant. These safety indicators are the most important for cyclists (and the Municipality and Pronova) since cyclists are more vulnerable to heavier injuries from accidents than car drivers from hitting a cyclist.

Economic and environmental indicators

Fuel consumption covers both economic and environmental factors, since fuel consumption creates emissions, which affect the climate, furthermore, fuel consumption costs more money for the drivers and has thus economic effects. Vehicle delay can be used to estimate fuel consumption. In a study from Sekhar et al. (2013) the fuel consumption from different vehicles is estimated for the idle time of a vehicle. This is also a factor that can be output from Vissim which is the time a vehicle is not moving. When the average idle time from traffic is multiplied by the fuel consumption per hour, after which this is multiplied by the number of vehicles, the total fuel consumption due to congestion can be estimated. Another important economic indicator is the potential construction cost, this will not be investigated in detail, but a rough estimation will be made, since it is an important factor for the decision-makers, at least in the short term. These factors are the most important for the Municipality itself since it wants to reach its sustainability goals and the construction costs are very important for the budget. Fuel consumption itself as an economic factor is mostly important to the users of the cars itself.

2.2.2 Important traffic flows

In this section the traffic flows for which these indicators need to be measured will be indicated, as well as during which time of the day. In various papers, it became clear that all the traffic flows were considered in the final comparison between the intersections. Also, these traffic flows were measured during the rush hours, since then the capacity of the intersection will be measured, rather than the demand. The effects (such as delay or other indicators that are indicated before) of a high demand relative to the capacity is the most important factor since this reviews whether an intersection is still functioning well during congestion-sensitive times. In the site visit, as discussed earlier, the morning rush hour is a lot less busy than the evening peak, both in motorised traffic and cyclists. Therefore, for the simulation and the assessment of the performance of the solutions, only the evening rush hour is considered.

2.2.3 Evaluation of results

In the end, there will be a lot of results following the simulations. These results from the different solutions need to be compared. The traffic flow indicators are delay (mean delay in seconds), travel time (mean travel time in seconds), and queue length (mean queue length in metres) will be compared per direction per mode of transport (cars+trucks and cyclists separately). This is because in this case, the distribution of delays does matter a lot for the different stakeholders. For safety, the overall results (total speed differences, conflict points, and conflict angles) can be compared, since for safety, the direction does matter less, since every accident is one accident too many, no matter to whom or where on the intersection it happens. The same accounts for the costs and the fuel consumption, only the total matters here. These trade-offs can be compared per factor and in the end, a summary can be given per solution.

2.3 Research objective

The objective of this research is to improve the safety and traffic flow at the intersection of the Europalaan and Tuunterstraat and to assess the effects of the proposed solutions concerning the traffic flows at the intersection of the Europalaan and Tuunterstraat in Winterswijk, as well as the environmental/economic factors.

2.4 Problem statement and research question

The intersection of the Europalaan and Tuunterstraat is not very safe for cyclists since 9 incidents happened during the past 5 years, also there is much delay at the intersection during rush hour. The VVN proposed two possible solutions, but there is a lack of knowledge on the effects of the proposed solutions by the VVN on the traffic flows, safety, environmental, and economic factors.

Since the context of the project is known and the research objective is known, the main research question can be formulated. This is the question that must be answered to complete the research objective. The main research question is:

What are the effects of the solutions proposed by the VVN and the Municipality of Winterswijk for the intersection of the Europalaan and Tuunterstraat in Winterswijk, on traffic flows, safety, environmental and economic effects?

This is the main question since in the end the most important objective is to find the best solution for the intersection, based on all those factors.

3. Research methods

The methodology will consist of three main parts. The first part will be an analysis of the available data and making this data ready to implement in the simulation model Vissim. The second step will be to construct these models with the different proposed solutions, with the data that was made implementable before. The last part will be an evaluation of the model and the results, such as a verification and validation of the model and an analysis of the results to compare the effects of the different solutions. An overview of the methodology can be seen in Figure 3.1.

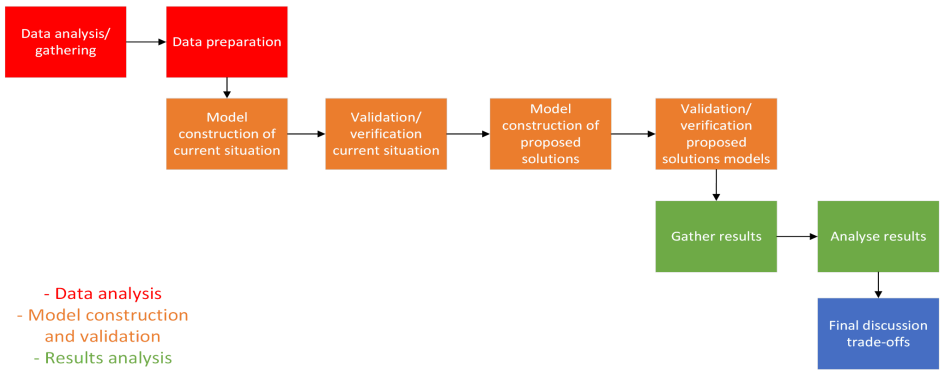


Figure 4.1: Overview of the methodology used in the Bachelor Thesis

3.1 Data analysis/collection and preparation

As can be seen in Figure 3.1, the first two steps are about data analysis and preparation of the data. In Chapter 2 the data that is available is already analysed a bit and therefore the main traffic flows are already indicated, however, this is not enough data to run a simulation model, since the traffic flows of right or left-turning traffic are unknown. Therefore, to run a microsimulation from this intersection, more data is needed. This data should be gathered for both light traffic and heavy traffic as well as for cyclists since there is no data at all about cyclists at this intersection.

The data preparation will consist of calculating the average per direction over the days that are counted, while also the total number of vehicles at a direction must be calculated, as well as the vehicle composition per direction (light vehicles ratio to heavy vehicles), these are the inputs for Vissim once the models are constructed.

3.2 Model construction

After the preparation of the data that is implemented in the model, the model itself is constructed. There are three scenarios made, the current infrastructure situation, the proposed solution by VVN, and the proposed solution by the Municipality of Winterswijk. The model is constructed with the background of the current situation (a picture from Google Maps). In the model, only the directions indicated in the traffic count are considered. Therefore, the traffic coming and going to the Jumbo is not simulated, due to limitations during the data collection.

The reason the current situation is modelled before and then validation and verification is done, instead of first constructing the models for the proposed solutions, is to check if the constructed

model behaves well. If some things must be changed, this is done already, instead of changing this error/problem for all three models in the end, then the other models are constructed without that mistake from the start.

The verification of the model is done in two ways, the first check is the comparison of the input data with the output data, this is done by comparing the number of vehicles that were the input with the number of vehicles generated by Vissim. The second form of verification is face validity, a comparison of the behaviour and traffic flows of the model with the behaviour and traffic flows seen during the traffic count.

The validation is done with two checks. The first check is done with measurements from two other days. The data from these days is implemented in the same way as the other data. The averages of delays are compared between the models per direction for cars and cyclists in percentages. In this way, it could be seen if the model also behaves the same on other days. The last check is the running of extreme condition tests, such as giving all traffic a very low desired speed or changing the mode split to only heavy traffic. In this way, it was tested if the model works the way it is expected since it is expected that there will be a lot of congestion if every vehicle can only drive 5 km/h.

3.3 Results analysis

After the construction of the models, the results of these models are gathered. Since the indicators that are measured are delays and travel times among others, the simulation models are run 10 times, due to the stochastic effect of Vissim (Fries et al., 2017).

The results of the current infrastructure situation are given before a comparison is made. So firstly, the models are evaluated separately, per category. As said before, for the travel time and the delay, this is done per direction, with cyclists and motorised traffic separately. These results are shown in total seconds, while queue length is in metres. As said before, the safety, environmental, and economic factors are not assessed separately per direction or else, but these factors are shown as a total per model. For example, the total number of conflicts between cyclists and other traffic, or the total fuel consumption.

After this the models are compared, this will also be done per category, however rather than using the units per indicator, such as seconds, metres queue, or litres fuel consumption, this is done with percentages after the value in the assigned units, such that it is easily to see which solution performs better on which factor/category.

4. Data collection

This data collection chapter explains the data collection strategy and the results. Furthermore, it points out the limitations of the data collection and describes the input data for the model and the assumptions made.

4.1 Data collection strategy

Figure 4.1: Traffic count directions for motorised traffic (Google Maps, 2024)

In the data collection, the goal was to gather data as input for the model and to know the traffic flows at the intersection. For this data collection, there are only two persons available (myself and another student at the municipality), this led to the limitation that not all possible directions around this intersection can be counted. Therefore, it was decided that the entrance and exit of the Jumbo are not counted. The directions for motorised vehicles that will be counted are indicated in Figure 4.1. The directions A, B, and C are counted directly, while traffic coming from and going to D are recorded by a camera and watched afterwards, since it would be too much for one person to count all the directions. These directions are both origins as destinations. The camera is also mainly used for counting cyclists, since otherwise, the person who counts the cyclists must watch the cyclists for a very long time if they go to the Handelscentrum (D), during that time some other cyclists that have a short route could be missed. The cycle directions are a lot more complicated than the directions for cars since cyclists tend to use one-way cycle paths as two-way cycle paths, therefore different figures are made with all the possible routes for cyclists from each direction. For the numbering of these routes, the standardized numbering in The Netherlands is used, to have a clear method behind the data collection (Wegenwiki, 2021). The routes that are prohibited are shown with red letters in the tables in Appendix B. The cyclists also have more directions due to the additional E direction that is not accessible by cars. Another assumption that is done is that traffic from the Europalaan (West) to the Handelscentrum is not coming from the Tuunterstraat, this assumption is made since it was not able to follow vehicles from the Tuunterstraat to the Handelscentrum, since then other vehicles would be missed, therefore it is assumed that these vehicles are coming from the Europalaan, also because the intensity on the Europalaan is a lot higher.

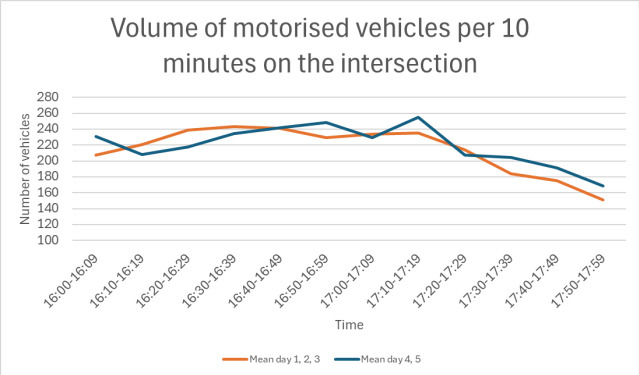
The total amount of traffic flows for motorised traffic that need to be counted is indicated in Table B1 in Appendix B.

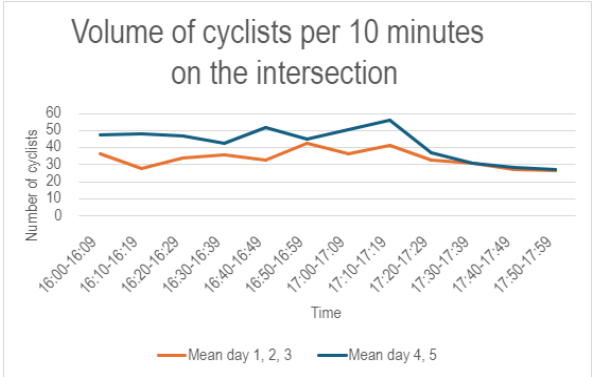
As already mentioned, there are a lot more possible routes for cyclists, these routes are indicated with two different tables, Table B2 was filled in directly during the data collection at the intersection, which can be seen in Appendix B, while the other table is filled in afterwards with the help of the video, which can be seen in Table B3 in Appendix B. If a cyclist comes from the Handelscentrum and goes to the Europalaan (West) then the cyclist is counted during the count at route no. 8, but this is removed afterwards when watching the video. The routes are visualised in Appendix B too.

This traffic count will be done during the evening rush hour (16:00-18:00), since this was observed as the busiest part of the day, both for motorised traffic and cyclists. This will be done for 5 days since three days can then be used for the calibration of the model, while the 2 other days can be used for the validation of the model.

4.2 Data collection results

Starting with the results of the data collection for motorised traffic. In the data collection of Basec, it was seen that the afternoon traffic volume peaked from 16:00 to 17:00 and decreased after that. In Figures 4.2 and 4.3 the average volume over days 1, 2 and 3 of motorised vehicles and cyclists is calculated for each 10 minutes from 16:00 and 18:00, the same is done for days 4 and 5. These values are points, but the points are drawn into a line to be able to make a better comparison. It can be seen that the traffic volume of motorised vehicles also peaked from 16:00 till 17:00 and decreased after 17:00, the same as in the data collection of Basec. The peak during days 4 and 5 was a bit higher and later on the day than during days 1, 2 and 3. For cyclists, no data is available, but in Figure 4.3 it can be seen that the number of cyclists does not have such a clear peak volume as the motorised traffic. The number of cyclists itself is also a lot less than the number of cars. Furthermore, it can be seen that there were around 1.5 times more cyclists on days 4 and 5. Which is mainly due to the weather circumstances. During days 4 and 5 it was sunny, while during day 1 it was raining a bit, which could lead to fewer cyclists.

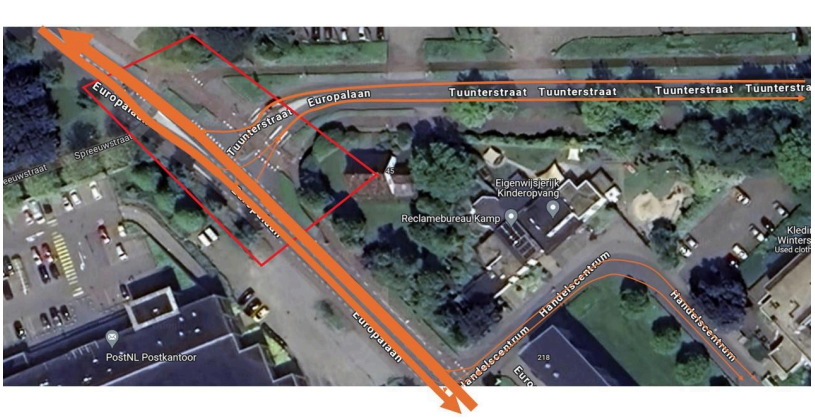


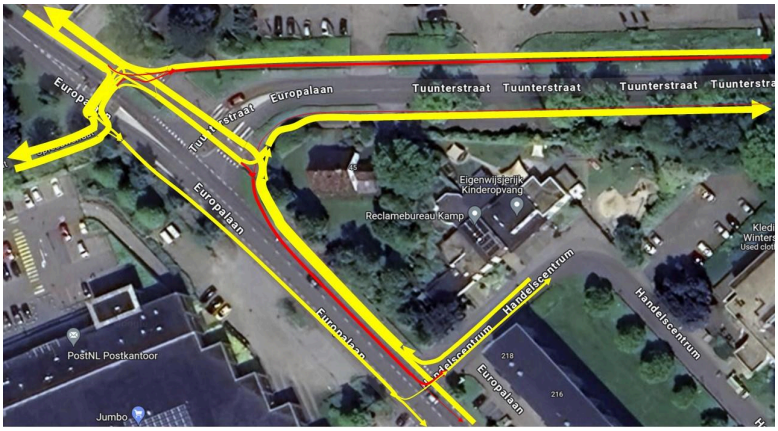


Figures 4.2 and 4.3: Total number of motorised vehicles and cyclists at the intersection

Another important aspect of the data collection is the origin and destination of the traffic and therefore the route choice. The traffic flow at the intersection for motorised vehicles is shown in Figure 4.3, where the thickness of the lines displays the traffic volume, in Figure 4.4 the same is done for the traffic flows of cyclists. The thickness of the lines represents the relative volumes of motorised vehicles and cyclists and therefore the thickness of the lines for motorised traffic can not be compared with the thickness of the lines for cyclists, since then the lines for cyclists would not be very well visible. In Figure 4.3 it can be seen that most of the motorised traffic originates from the Europalaan (East) and the destination of most of the traffic is Europalaan(West), so by far most of the traffic is travelling from one side of the Europalaan to the other. Furthermore, more traffic is driving on the Tuunterstraat than on the Handelscentrum, but it is far less than on the Europalaan. A more detailed insight into the origin, destination, and route choice of motorised traffic is given in Appendix C. Also a more detailed route choice is given in Appendix C per direction per 10 minutes, instead of only 2-hour averages. In Figure 4.4 it can be seen that there is a significant amount of cyclists that are cycling against the direction, represented with the red lines, instead of the legal yellow routes. Furthermore, most of the cyclists are seen at the Europalaan(West) and Jumbo, but also cyclists from the Europalaan(East) and cyclists to the Tuunterstraat make up a large share of the total volume of

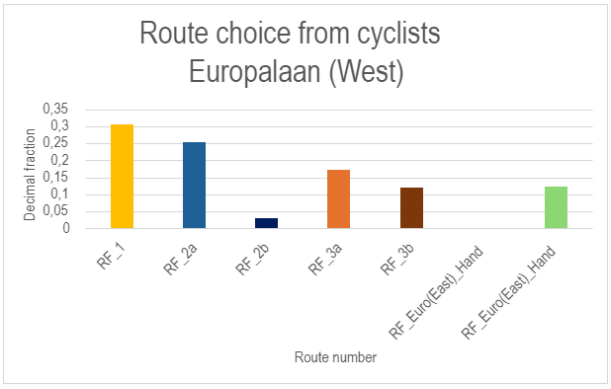
cyclists. Because the number of cyclists at the intersection does not follow a clear pattern over time and the amount is far less compared to the number of cars, no route choices are provided per 10 minutes, also because there are a lot of routes, showing averages per 10 minutes would not give a readable graph.





Figures 4.3 and 4.4: Traffic flow volumes of motorised vehicles and cyclists at the intersection during the afternoon peak

Instead of route choices from cyclists from all directions per 10 minutes, route choices from the sum of 2 hours are presented to give a more detailed (quantitative) insight into the traffic flows from cyclists. An example of such a graph can be seen in Figure 4.5, where besides the graph a picture is shown with the numbers of the routes corresponding to the route numbers in the graph. Route choices from all directions are shown in Appendix D, as well as the origin and destinations of cyclists. In Figure 4.5 the routes are represented, where the decimal fraction is the share of that route of the total volume of cyclists from the origin that is stated in the title (in this case the Europaal (West)). It can be seen that most of the cyclists that are coming from the Europalaan(West) are heading towards the Jumbo (Spreeuwstraat), but also a quarter of them are going to the Europalaan(East). Overall the origin of the cyclists is spread along all directions, however, most of them come from the Europalaan(West). This is also the destination for most cyclists, however, a lot of cyclists go to the Jumbo and the Tuunterstraat.



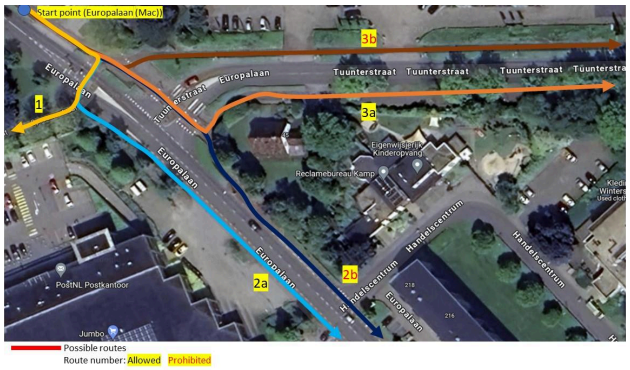
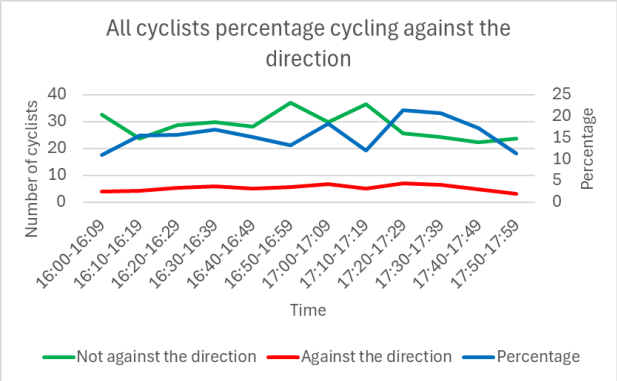
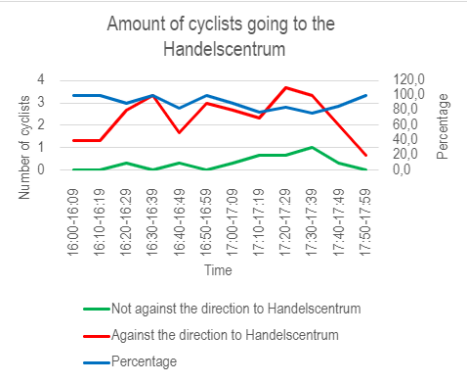


Figure 4.5: Route choice from cyclists that are coming from the Europalaan (West)

One of the main safety concerns, as discussed before, is cyclists who are using the one-way cycle path as a two-way cycle path, both on the Tuunterstraat and the Europalaan to the

Handelscentrum. In Figures 4.6 and 4.7 the amount of cyclists that are cycling against the direction is shown, as well as the percentage, the amount of cyclists is the average number of cyclists from 16:00 till 18:00 during days 1, 2 and 3.





Figures 4.6 and 4.7: Percentage of all cyclists that are cycling against the direction and percentage of cyclists that cycle against the direction to the Handelscentrum

In Figure 4.6 it can be seen that of all cyclists that are cycling at the intersection, about 10 to 20 percent are cycling against the direction, including the cyclists that are cycling from the Jumbo to the Europalaan(West), which only consists of two-way cycle paths. In Figure 4.7 it can be seen that the percentage of cyclists who are cycling against the direction to the Handelscentrum is 80 to 100 percent. This shows clearly that almost none of the cyclists followed the legal route. Furthermore, only some cyclists from the Jumbo to the Handelscentrum followed the legal route. The percentage of cyclists cycling against the direction to and from the Tuunterstraat is 10 to 40 and 0 to 30 percent, as shown in Appendix D. This is also a significant number of cyclists and can also be seen in Figure 4.4, where the red lines represent the cyclists going against the direction. This behaviour of cyclists is something to take into account in the final considerations and recommendations.

4.3 Data collection conclusions and limitations

From the data collection, it became clear that most of the motorised traffic is going straight on the Europalaan and the peak volume is from 16:00 to 17:00. The number of cyclists does not seem to follow a clear deviated pattern from a straight line and is more sensitive to the weather circumstances.

Another major conclusion is that there are indeed a lot of cyclists using one-way cycle paths in the area as two-way cycle paths, especially to the Handelscentrum. This also leads to more conflict points with cars and affects the traffic flow, since vehicles turning left (or right) have to look out more, which causes longer delays, as seen during the count.

The data collection also had some limitations, the main limitation was that some traffic flows could not be measured because only two persons were available for the count. Therefore, traffic from and to the Jumbo could not be counted as well as traffic from the Tuunterstraat to the Handelscentrum. This could lead to fewer delays in the model than is seen in reality. Another limitation is that mainly cyclists tend to cycle unique routes, such as crossing the street at a point where no crossing is provided. This does not happen every 10 minutes but does occur a few times during the afternoon peak. These routes are not counted, since it would give a whole set of unique routes that are only cycled incidentally.

5. Current situation model

5.1 Overview model and input data

For the simulation of traffic flows three things are demanded. The first thing is the total traffic volume at the start of each link, so for the normal roads this is the cars and trucks combined, while for the cycle paths, this is the number of cyclists. These volumes are put in the model for each 10 minutes of the afternoon peak. However, the data has to be put into Vissim as averages per hour, for every 10 minutes. The intensities that are calculated for the current situation model can be seen in Appendix E. Another thing that is needed to simulate the traffic flows is the mode split on each link, per 10 minutes, this is the share of cars compared to the share of trucks for motorised vehicles, while cyclists have always a share of 100%, since no other traffic modes are counted on the cycle paths. These shares have values from 0 to 1 and differ per 10 minutes per link. These mode splits can also be seen in Appendix E. Last but not least the route choices need to be calculated, which are implemented in the model with static routes. For motorised traffic, the route choices can be seen in Table 5.1. The directions in this table correspond with the directions in Figure 5.1, which is an overview of the current situation model in Vissim. The route choices from cyclists can be seen in Appendix E as well and correspond with the route choice graph in Appendix D.

Table 5.1: Route choice motorised traffic

Routes	Decimal fraction
AB	0,729
AC	0,165
AD	0,106
BA	0,866
BC	0,104
BD	0,028
CA	0,739
CB	0,261
DA	0,814
DB	0,1855

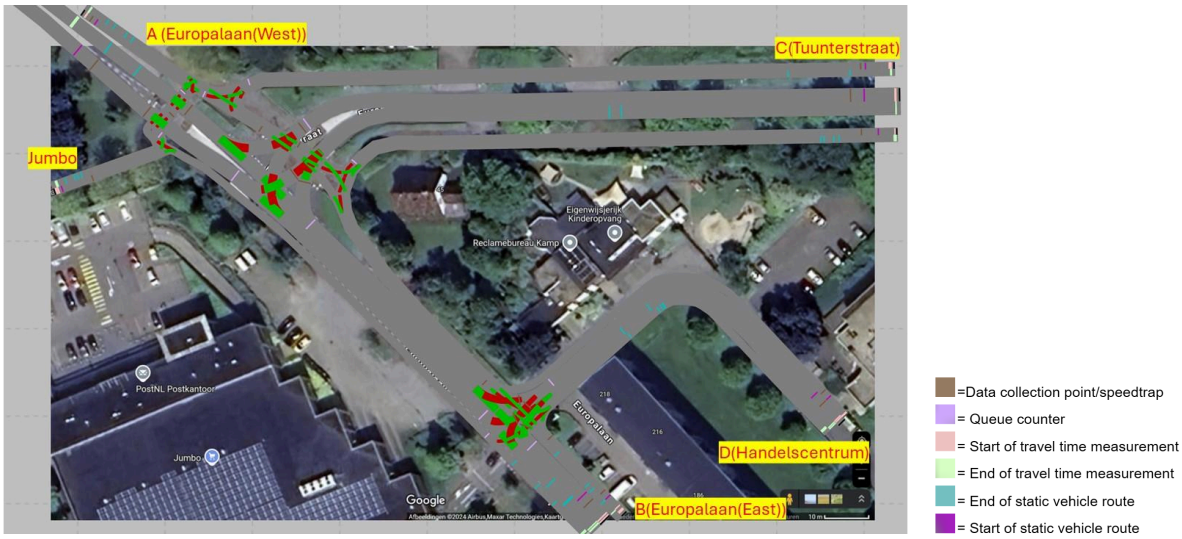
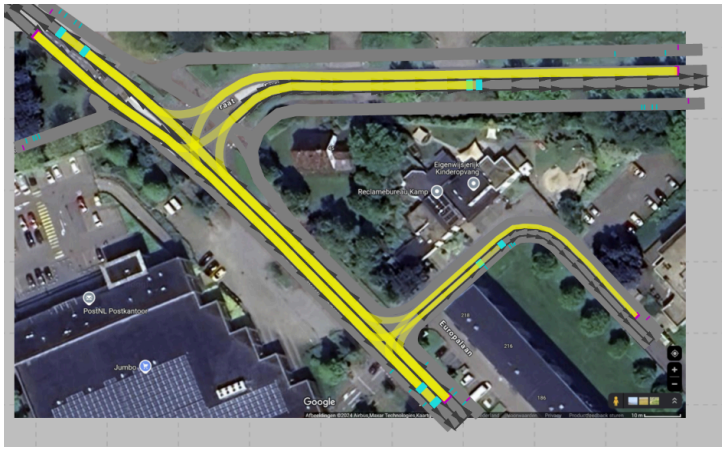


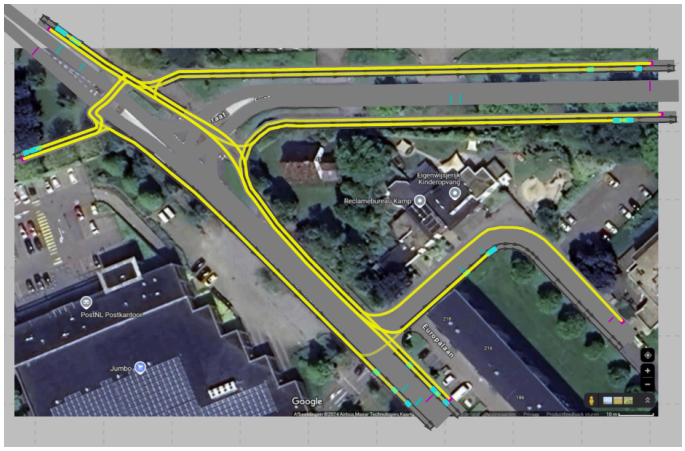
Figure 5.1: Current infrastructure situation model in Vissim

In Figure 5.1, the current infrastructure situation is shown in Vissim. The legend shows the functions of the data points in the model. These points collect data and define the vehicle routes. In the model, the road width on the Europalaan and Tuunterstraat is 3.0 metres, while the road at the Handelscentrum is 2 metres since this road is shared with cyclists. The cycle paths/lanes in the area are 1.5 metres, which is slightly smaller than in reality, however, because cyclists are cycling against the direction, one-way cycle paths have to be put into Vissim as two-way cycle paths, to let cyclists cycle against the direction. This makes the total width slightly larger than in reality, but this will not have a large impact.

Another road characteristic is the priority rules. As said before, the traffic on the Europalaan has priority over the traffic from the Handelscentrum and Tuunterstraat. One difference that is made is that the cyclists that are cycling against the direction to the Handelscentrum have been given priority over the motorised traffic from the Handelscentrum, this would not be the case by law, since traffic that drives against the direction would never have priority, but in reality during the data collection, it was observed that the cyclists were almost always given priority by cars.

Desired speeds are also important in the settings of the model. In the data collection from Basec in 2019, as discussed earlier, it was seen that the mean speed on the Europalaan was 44 km/h since the speed regulations on the other roads are the same as on the Europalaan, this is adopted for all the roads. Since Vissim overestimates the speed (setting 50 km/h as the desired speed would give a mean speed of >50 km/h), it is chosen that the desired speed is set to 40 km/h, since this would result in an average speed of around 44 km/h. The desired speed for cyclists is set to 15 km/h since the mean speed of cyclists is around 17 km/h (Boer, 2022).





Figures 5.2 and 5.3: Static routes motorised traffic and cyclists

In Figures 5.2 and 5.3 the static routes that are implemented in Vissim are shown. Here it can be seen that the cyclists use the one-way cycle paths besides the Tuunterstraat and from the Europalaan to the Handelscentrum are used as two-way cycle paths.

5.2 Results

As said earlier, the model is run 10 times to obtain the results. These results are then translated into tables with mean and peak travel times and delays for each route travelled, for motorised vehicles and cyclists. These results are shown later when the comparison with the other models is made, so these results can be seen in Chapter 6.2.

In this section, only the delays, queue lengths and fuel consumption are discussed, since travel time on itself is not interesting since the distance between routes is different and therefore a larger travel time could also be the cause of a longer route. This is helpful in the comparison with the solutions. In the discussion of all the results, the mean of an indicator (travel time, delay, queue length and speed) is the total average over the average per 10 minutes per run. The peak delay and travel time are the highest values of all these 10-minute averages in all 10 runs. The maximum queue length is the maximum queue length that is ever seen during these

10 runs. It could be seen in the results that the mean delays are not very high, both for motorised vehicles and cyclists, however, there do occur some spikes in these delays, for example, the maximum delay for motorised traffic was 35 seconds, for cars travelling from the Tuunterstraat to the Europalaan (West), which have to make a left turn. The traffic that has to turn left at the intersection is also the traffic with the highest delays. The cyclists with the highest delays are the cyclists that have to cross the Europalaan at the cyclists' crossing since the cyclists do not have priority there.

The mean and max queue lengths can be seen in Tables 5.4 and 5.5 for motorised vehicles and cyclists. The names and places of these queues can be seen in Appendix F. As can be seen, the mean queue lengths are very short, only the queue at the left turn from the Europalaan(West) to the Tuunterstraat is 2 metres on average, while also the maximum queue length there is 150 metres. Another queue that stands out is the queue at the left turn from the Europalaan(West) to the Handelscentrum. Cyclists are rarely standing in a queue, so the mean queue length is very short, while the max queue length consists of around 10 cyclists max.

Table 5.4 and 5.5: Mean and max queue length motorised vehicles and cyclists

Motorised vehicles	Mean queue lenght (m)	Queue lenght max (m)
A_BCD	2,0	150,6
B_AC	0,0	11,6
C_AB	0,1	27,3
B_ACD	0,0	28,0
A_BD	0,5	86,9
D_AB	0,0	16,9
Sum	2,6	321,3

Cyclists	Mean queue lenght (m)	Queue lenght max (m)
Jumbo	0,0	0,0
Europalaan(West_	0,1	20,8
Europalaan(West)_Tuunt(Wrong)	0,4	24,7
Tuunt(Wrong)	0,0	2,9
Tuunt	0,0	0,0
Europalaan_Handelscentrum	0,0	0,0
Sum	0,5	48,3

The fuel consumption is calculated for each route, this is the idle time of a vehicle, which is calculated by Vissim, multiplied by the idle fuel consumption, which is around 0.5 litres per hour (Park+, 2020). This is calculated for the total duration of the simulation, which is two hours. The (idle) fuel consumption for the current situation is 2.25 litres per 2 hours. So this is the total use of fuel of vehicles that are idle (stationary) A breakdown of these calculations, based on the idle time and the average number of vehicles is shown in Appendix F.

5.3 Verification and validation

Now the model is constructed, and the results are known, the model should be verified and validated to be sure that the model works as expected. First, the verification will be done with a check from input compared to the output data and with face validity, to see if the model behaves the same as in reality. In the validation the model will be simulated with the data from days 4 and 5 and extreme scenario tests will be performed.

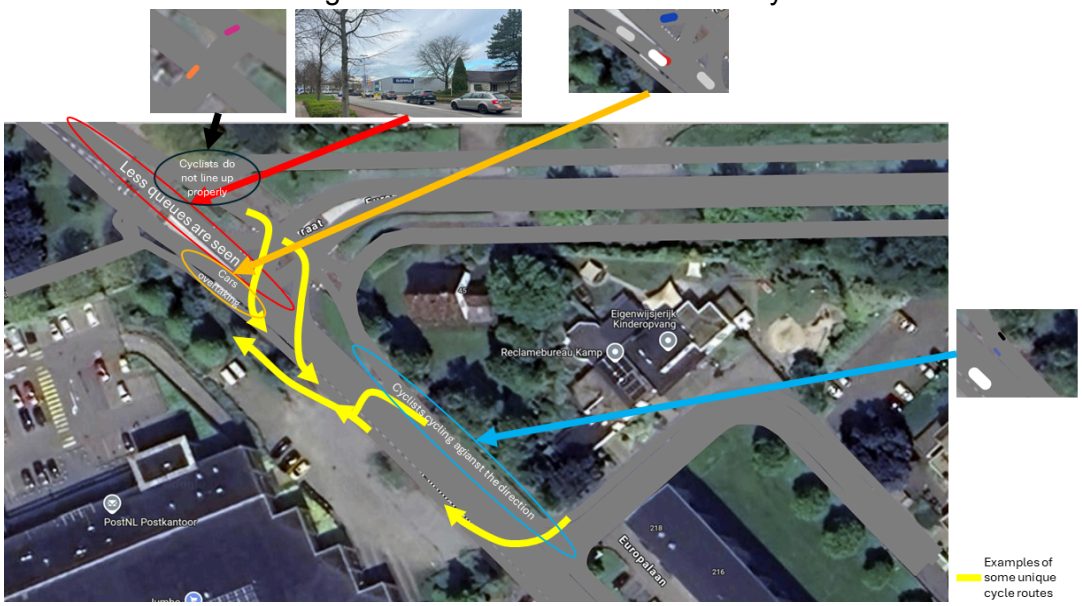
5.3.1 Verification

In Table F2 in Appendix F the first step of the verification can be seen, the verification of the number of vehicles and cyclists generated compared to the data counted. It can be seen that for motorised vehicles the model generates slightly more vehicles, while for cyclists the model generates slightly fewer cyclists, but also no major differences are seen. It is also tested if the vehicles that are generated are following the correct assigned routes and if these route choices are in the same ratio. This can be seen in Appendix F. It can be seen that for cars the route choices are well-defined, but the most concern is about the cyclists' route choices since these were sometimes not well incorporated in other models. In this model, the route choices for cyclists are well incorporated and most of the ratios are still the same.

The second step in the verification of the model is face validity. In this step, the operational phase of the model is compared with the reality observed during the data collection, to see if the

model represents reality well. This comparison is also shown visually in Figure 5.4. In the model, there occurs somewhat less congestion at the Europalaan because the left turn to the entrance of the Jumbo is not modelled, which was a result of the limitation of persons in the data collection. Furthermore, the queues occur at the same places, at the left turns to the Tuunterstraat and Handelscentrum and the Tuunterstraat. The only difference is that there, again, is no queue at the left turn to the Jumbo, for the same reasons. Another thing that is modelled is that the cyclists are cycling against the direction, as observed during the data collection. One minor flaw in the model is that cars are going partly through each other at the left turn at the Europalaan to the Tuunterstraat. This error did not occur on purpose, but in reality, cars are overtaking the waiting cars on some occasions, using the cycle path, therefore this error is partly also realistic, since cars would overtake the waiting cars there sometimes. Another thing that is not seen in the model is that cars give way to cyclists to cross the Europalaan even though the cyclists do not have priority, this is not modelled, which leads to fewer queues/delays at the crossing. Another minor flaw is that cyclists will line up behind each other in front of a crossing instead of beside each other, this will lead to somewhat larger delays, especially if one cyclist can cross the road and one cannot, since in reality both cyclists can cross the road at the same time. Last but not least some cyclists are cycling unique routes in reality, such as crossing the Europalaan in a lot of different places, these are not incorporated in the model as well, but do not have a large effect on the traffic flow since these cyclists will wait until there are no cars on the road and the road is safe to cross.

Figure 5.4: Visualisation Face validity



5.3.2 Validation

To see if the model is a good representation of reality and the model behaves well, also validation is done. The first step of the validation data from days 4 and 5 of the data collection is implemented in Vissim in the same way the data from days 1, 2 and 3 is implemented. This data can be seen in Appendix F. As seen earlier in the data collection Chapter, the traffic flows and volumes on days 4 and 5 were a bit different from during days 1, 2 and 3, therefore this validation step is done to check whether the obtained results and the effects/conclusions are not only true for the dataset from days 1, 2 and 3, but that it is more generalizable.

Table 5.7 and 5.8: Travel time and delay motorised vehicles and cyclists

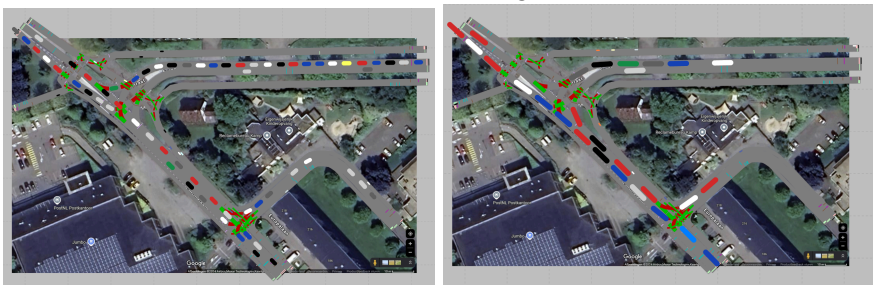
Motorised vehicles	Mean travel time (s)	Travel time peak (s)	Mean delay (s)	Peak delay (s)
Europalaan (West) to Europalaan (East) (AB)	30,4 (117%)	52,6 (121%)	6,1 (167%)	28,4 (136%)
Europalaan (West) to Handelscentrum (AD)	46,3 (113%)	82,3 (148%)	9,1 (164%)	45,2 (235%)
Europalaan (West) to Tuunterstraat (AC)	44,7 (114%)	69,6 (120%)	12,2 (151%)	37,1 (141%)
Tuunterstraat to Europalaan (West) (CA)	24,3 (97%)	34,1 (103%)	4,4 (132%)	14,5 (129%)
Tuunterstraat to Europalaan(East) (CB)	37,2 (99%)	60,7 (94%)	11,0 (116%)	36,0 (101%)
Europalaan(East) to Handelscentrum (BD)	18,6 (100%)	24,6 (108%)	0,3 (94%)	5,7 (110%)
Europalaan(East) to Tuunterstraat (BC)	26,7 (99%)	28,8 (92%)	1,0 (110%)	2,7 (60%)
Europalaan(East) to Europalaan(West) (BA)	15,1 (101%)	16,6 (105%)	0,7 (108%)	2,3 (136%)
Difference in total (%)	243,3 (87%)	369,2 (94%)	44,8 (115%)	171,8 (115%)

>140%
120-140%
80-120%
60-80%
<60%

Cyclists	Mean travel time (s)	Travel time peak (s)	Mean delay (s)	Peak Delay (s)
Jumbo to Europalaan(East) (10a)	32,5 (101%)	37,1 (99%)	0,0 (107%)	0,5 (79%)
Jumbo to Handelscentrum	49,6 (97%)	70,4 (103%)	2,4 (61%)	18,2 (139%)
Jumbo to Tuunterstraat (11a)	48,0 (101%)	62,7 (103%)	3,8 (111%)	16,2 (82%)
Jumbo to Tuunterstraat(wrong) (11b)	36,4 (101%)	55,4 (117%)	3,8 (111%)	24,7 (151%)
Jumbo_Europalaan(West) (12)	18,2 (99%)	31,8 (99%)	3,6 (98%)	17,0 (110%)
Europalaan(West) to Jumbo (1)	19,3 (103%)	32,5 (95%)	3,9 (116%)	17,7 (90%)
Europalaan(West) to Europalaan(East) (2a)	40,9 (100%)	52,2 (91%)	3,3 (102%)	10,5 (59%)
Europalaan(West) to Tuunterstraat (3a)	41,2 (101%)	47,8 (97%)	0,3 (126%)	5,5 (126%)
Europalaan(West) to Tuunt(wrong) (3b)	39,5 (99%)	46,5 (97%)	0,2 (157%)	4,0 (121%)
Europalaan(West) to Handelscentrum	47,0 (100%)	54,1 (96%)	0,4 (168%)	8,0 (223%)
Europalaan(East) to Tuunterstraat (7a)	46,8 (99%)	54,0 (100%)	0,0 (43%)	0,9 (17%)
Europalaan(East) to Europalaan(West) (8)	34,8 (100%)	43,7 (83%)	0,2 (85%)	7,2 (98%)
Europalaan(East) to Jumbo (9)	43,2 (100%)	59,2 (102%)	4,4 (97%)	21,0 (92%)
Handelscentrum to Tuunterstraat	59,7 (100%)	68,7 (100%)	0,1 (283%)	6,9 (346%)
Handelscentrum to Europalaan(West)	48,3 (101%)	63,4 (101%)	0,3 (355%)	19,7 (256%)
Handelscentrum to Jumbo	57,1 (103%)	103,0 (149%)	6,0 (140%)	43,6 (246%)
Tuunterstraat to Handelscentrum	70,9 (101%)	84,7 (105%)	0,5 (90%)	6,6 (130%)
Tuunterstraat to Europalaan(West) (4)	38,8 (100%)	45,2 (99%)	0,0 (38%)	2,3 (45%)
Tuunterstraat to Jumbo (5)	47,3 (101%)	59,4 (104%)	4,4 (117%)	17,6 (135%)
Tuunterstraat to Europalaan(East) (6a)	69,7 (200%)	105,7 (112%)	5,2 (100%)	40,0 (181%)
Tuunterstraat(Wrong) to Handelscentrum	61,6 (101%)	73,1 (103%)	1,4 (218%)	9,6 (93%)
Tuunt to Europalaan(East_wrong) (6b)	58,3 (100%)	67,2 (95%)	0,1 (34%)	1,7 (43%)
Sum of all cyclists flows	1009,4 (100%)	1317,8 (103%)	44,2 (107%)	299,4 (127%)

In Table 5.7, the results can be seen from the model of days 4 and 5 for motorised traffic. This displays a comparison between days 4 and 5 with days 1, 2 and 3, where the first value in each cell is the time in seconds, while the second value is a percentage, this is the percentage increase (>100%) or decrease (<100%) compared to the model with the data from days 1, 2 and 3. These travel times and delays are compared to see if the model also behaves well on other days. The cells are coloured according to the colour scheme in Table 5.7, this colour scheme applies to all other tables in this report too. It can be seen that there was more delay in the validation model. This could be explained by the fact that there were slightly more vehicles during the peak than during the first three days. There were also a lot more cyclists during days 4 and 5, which also led to more delays for cars that were coming from and going to the Tuunterstraat since the motorised vehicles needed to give way for cyclists at the crossing. In Table 5.8 the travel time and delay results for cyclists can be seen. It can be seen that also cyclists have more delays and slightly longer travel times. The high percentages of the delays can be explained by the fact that these delays were very small. Furthermore, in Tables F5 and F6 in Appendix F, the mean and peak queue lengths are compared. The queue lengths also became somewhat longer on average, but no large differences were seen.

The second step of validation is performing extreme condition tests. This is to test extreme conditions in which the effect is obvious and to test if the model works as intended. The first extreme condition test is to give all vehicles a desired speed of 5 km/h, while the second test is to generate only trucks, instead of cars. The expected result of both of these tests is a completely congested intersection. The results of these tests can be seen in Appendix F. The travel times and delays were all longer, sometimes even up to 100 times longer. The simulation generated also fewer vehicles since it was not able to generate all the vehicles



Figures 5.5 and 5.6: Extreme condition tests desired speed of 5 km/h and all vehicles are trucks

6. Proposed solution models

Now the traffic flows in the current situation are modelled and analysed, models can be made for the proposed solutions to be able to compare the effects of the solutions with the current situation. In this Chapter these models are introduced, verified and validated and the results of these models will be compared with the current situation.

6.1 Overview models

Starting with the proposed solutions by VVN. This solution is already explained in the introduction and can be seen in Figure 6.1. A passage for cyclists will be created at the Tuunterstraat and the cycling path along the Tuunterstraat will become a two-way cycle path. The cycling paths crossing the Europalaan will be connected to the two-way cycle path with an angle of 90 degrees. The desired speeds and priority rules are still the same as in the current situation model. At the Handelscentrum the new intersection will have equal priorities. The new cycle crossing of the Tuunterstraat will be regulated the same as the already existing cycling crossing at the Europalaan.

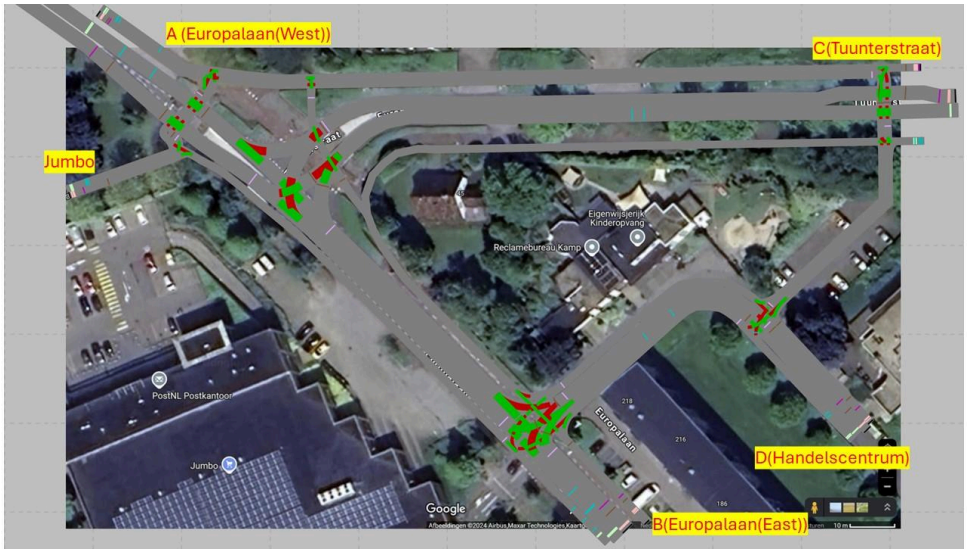


Figure 6.1: VVN solution model in Vissim

Some other assumptions are made in this model, the resulting input (only shown when there are changes compared to the current situation input) for the Vissim model can be found in Appendix H. The first assumption is that there is no change in the input for motorised traffic since there is no change in their infrastructure. The infrastructure for cyclists does change, therefore also some routes and inputs do change. The first important assumption is that cyclists are not cycling against the direction anymore. It could be argued that this would be the case since cyclists have to travel further when cyclists are following the legal (new) route. Cyclists who were cycling already against the direction on the Tuunterstraat are therefore added to the legal side of the Tuunterstraat. The cyclists that were cycling against the direction to the Tuunterstraat are expected to continue this route since it is now facilitated with the two-way cycle path north of the Tuunterstraat. The last assumption is that cyclists will follow the shortest route, so, for example, cyclists from the Europalaan (East) to the Tuunterstraat will cycle via the Handelscentrum.

The model of the proposed solution by the Municipality of Winterswijk can be seen in Figure 6.2. In this solution, the current entrance of the Handelscentrum is closed off for motorised traffic and

the new passage on the Tuunterstraat is accessible for both motorised traffic and cyclists. Furthermore, the cycle path along the Europalaan to the Handelscentrum (and further) is transformed into a two-way cycle path. The cycle path along the other side of the Europalaan is therefore removed. The desired speeds in this model are still the same, while the priority rules are the same, but the new intersection at the Handelscentrum is an equal priority intersection, while the new intersection on the Tuunterstraat gives priority to traffic on the Tuunterstraat.

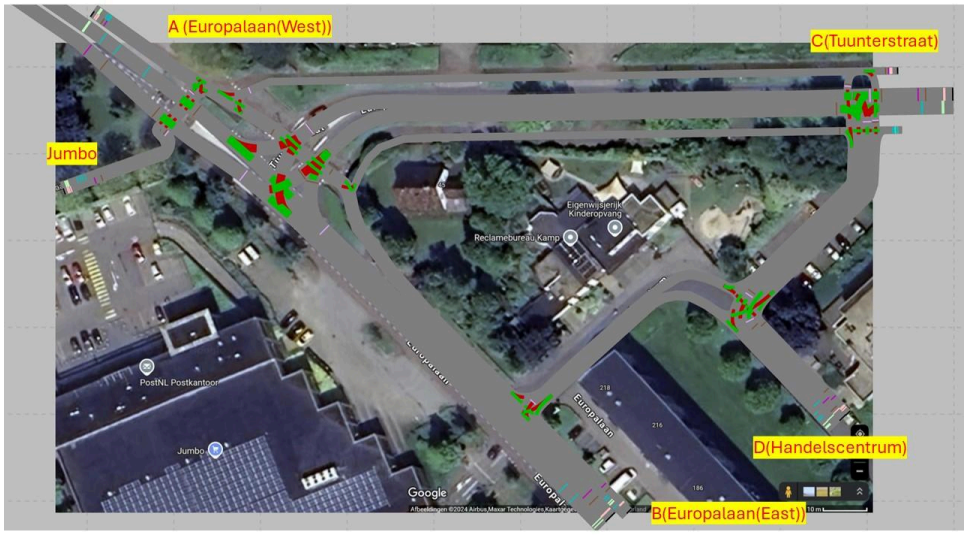
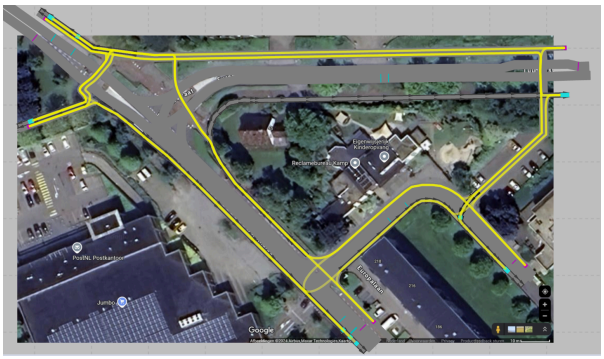
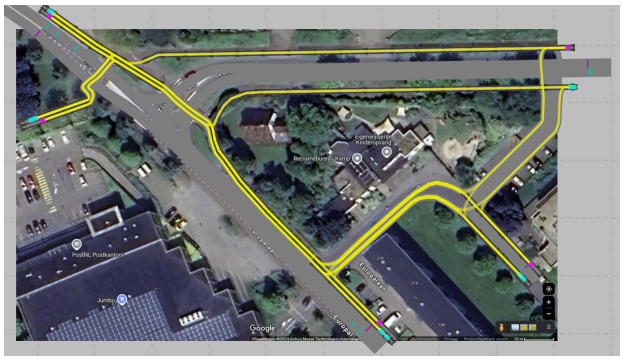


Figure 6.2: Municipality solution model in Vissim

Also, some assumptions are made again for the input of the model, these inputs can be seen in Appendix I. It is assumed that motorised traffic from B to D and vice versa are expected to take the entrance of the Handelscentrum in the south of the area since this is shorter than the entrance on the Tuunterstraat and is therefore not considered in the model anymore. Motorised traffic from A to D and vice versa are expected to drive via the new intersection on the Tuunterstraat. For cyclists the same assumptions apply as for the VVN model, cyclists are expected to not cycle against the direction anymore, while this is sometimes debatable, and follow the shortest routes available. The static routes for cyclists of both models can be seen in Figures 6.3 and 6.4. The assumptions explained before can be seen in these figures, cyclists are not cycling against the direction anymore and the shortest routes are cycled, this incorporates for example the new passage for cyclists is also used to cycle from the Tuunterstraat to the Europalaan(East).





Figures 6.3 and 6.4: Static routes cyclists proposed solution VVN and Municipality of Winterswijk

6.2 Comparison results proposed solutions with the current infrastructure situation

The results of these models will be compared with the current situation to see what the effects of the solutions are on the traffic flows. The comparison of these results can be seen in Tables 6.1, 6.2 and 6.3, where the travel times and delays can be seen for motorised traffic and cyclists, and a comparison of the legal routes compared to the illegal routes cycled in the current situation. The first column, without colours, displays the results of the current infrastructure situation, whereas the second column is for the results from the VVN solution and the third column is for the results from the Municipality solution. The colours are divided into the same colour scheme as seen before in Chapter 5.3.2. The sum of traffic flows, the last row, represents a comparison between the sum of the routes that both scenarios have in common, to have a fair comparison. This results in solutions that have a smaller total amount of seconds, but a percentage increase.

Tables 6.1, 6.2 and 6.3: Comparison of all scenarios of travel times and delays of motorised vehicles and cyclists + comparison of legal with illegal routes

Motorised vehicles	Mean travel time (s)	Mean travel time VVN (s)	Mean travel time Mun. (s)	Travel time peak (s)	Travel time peak VVN (s)	Travel time peak Mun. (s)	Mean delay (s)	Mean delay VVN (s)	Mean delay Mun. (s)	Peak delay (s)	Peak delay VVN (s)	Peak delay Mun. (s)
Europalaan (West) to Europalaan (East) (AB)	26,7	26,0 (98%)	28,4 (107%)	44,5	43,3 (97%)	43,5 (98%)	3,8	3,7 (96%)	4,4 (115%)	21,6	20,8 (96%)	19,4 (90%)
Europalaan (West) to Handelscentrum (AD)	41,6	40,9 (98%)	58,1 (140%)	58,8	55,7 (95%)	77,7 (132%)	5,8	5,5 (95%)	9,5 (162%)	20,7	19,2 (93%)	29,2 (141%)
Europalaan (West) to Tuunterstraat (AC)	39,4	39,3 (100%)	41,7 (106%)	58,0	57,7 (100%)	63,8 (110%)	8,5	8,1 (95%)	8,6 (100%)	26,8	26,3 (98%)	30,3 (113%)
Tuunterstraat to Europalaan (West) (CA)	23,6	25,0 (106%)	25,8 (109%)	28,7	33,0 (115%)	38,9 (136%)	3,7	3,4 (92%)	5,0 (135%)	8,8	11,2 (128%)	18,3 (209%)
Tuunterstraat to Europalaan(East) (CB)	35,8	37,5 (105%)	37,8 (106%)	54,8	64,7 (118%)	72,4 (132%)	9,5	9,5 (100%)	10,7 (112%)	27,8	35,7 (128%)	45,1 (162%)
Europalaan(East) to Handelscentrum (BD)	18,6	18,5 (100%)		22,7	22,8 (100%)		0,3	0,3 (105%)		4,1	5,2 (126%)	
Europalaan(East) to Tuunterstraat (BC)	26,6	27,1 (102%)	26,9 (101%)	29,6	31,2 (105%)	28,6 (96%)	0,9	0,9 (101%)	0,5 (59%)	3,5	4,5 (129%)	1,9 (55%)
Europalaan(East) to Europalaan(West) (BA)	15,0	14,9 (99%)	14,4 (96%)	16,1	15,9 (99%)	14,4 (89%)	0,7	0,7 (104%)	0,3 (48%)	1,8	1,7 (94%)	1,6 (88%)
Handelscentrum to Europalaan(West) (DA)	28,1	27,7 (98%)	43,2 (154%)	33,0	32,0 (97%)	53,1 (161%)	2,4	2,0 (86%)	6,1 (257%)	7,0	6,1 (87%)	15,9 (228%)
Handelscentrum to Europalaan(East) (DB)	23,4	23,4 (100%)		39,9	38,5 (97%)		4,8	4,8 (102%)		21,0	19,3 (92%)	
Sum of all same traffic flows	278,7	280,3 (101%)	276,3 (117%)	386,1	372,0 (102%)	392,3 (121%)	40,4	39,0 (96%)	45,0 (127%)	143,0	149,8 (104%)	161,7 (137%)

Cyclists	Mean travel time (s)	Mean travel time VVN (s)	Mean travel time Mun. (s)	Travel time peak (s)	Travel time peak VVN (s)	Travel time peak Mun. (s)	Mean delay (s)	Mean delay VVN (s)	Mean delay Mun. (s)	Peak Delay (s)	Peak Delay VVN (s)	Peak Delay Mun. (s)
Jumbo to Europalaan(East) (10a)	32,2	31,7 (98%)	40,3 (125%)	37,6	37,0 (98%)	55,5 (148%)	0,0	0,0 (69%)	3,3 (14433%)	0,7	0,7 (111%)	19,5 (2990%)
Jumbo to Handelscentrum	51,3	49,6 (97%)	55,2 (108%)	68,7	69,5 (101%)	67,1 (98%)	3,9	3,7 (96%)	3,9 (102%)	13,1	17,5 (134%)	16,6 (127%)
Jumbo to Tuunterstraat (11a)	47,7	49,8 (104%)	48,7 (102%)	60,7	66,4 (109%)	64,6 (106%)	3,4	3,8 (112%)	3,8 (111%)	19,7	16,0 (82%)	23,1 (118%)
Jumbo to Tuunterstraat(wrong) (11b)	36,1			47,3			3,5			16,4		
Jumbo_Europalaan(West) (12)	18,3	19,9 (109%)	19,1 (105%)	32,0	28,7 (90%)	26,4 (83%)	3,7	3,3 (90%)	3,3 (90%)	15,4	13,1 (85%)	12,0 (78%)
Europalaan(West) to Jumbo (1)	18,8	19,2 (102%)	18,8 (100%)	34,1	48,9 (144%)	32,5 (95%)	3,3	3,5 (106%)	3,3 (98%)	19,6	34,2 (174%)	17,9 (91%)
Europalaan(West) to Europalaan(East) (2a)	40,7	41,1 (101%)	34,0 (84%)	57,6	71,4 (124%)	40,5 (70%)	3,2	3,7 (117%)	0,1 (4%)	17,8	33,5 (189%)	6,3 (35%)
Europalaan(West) to Tuunterstraat (3a)	40,9	42,8 (105%)	42,2 (103%)	49,1	55,6 (113%)	49,3 (100%)	0,3	0,8 (296%)	0,5 (205%)	4,3	8,5 (196%)	6,2 (142%)
Europalaan(West) to Tuunt(wrong) (3b)	39,8			47,9			0,1			3,3		
Europalaan(West) to Handelscentrum	47,0	58,7 (125%)	47,4 (101%)	56,3	70,6 (125%)	53,5 (95%)	0,2	0,8 (387%)	0,2 (75%)	3,6	6,6 (184%)	4,0 (110%)
Europalaan(East) to Tuunterstraat (7a)	47,4	29,6 (62%)	31,2 (66%)	53,9	34,8 (65%)	41,4 (77%)	0,0	0,3 (644%)	0,9 (2086%)	5,5	4,9 (89%)	8,8 (160%)
Europalaan(East) to Europalaan(West) (8)	34,9	36,2 (104%)	34,2 (98%)	52,8	41,0 (78%)	39,0 (74%)	0,2	0,1 (43%)	0,0 (10%)	7,4	1,3 (17%)	1,5 (20%)
Europalaan(East) to Jumbo (9)	43,4	45,8 (106%)	43,0 (99%)	57,9	90,9 (157%)	58,8 (102%)	4,5	5,0 (111%)	4,4 (97%)	22,9	54,4 (237%)	23,6 (103%)
Handelscentrum to Tuunterstraat	59,8	17,9 (30%)	17,7 (30%)	69,0	20,7 (30%)	22,2 (32%)	0,0	0,0 (3%)	0,1 (165%)	2,0	0,1 (4%)	4,0 (201%)
Handelscentrum to Europalaan(West)	47,7	48,6 (102%)	48,4 (102%)	63,0	48,6 (77%)	57,2 (91%)	0,1	0,2 (203%)	0,4 (366%)	7,7	8,2 (106%)	3,3 (43%)
Handelscentrum to Jumbo	55,4	58,3 (105%)	56,2 (101%)	69,1	72,3 (105%)	69,6 (101%)	4,2	4,0 (95%)	4,8 (113%)	17,7	13,4 (76%)	4,8 (27%)
Tuunterstraat to Handelscentrum	70,0	23,2 (33%)	23,4 (33%)	80,7	26,9 (33%)	33,6 (42%)	0,5	0,8 (142%)	1,1 (200%)	5,1	5,6 (111%)	7,6 (149%)
Tuunterstraat to Europalaan(West) (4)	38,9	38,6 (99%)	38,9 (100%)	45,4	44,3 (97%)	45,2 (99%)	0,1	0,0 (12%)	0,1 (99%)	5,1	1,0 (19%)	3,0 (59%)
Tuunterstraat to Jumbo (5)	46,6	46,4 (100%)	46,5 (100%)	57,4	58,8 (103%)	54,7 (95%)	3,8	3,6 (96%)	3,9 (103%)	13,0	13,8 (105%)	12,1 (92%)
Tuunterstraat to Europalaan(East) (6a)	69,9	39,9 (57%)	35,0 (50%)	94,0	66,6 (71%)	44,1 (47%)	5,2	3,8 (74%)	1,3 (26%)	22,2	30,3 (137%)	9,4 (42%)
Tuunterstraat(Wrong) to Handelscentrum	61,0			70,9			0,6			10,3		
Tuunt to Europalaan(East_wrong) (6b)	58,1			71,1			0,3			3,9		
Sum of all cyclists flows	1005,8	697,3 (86%)	680,2 (84%)	1276,6	953,0 (92%)	855,2 (82%)	41,3	37,7 (102%)	35,4 (96%)	236,5	263,1 (130%)	183,6 (91%)

Routes now compared to illiegal routes taken	Mean travel time (s)	Mean travel time (s)	Travel time peak (s)	Travel time peak (s)	Mean delay (s)	Mean delay (s)	Peak Delay (s)	Peak Delay (s)
Europalaan(West) to Handelscentrum	58,7 (125%)		70,6 (125%)		0,8 (387%)		6,6 (184%)	
Jumbo to Handelscentrum	49,6 (97%)		69,5 (101%)		3,7 (96%)		17,5 (134%)	
Tuunterstraat(Wrong) to Handelscentrum	23,2 (38%)		26,9 (38%)		0,8 (124%)		5,6 (54%)	
Tuunt to Europalaan(East_wrong) (6b)	39,9 (69%)	35 (60%)	66,6 (94%)	44,1 (62%)	3,8 (1398%)	1,3 (488%)	30,3 (787%)	94 (243%)
Jumbo to Tuunterstraat(wrong) (11b)		48,7 (135%)		64,6 (137%)		3,7 (109%)		23,1 (141%)
Europalaan(West) to Tuunt(wrong) (3b)		42,2 (106%)		49,3 (103%)		0,5 (509%)		6,2 (187%)
Tuunterstraat(Wrong) to Handelscentrum		23,4 (38%)		33,6 (47%)		1,1 (174%)		7,6 (73%)

In Table 6.1 it becomes clear that the solution of the VVN does have a slightly negative effect (+1% increase (101% compared to the current situation) from the mean travel time) on the traffic flow from motorised traffic. This is mainly the result of a longer travel time from traffic from the Tuunterstraat. The mean delay is decreasing compared to the current infrastructure situation (-4%), and the peak delay increased slightly (+4%). Furthermore, it becomes clear that the proposed solution from the Municipality has a higher negative impact on the travel times and delays of motorised traffic than the solution of VVN, which is a 14% increase in mean travel time against a 1% increase at the VVN solution. Also, the mean delay increased at the Municipality solution, by 13%. This increase in travel time and delay in the solution of the Municipality is mainly the effect of the closure of the entrance of the Handelscentrum at the Europalaan. Furthermore, more cyclists are using the crossing of the Tuunterstraat, which motorised traffic has to give priority.

Moreover, it can be seen in Table 6.2 that the overall mean travel times of cyclists do decline in both solutions -14% and -16% for the solutions of VVN and the Municipality, respectively. The mean delay for cyclists in the solution of VVN does get higher compared to the current situation, +2%, with an even higher increase in peak delay, +30%. This can be explained by the fact that the route cycled for cyclists is much shorter when following the new passage to the Tuunterstraat from the Europalaan(East) and the Handelscentrum, but this route does have more intersections, where cyclists would stand still more, which results in a higher delay on the route itself. The delay of cyclists in the solution of the Municipality is lower than the current situation, in both the mean delay (-4%) and the peak delay (-9%). This means that the delay for cyclists in the solution of the Municipality is 6% and 39% shorter than in the solution from VVN. This is mainly the result of the construction of the two-way cycle path to the Handelscentrum in the solution of the Municipality since cyclists can cross the Tuunterstraat while having priority, while in the solution of the VVN, the cyclists have to cross the Tuunterstraat while giving priority to motorised traffic.

Last but not least in Table 6.3 it can be seen that the route that cyclists have to cycle from the Europalaan(West) to the Handelscentrum, in the solution of VVN, takes longer than cycling against the direction to the Handelscentrum, it could therefore be questioned whether cyclists would follow this route. The other routes that can be cycled in this proposed solution of VVN are shorter than the illegal routes cycled in the current situation and are therefore good alternatives. In the solution of the Municipality, the only travel times that do increase for cyclists, are cyclists from the Jumbo and cyclists that were cycling to the Tuunterstraat on the wrong side, as can be seen in Table 6.3. Since the cycling path alongside the Jumbo/Europalaan is removed and cyclists are not cycling on the wrong side of the Tuunterstraat anymore, whether cyclists would not do this anymore, is debatable since nothing changed on that cycle path along the Tuunterstraat.

In Table 6.4 the mean and max queue lengths for motorised vehicles can be seen. The names and places of these queues can be seen in Appendix F. It becomes clear that the queue lengths do not increase that much, only the queue at the Tuunterstraat does increase significantly, this does correspond to the longer travel times. The total fuel consumption at the intersection during two hours is 2.26L and therefore almost the same as the current situation. This since the average idle time is lower than in the current situation. A breakdown of this per route is shown, together with the queue lengths for cyclists in Appendix J. These results for the solution of the Municipality are shown in Appendix K. The fuel

Table 6.4: VVN solution mean and max queue length motorised vehicles

Motorised vehicles	Mean queue lenght (m)	Queue lenght max (m)
A_BCD	1,9 (94%)	151,6 (101%)
B_AC	0,0 (1268%)	70,9 (810%)
C_AB	0,1 (82%)	23,4 (86%)
C_ACD	0,0 (91%)	28,0 (100%)
A_BD	0,5 (108%)	92,3 (106%)
D_AB	0,1 (190%)	21,0 (124%)
D_ABC	0,0	5,70
Difference in total (%	2,5 (87%)	387,0 (129%)

consumption in the solution of the Municipality is 2.51L/2h, which is significantly higher than the current situation, which is the result of higher delays.

The verification and validation of both models are performed with the same method as for the current infrastructure situation model. The verification and validation of the VVN solution can be seen in Appendix L, while the verification and validation of the Municipality solution can be seen in Appendix M. The results of these tests were equal to the results obtained during the verification and validation steps for the current infrastructure situation model.

6.3 Effects assumptions

As described earlier, in the construction of the models, some assumptions were made. In this section, the effects of the biggest assumption, which is most likely to be different in reality, will be investigated. This assumption is the assumption that no motorised traffic from the Tuunterstraat will go to the Handelscentrum, since this could not be counted during the data collection. This is known to be not true in reality, however, the share of traffic that travels from the Tuunterstraat to Handelscentrum is not known. Since the vehicles that turn left to the Handelscentrum are counted as traffic from the Europalaan(West) and the total number of vehicles from AB is 690 and from C to B is 72, it is assumed that 10% of the vehicles turning left to the Handelscentrum is coming from the Tuunterstraat and not from the Europalaan(West).

The effects of this assumption can be seen in Appendix N, where this change is incorporated in all models, the results of these models are compared to the current situation model where the assumptions were still in place. It can be seen that the travel times and delays for the traffic flows that were incorporated in the first model are a bit higher, while the travel times and delays for traffic from the Tuunterstraat to the Handelscentrum are less in the solution of the Municipality than the solution from VVN and the current situation. This has only limited to no influence on the delay at the intersection since there are relatively little amounts of vehicles.

Another test that has been done is how the intersection will perform in the future, with increasing amounts of traffic. For this, some traffic increases are used. It is assumed that motorised traffic will increase by 20% by 2050 (European Federation for Transport and Environment AISBL, 2024), since also values of 50% are seen in other research, this value will be tested as a very extreme scenario. For cyclists, it is assumed that the volume will increase by 15% by 2050 (Van den Beuken & Kuijt, 2021) and a 45% increase is tested as a very extreme scenario.

The results from this test can also be seen in Appendix N, where these volume increments are incorporated into the models and compared to the current situation normal model. It can be seen that for an increase of 20% for motorised traffic the VVN solution is already performing worse than the current situation with an increase of 20%, while the travel time for cyclists is still less, this is also the case for the solution of the Municipality. For an increase of 50%, the VVN solution is performing almost as badly for motorised traffic as the Municipality solution, while also the performance for cyclists is comparable, but the travel time for cyclists is still lower than the current situation without the increase in volume. The current situation with an increase of 50% is worse for both motorised traffic and cyclists compared to the current situation without such an increase. Overall can be concluded that the differences seen during the normal comparisons are bigger with the increase in volume. An interesting point is that the VVN solution is performing a lot worse for motorised traffic than the current situation with a volume increase of 50% since this was around the same or better without the increase.

7. Assessment safety indicators

Now the effects of the solutions on the traffic flows and environmental factors are known, it is important to analyse another major factor in the performance of the new solutions, which is safety. The safety concern is the main reason why this intersection needs to be changed, with underlying traffic flows as the correlation of this problem. Since the problem is already explained in the introduction, the focus of this chapter will be on analysing the safety indicators that were set earlier, which are the number of conflict points, the conflict angles, the speeds at those conflict points and the number of traffic passing these conflict points.

7.1 Current situation

All the conflict points of cars with cyclists in the current situation can be seen in Figure 7.1, corresponding to it is a Table in Appendix M with the speeds, conflict angles and the number of vehicles passing at each conflict point.

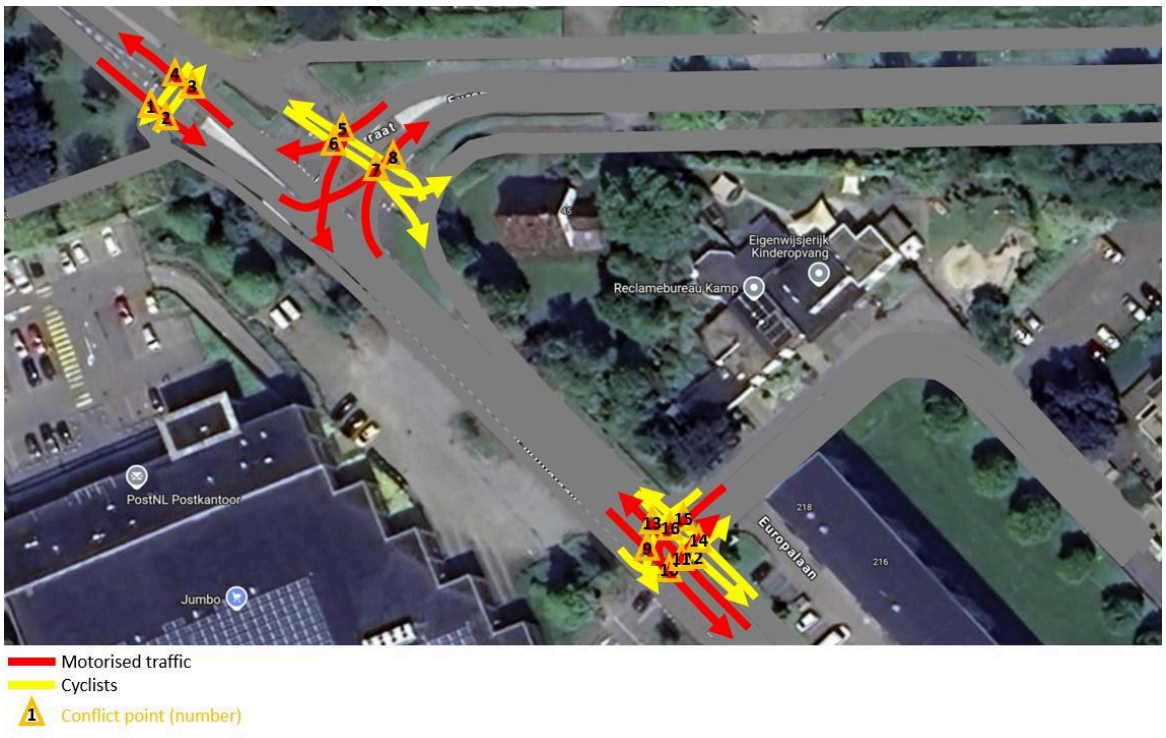


Figure 7.1: Conflict points current situation

It can be seen that there are 16 conflict points in the current situation. The number of vehicles passing these conflict points is 917 and most conflict angles are 90 degrees. Furthermore, the speeds were the highest at the conflict points where motorised vehicles are going straight, instead of turning right or left, which leads to a higher speed difference between motorised vehicles and cyclists. Another thing that needs to be taken into account is the conflict points that are created from traffic from the exit of the Jumbo, which is not modelled but creates conflict points in reality. These conflict points can be seen in Appendix M. These conflict points make the situation at this intersection even more hectic. One of the main safety concerns that are not incorporated in numbers is that cyclists are using the one-way cycle path as a two-way cycle path and are therefore not expected by cars.

7.2 VVN proposed solution

Then the conflict points that are there if the proposed solution by VVN is implemented. In Figure 7.2 it becomes clear that there will be 20 conflict points. The corresponding Table to these conflict points can be seen in Appendix M.

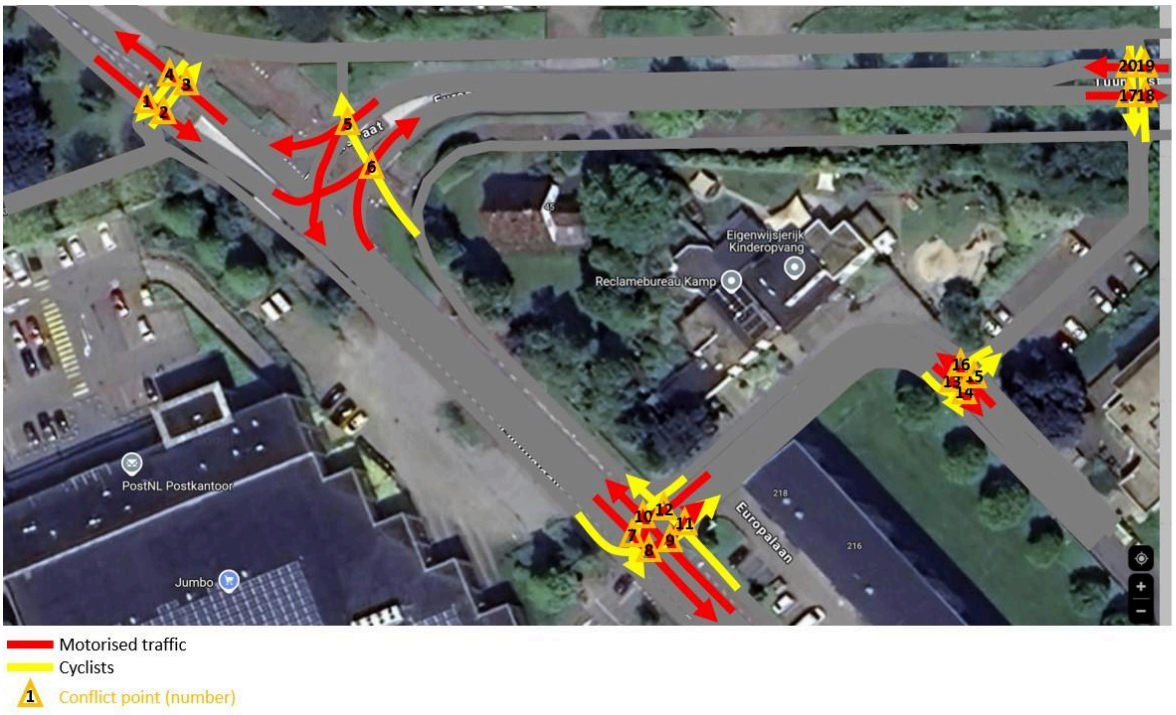


Figure 7.3: Conflict points Municipality solution

The number of vehicles passing these conflict points is 834, which is lower than in the current situation. This is mainly the result of removing some conflict points at the intersection of the Europalaan with the Handelscentrum, while there are conflict points introduced at the less busy Handelscentrum and Tuunterstraat, compared to the Europalaan. The speeds on the Handelscentrum will also be lower than on the Europalaan since it is a smaller street and the conflict points are right after a bend. On the Tuunterstraat the speeds will be comparable to the speeds on the Europalaan but can be a bit lower because traffic is coming from a 30 km/h zone and a railway crossing. The situation at the intersection of the Europalaan and Handelscentrum is a bit less hectic in this situation, however, there are again some conflict points with traffic from the exit of the Jumbo, which is shown in Appendix M. Furthermore the safety concern of cyclists cycling against the direction remains partly in place, since the new route provided to the Handelscentrum is still longer than cycling against the direction, but the number of cyclists doing this would most likely be lower than at the current situation.

7.3 Municipality solution

The conflict points in the solution of the Municipality are displayed in Figure 7.3. As can be seen, there are 18 conflict points in this solution.

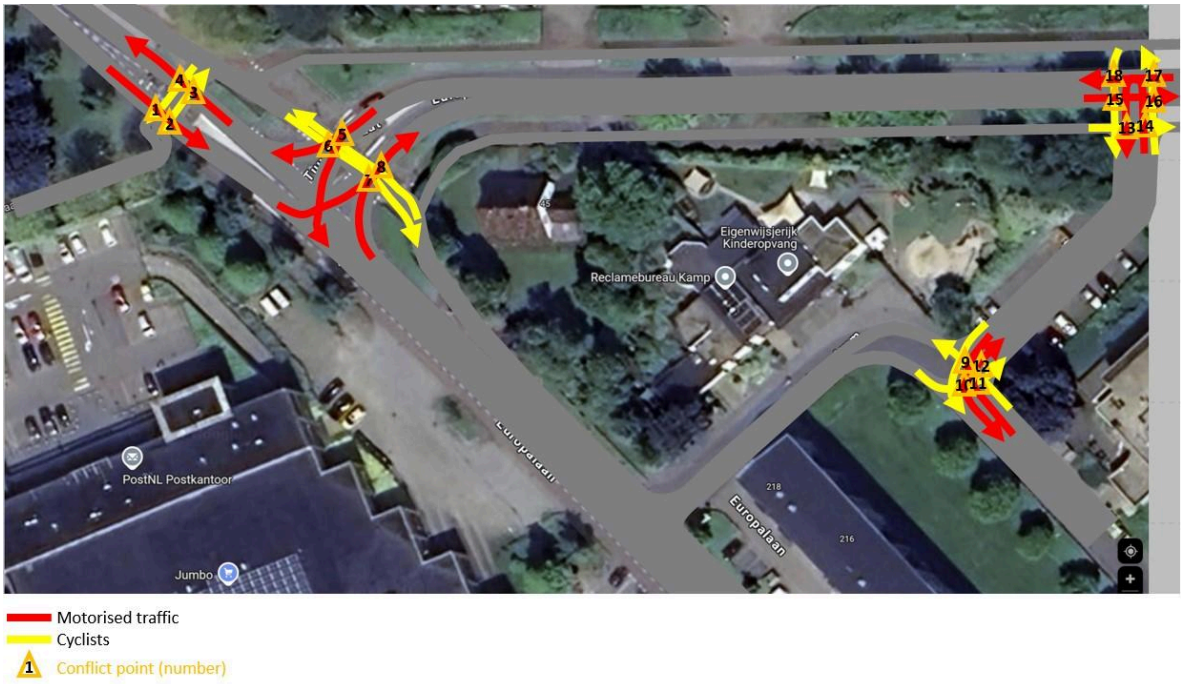


Figure 7.3: Conflict points Municipality solution

In the corresponding Table in Appendix M, it can be seen that the number of vehicles passing these conflict points is 677, the lowest number of the scenarios. This is the result of removing all conflict points at the intersection of the Handelscentrum and the Europalaan since the Handelscentrum is closed off for motorised traffic and the cycling lane along the Jumbo is also removed, this also removes the hectic situation at that intersection. These conflict points are introduced on the less busy Handelscentrum and Tuunterstraat. As said before, the speeds at these intersections might be a little bit less. Furthermore, the safety concern of motorised traffic not expecting cyclists that are cycling against the direction to the Handelscentrum is removed, since this is now facilitated and the motorised traffic will be aware of this. This safety concern is only still in place on the cycling path in the north of the Tuunterstraat, however, this will only result in cyclist-cyclist conflict, which is less dangerous in terms of injuries than car-cyclist accidents.

7.4 Conclusion safety indicators

It can be concluded that the solutions do not reduce the number of conflict points, but it does lower the amount of traffic passing them. At the solution of the Municipality, the fewest amount of traffic is passing the conflict points. Furthermore, it reduces the speed difference at the conflict points and reduces (the VVN solution) or completely removes (the Municipality solution) the number of cyclists that are cycling against the direction of the Handelscentrum Last but not least, the hectic situation in the intersection of the Handelscentrum and the Europalaan is simplified (at the VVN solution) or completely solved (the Municipality solution). However, at both solutions, some safety concerns still exist, at the VVN solution it will be likely that cyclists still cycle against the direction to the Handelscentrum and at the Municipality solution it will be likely that cyclists will cycle against the direction on the cycle path north of the Tuunterstraat. All in all, the requirements set, that visitors of shops etc. and school children need to cycle safe(r) to their destinations is achieved by both solutions, however, the solution of the Municipality is safer for scholars since the intersection at the exit of the Jumbo is on the school route.

8. Discussion, conclusion, and recommendations

In this chapter, the methods followed will be discussed, and the trade-offs will be concluded between the scenarios. In the end, a small recommendation is made.

8.1 Discussion

During this research, there were some limitations or missing parts that could lead to some difference in the results, these limitations, and assumptions with their possible effects are discussed here.

The first limitation is the limitation of the data collection. In the data collection, it was not possible to count the directions to and from the Jumbo. The motorised traffic going left from the Europalaan to the entrance of the Jumbo made a difference in the effects in the simulation model since less congestion did occur since motorised traffic did not have to wait for traffic that wanted to turn left here. In reality, a long queue did occur here, while this was not the case in the model because of this data collection limitation.

Another limitation was that the speeds at some conflict points could not be captured in the model since these conflict points were in the middle of some roads and therefore no data collection point could be placed in the model. This has no large impact on the results, but some gaps in the speed results were seen as an effect of this. In the modelling, another limitation was found, which was that the travel times of cyclists to the Handelscentrum could not be split into one illegal and one legal route but were added up. Since not many cyclists followed the legal route, the effect of this is small, but no comparison could be made between the two routes.

Last but not least, no model was made from the two solutions when cyclists were continuing their behaviour of using one-way cycle paths as two-way cycle paths. As a result, the legal routes taken in the solutions are compared with the illegal routes taken in the current situation model, while it could be that the illegal route in the solutions would have longer travel times due to other changes, for example in traffic flows or infrastructure.

8.2 Analysis of trade-offs/conclusion

As could already be seen in the past chapters, both solutions have positive and negative effects on traffic flows, safety, and the environment. An overview of these effects per category can be found in Table 8.1.

Table 8.1: Trade-offs solutions

Category	**Effects VVN solution (compared to current situation)**	**Effects Municipality solution (compared to current situation)**
Traffic flow - motorised traffic	-/+ (102%)	- (123%)
Traffic flow - cyclists	+ (93%)	++ (84%)
Safety	+/-	+
Economic	-	-
Environmental	-/+ (+0.01 L/2h)	- (+0.26 L/2h)

The effects on the traffic flows are calculated into one value, this is done by summing up all the total amounts of seconds for all the routes in a solution for mean and peak travel times and mean and peak delays. This is because the average from the percentages could not be taken due to the large differences between travel times and delays and therefore also the impact. The values in Table 8.1 are representative of the overall pattern seen in the raw results. The solution of VVN has a negligible impact (+2%) on the traffic flow for motorised traffic, since this infrastructure did not change, while it has a positive impact on the traffic flow for cyclists (-7%) since the travel time did decrease by a lot, however, the delay is somewhat higher. The safety in this scenario is somewhat better since some cyclists would travel via the new passage, however, this route is still longer, and therefore it is expected that cyclists would stick to their current habit and therefore this would not lead to a full solution to the current problem. Environmentally, which is assessed by fuel consumption during idle time at the intersection, this solution has almost the same fuel consumption as the current situation (+0.01 L/2h). The economic part is a qualitative comparison with the solution of the Municipality. It is clear that both scenarios cost money, and it is expected that the money that it will cost is somewhat comparable, since for both scenarios a part of the current existing road needs to be shifted some metres (in other places), cycle paths have to be broadened to accommodate two-way traffic and a new passage needs to be created. The solution of the Municipality will be a little bit more expensive due to the larger amount of asphalt that needs to be made, however combining this with the project of the Woonplaats will have opportunities for co-funding, therefore the total costs are expected to be almost equal. The solution of the Municipality harms the traffic flow for motorised traffic (+23%), since travel times, delays and queues got longer in the simulation. However, it has an even larger positive effect on the traffic flow for cyclists (-16%), since the travel times did decrease further compared to the VVN solution, and also the delays were shorter than in the other scenarios. The solution of the Municipality has also a positive impact on safety since far less traffic is crossing conflict points (677 veh/2h), compared to the other scenarios (838 and 917 veh/2h) with somewhat lower speeds. Furthermore, the unclear and hectic situation at the intersection of the Europalaan, Handelscentrum and the exit of the Jumbo is completely solved. Last but not least, the solution of the Municipality does have a slight negative impact on the environment (+0.26 L/2h).

8.3 Recommendations

Both scenarios have positive and negative effects. These trade-offs have to be reviewed by the Municipality itself, however, both solutions do have good solutions/ideas. First, the idea of a new passage in both solutions is a good solution. Furthermore, the closure of the current entrance of the Handelscentrum is a good idea to solve the safety problem there, however, it does have some disadvantages for the traffic flow of motorised vehicles. The removal of the cycle lane along the Jumbo is also good for the safety at the intersection, as well as providing the two-way cycle lane to the Handelscentrum that continues further along the Europalaan. A two-way cycle path along the Tuunterstraat is also a good solution since a lot of cyclists are cycling against the direction on the cycle path north of the Tuunterstraat as well. This all led to both solutions performing quite well concerning the requirements, both solutions make the situation safe(r) and the area stays accessible, also the Municipality could argue that the solutions are sustainable since they encourage people to cycle more, so it is sustainable even when there is more fuel consumption. The solutions are also viewed as not too expensive by the Municipality. Since both solutions have strong points and weaknesses, something that could be taken into consideration is combining these ideas of both solutions into one solution. This would be a bit more expensive but is a good step towards the goal of the Municipality of Winterswijk to have 0 traffic deaths in 2030.

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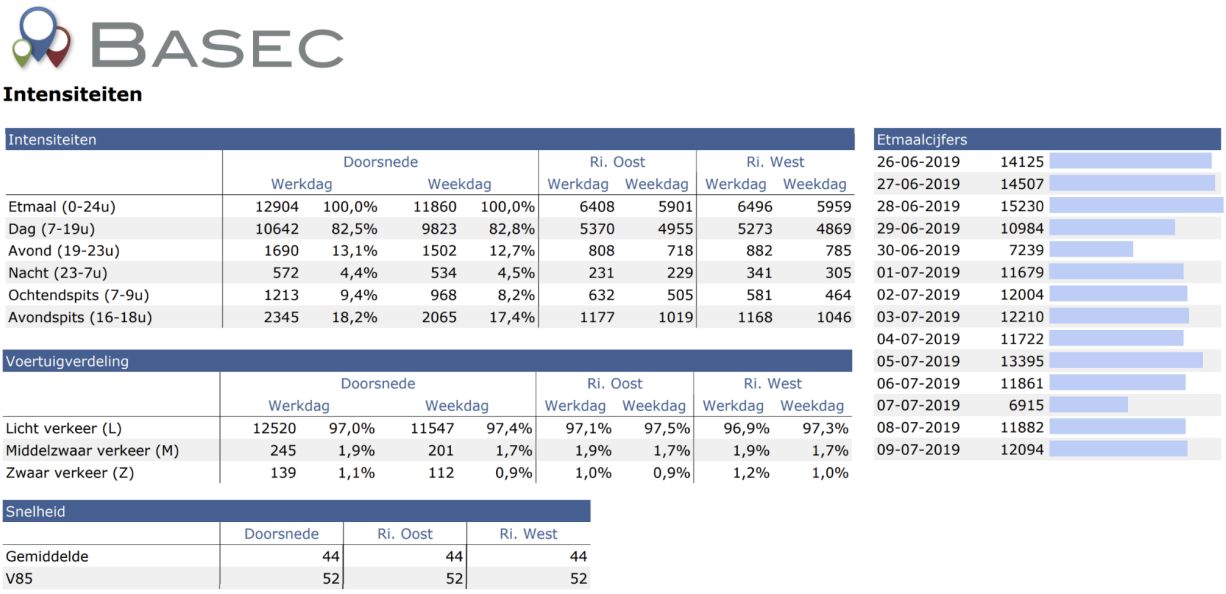
10. Appendices

10.1 Appendix A: Intensities Europalaan and Tuunterstraat

As can be seen in the figures, these measurements were done from 26-06-2019 to 09-07-2019. The vehicle distribution was determined using the axle combinations. These measurements on the Europalaan are done between the N319 and the Europark, west of the intersection with the Tuunterstraat. This means that there are two roads, the Europark and the Spreeuwstraat, between the measurement point and the intersection of interest. The measurements on the Tuunterstraat are done between the intersection with the Europalaan and the Kalverstraat, which means that there is no road between the measurement point and the intersection with the Europalaan.



BASEC

Intensiteiten

Intensiteiten

	Doorsnede				Ri. Oost		Ri. West	
	Werkdag		Weekdag		Werkdag	Weekdag	Werkdag	Weekdag
Etmaal (0-24u)	12904	100,0%	11860	100,0%	6408	5901	6496	5959
Dag (7-19u)	10642	82,5%	9823	82,8%	5370	4955	5273	4869
Avond (19-23u)	1690	13,1%	1502	12,7%	808	718	882	785
Nacht (23-7u)	572	4,4%	534	4,5%	231	229	341	305
Ochtendspits (7-9u)	1213	9,4%	968	8,2%	632	505	581	464
Avondspits (16-18u)	2345	18,2%	2065	17,4%	1177	1019	1168	1046

Etmaalcijfers

26-06-2019	14125
27-06-2019	14507
28-06-2019	15230
29-06-2019	10984
30-06-2019	7239
01-07-2019	11679
02-07-2019	12004
03-07-2019	12210
04-07-2019	11722
05-07-2019	13395
06-07-2019	11861
07-07-2019	6915
08-07-2019	11882
09-07-2019	12094

Voertuigverdeling

	Doorsnede				Ri. Oost		Ri. West	
	Werkdag		Weekdag		Werkdag	Weekdag	Werkdag	Weekdag
Licht verkeer (L)	12520	97,0%	11547	97,4%	97,1%	97,5%	96,9%	97,3%
Middelzwaar verkeer (M)	245	1,9%	201	1,7%	1,9%	1,7%	1,9%	1,7%
Zwaar verkeer (Z)	139	1,1%	112	0,9%	1,0%	0,9%	1,2%	1,0%

Snelheid

	Doorsnede	Ri. Oost	Ri. West
Gemiddelde	44	44	44
V85	52	52	52

Figure A1: Intensities Europalaan

BASEC

Intensiteiten

Intensiteiten	Doorsnede				Ri. Oost		Ri. West	
	Werkdag		Weekdag		Werkdag	Weekdag	Werkdag	Weekdag
Etmaal (0-24u)	2562	100.0%	2360	100.0%	1309	1203	1253	1157
Dag (7-19u)	2254	88.0%	2085	88.4%	1165	1071	1090	1014
Avond (19-23u)	238	9.3%	210	8.9%	117	104	121	106
Nacht (23-7u)	70	2.7%	64	2.7%	27	28	43	36
Ochtendspits (7-9u)	248	9.7%	207	8.8%	120	100	128	106
Avondspits (16-18u)	452	17.6%	394	16.7%	247	212	205	182

Voertuigverdeling	Doorsnede				Ri. Oost		Ri. West	
	Werkdag		Weekdag		Werkdag	Weekdag	Werkdag	Weekdag
Licht verkeer (L)	2508	97.9%	2313	98.0%	97.4%	97.6%	98.4%	98.5%
Middelzwaar verkeer (M)	25	1.0%	21	0.9%	1.0%	0.9%	0.9%	0.9%
Zwaar verkeer (Z)	29	1.1%	25	1.1%	1.6%	1.5%	0.7%	0.6%

Snelheid	Doorsnede	Ri. Oost	Ri. West
Gemiddelde	44	44	44
V85	52	52	52

Etmaalcijfers	
10-06-2023	2369
11-06-2023	1335
12-06-2023	2512
13-06-2023	2351
14-06-2023	2494
15-06-2023	2589
16-06-2023	3019
17-06-2023	2612
18-06-2023	1354
19-06-2023	2390
20-06-2023	2344
21-06-2023	2452
22-06-2023	2681
23-06-2023	2772
24-06-2023	2242
25-06-2023	1211

Figure A2: Intensities Tuunterstraat

10.2 Appendix B: Traffic count directions cyclists

Table B1: Table with directions counted for heavy and light motorised vehicles and periods

WHAT	Light motorised traffic									
FROM	Europalaan (Mac)			Europalaan			Tuunterstraat		Handelscentrum	
TO	Europalaan	Tuunterstraat	Handelscentrum	Europalaan (Mac)	Tuunterstraat	Handelscentrum	Europalaan	Europalaan (Mac)	Europalaan (Mac)	Europalaan
DI. NO.	AB	AC	AD	BA	BC	BD	CA	CB	DA	DB
16:00-16:09										
16:10-16:19										
16:20-16:29										
16:30-16:39										
16:40-16:49										
16:50-16:59										
17:00-17:09										
17:10-17:19										
17:20-17:29										
17:30-17:39										
17:40-17:49										
17:50-17:59										

WHAT	Heavy motorised traffic									
FROM	Europalaan (Mac)			Europalaan			Tuunterstraat		Handelscentrum	
TO	Europalaan	Tuunterstraat	Handelscentrum	Europalaan (Mac)	Tuunterstraat	Handelscentrum	Europalaan	Europalaan (Mac)	Europalaan (Mac)	Europalaan
DI. NO.	AB	AC	AD	BA	BC	BD	CA	CB	DA	DB
16:00-16:09										
16:10-16:19										
16:20-16:29										
16:30-16:39										
16:40-16:49										
16:50-16:59										
17:00-17:09										
17:10-17:19										
17:20-17:29										
17:30-17:39										
17:40-17:49										
17:50-17:59										

Table B2: Table with directions counted for cyclists during the count

VAN	Europalaan (Mac)					Tuunterstraat				Tuunterstraat (verkeerde kant)			
NAAR	Jumbo	EU-laan	EU-laan	Tuunt	Tuunt	EU-laan (M)	Jumbo	EU-laan	EU-laan	EU-laan (M)	Jumbo	EU-laan	EU-laan
RI. NR.	1	2a	2b	3a	3b	4	5	6a	6b	41	51	61a	61b
16:00-16:09													
16:10-16:19													
16:20-16:29													
16:30-16:39													
16:40-16:49													
16:50-16:59													
17:00-17:09													
17:10-17:19													
17:20-17:29													
17:30-17:39													
17:40-17:49													
17:50-17:59													

VAN	Europalaan				Jumbo				
NAAR	Tuunt	Tuunt	EU-laan (M)	Jumbo	EU-laan	EU-laan	Tuunt	Tuunt	EU-laan (M)
RI. NR.	7a	7b	8	9	10a	10b	11a	11b	12
16:00-16:09									
16:10-16:19									
16:20-16:29									
16:30-16:39									
16:40-16:49									
16:50-16:59									
17:00-17:09									
17:10-17:19									
17:20-17:29									
17:30-17:39									
17:40-17:49									
17:50-17:59									

Table B3: Table with directions counted for cyclists afterwards from the video

VAN	Handelscentrum				
NAAR	Tuunt	Tuunt	EU-laan (M)	Jumbo	Jumbo
VIA	EU-laan	EU-laan	EU-laan	EU-laan	EU-laan
16:00-16:09					
16:10-16:19					
16:20-16:29					
16:30-16:39					
16:40-16:49					
16:50-16:59					
17:00-17:09					
17:10-17:19					
17:20-17:29					
17:30-17:39					
17:40-17:49					
17:50-17:59					

Datum	
Weer	

VAN	Jumbo	Jumbo	EU-laan (M)	EU-laan (M)	Tuunter	Tuunter	Tuunter
NAAR	HANDELSCENTRUM						
VIA	EU-laan	EU-laan	EU-laan	EU-laan	EU-laan	EU-laan	EU-laan
16:00-16:09							
16:10-16:19							
16:20-16:29							
16:30-16:39							
16:40-16:49							
16:50-16:59							
17:00-17:09							
17:10-17:19							
17:20-17:29							
17:30-17:39							
17:40-17:49							
17:50-17:59							

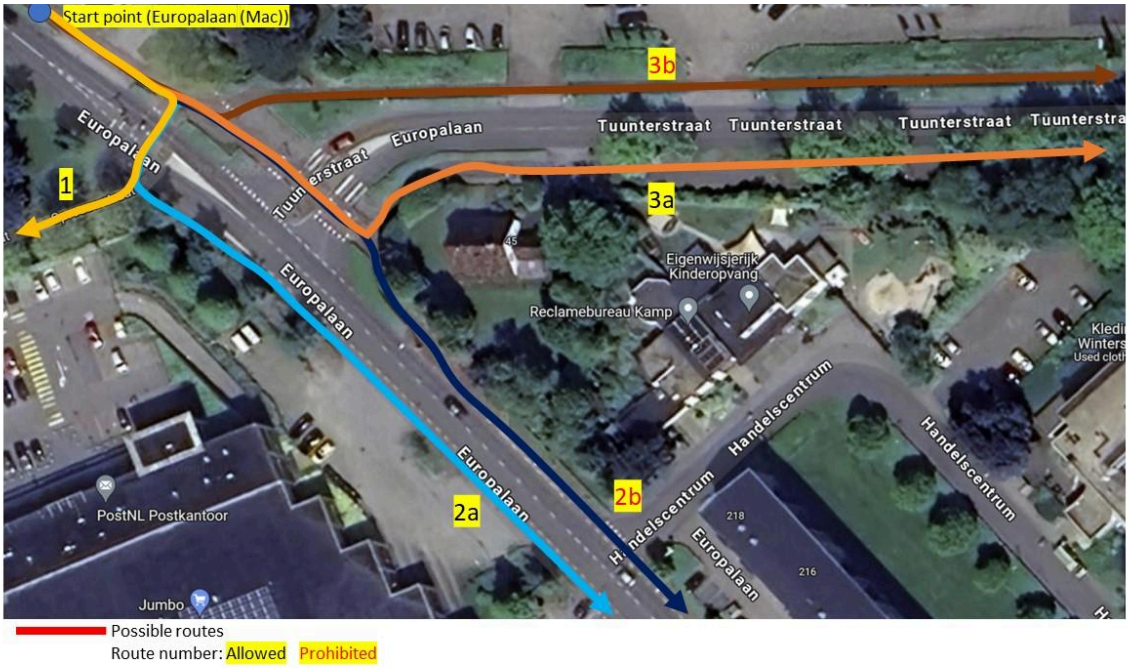


Figure B1: Possible routes for cyclists from the direction of the Europalaan (Mac/West)

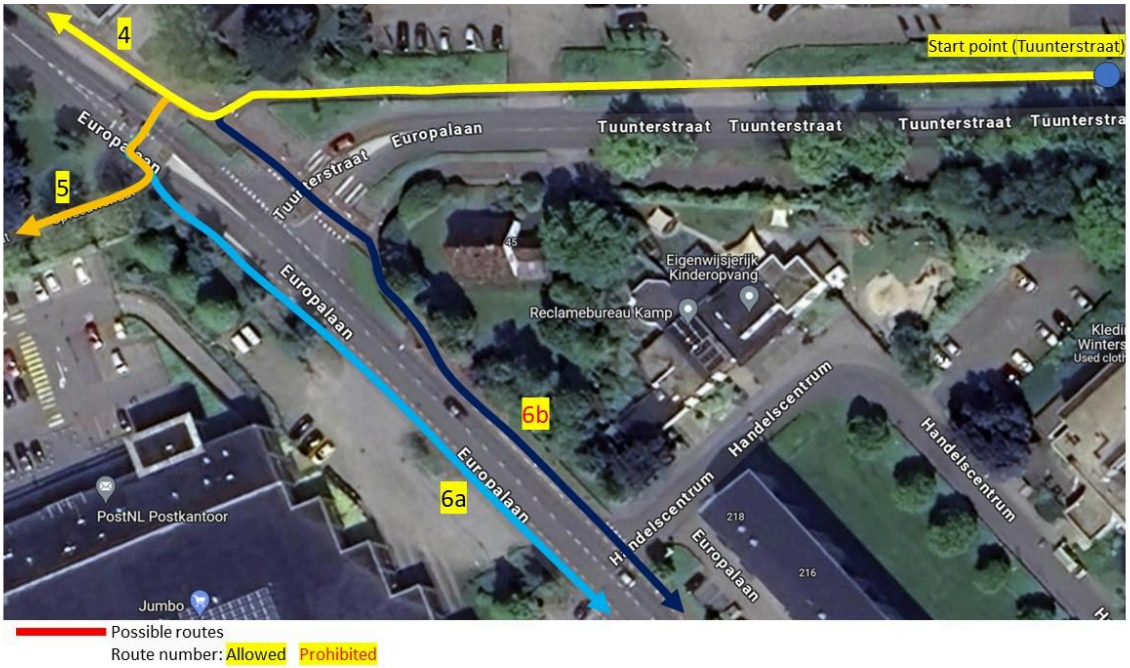


Figure B2: Possible routes for cyclists from the Tuunterstraat

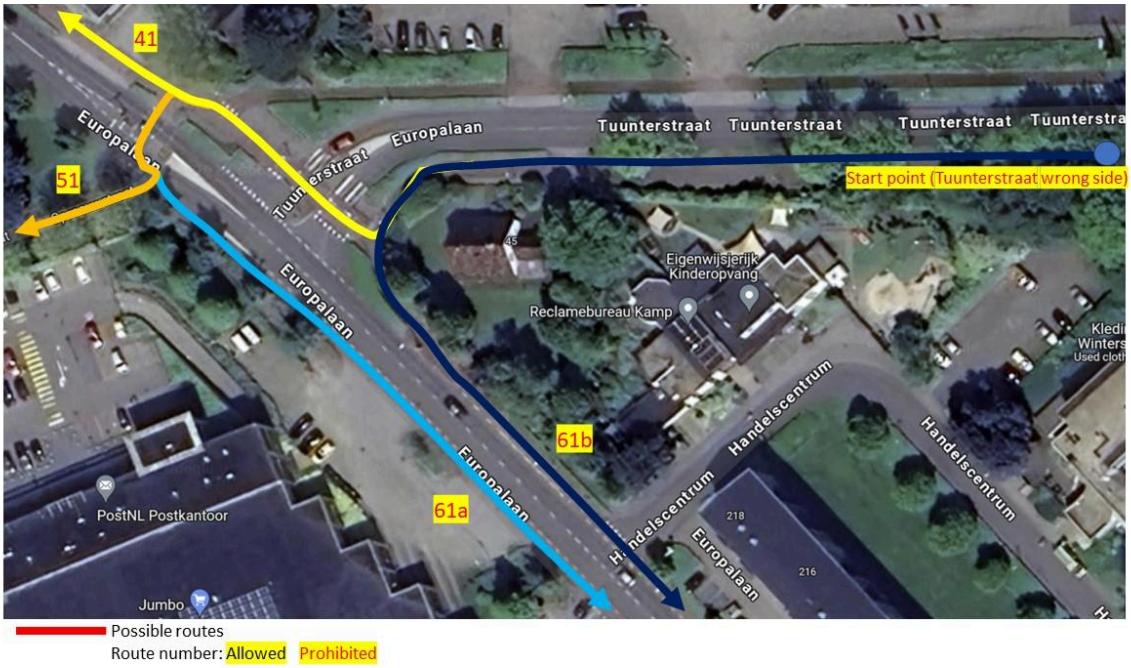


Figure B3: Possible routes for cyclists from the Tuunterstraat (wrong side)

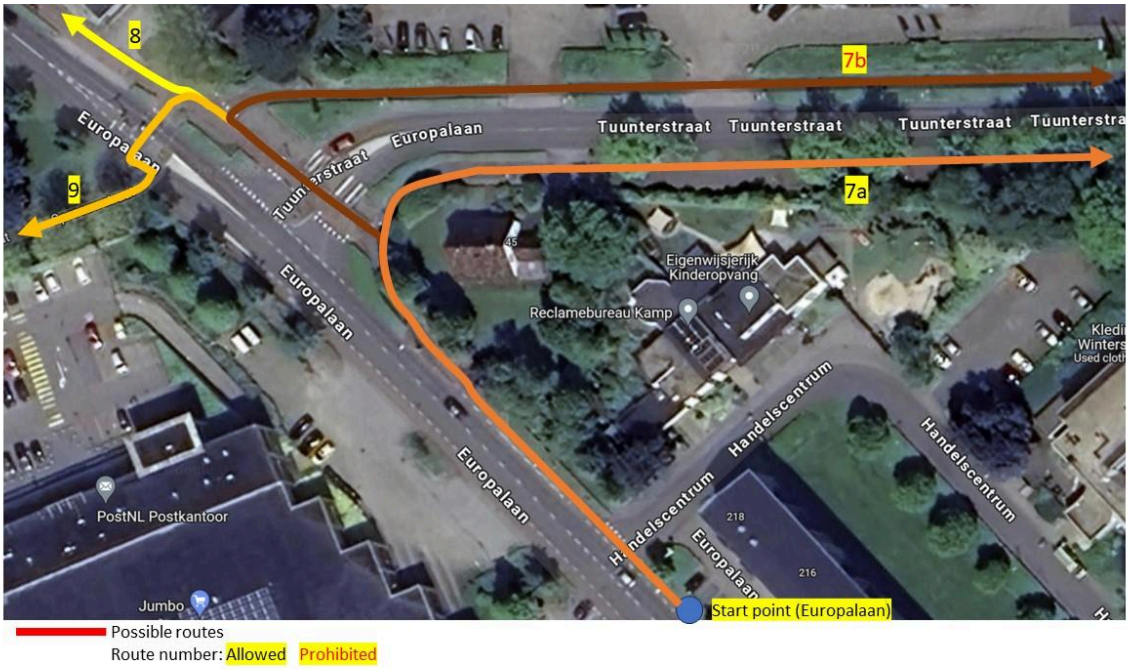


Figure B4: Possible routes for cyclists from the Europalaan (East)

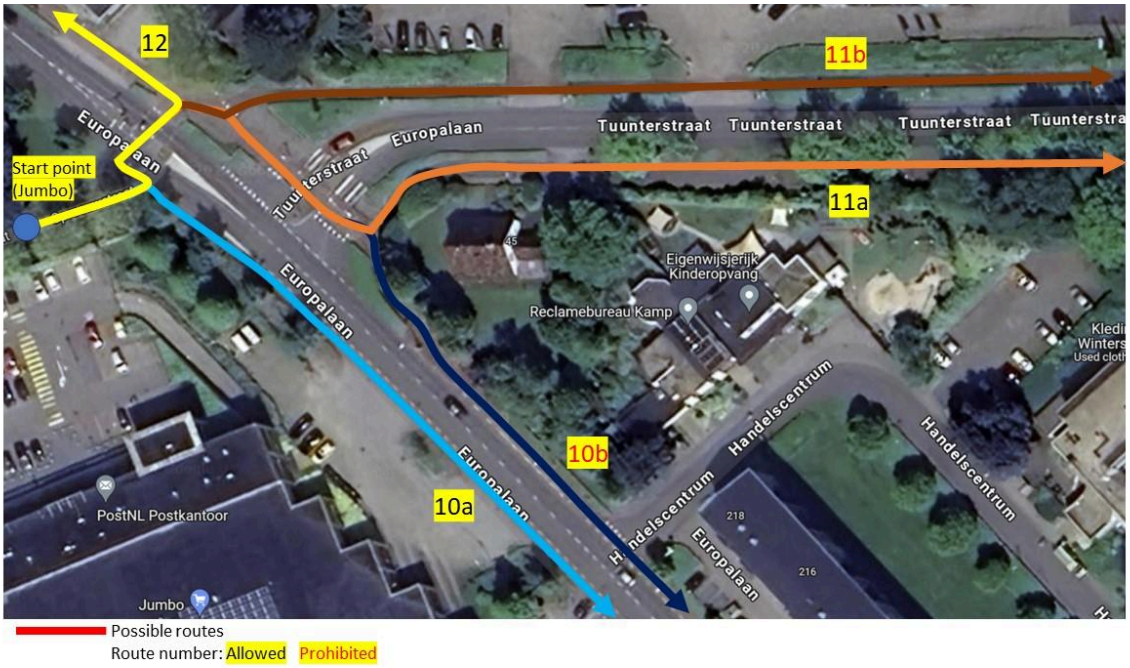


Figure B5: Possible routes for cyclists from the direction of the Jumbo

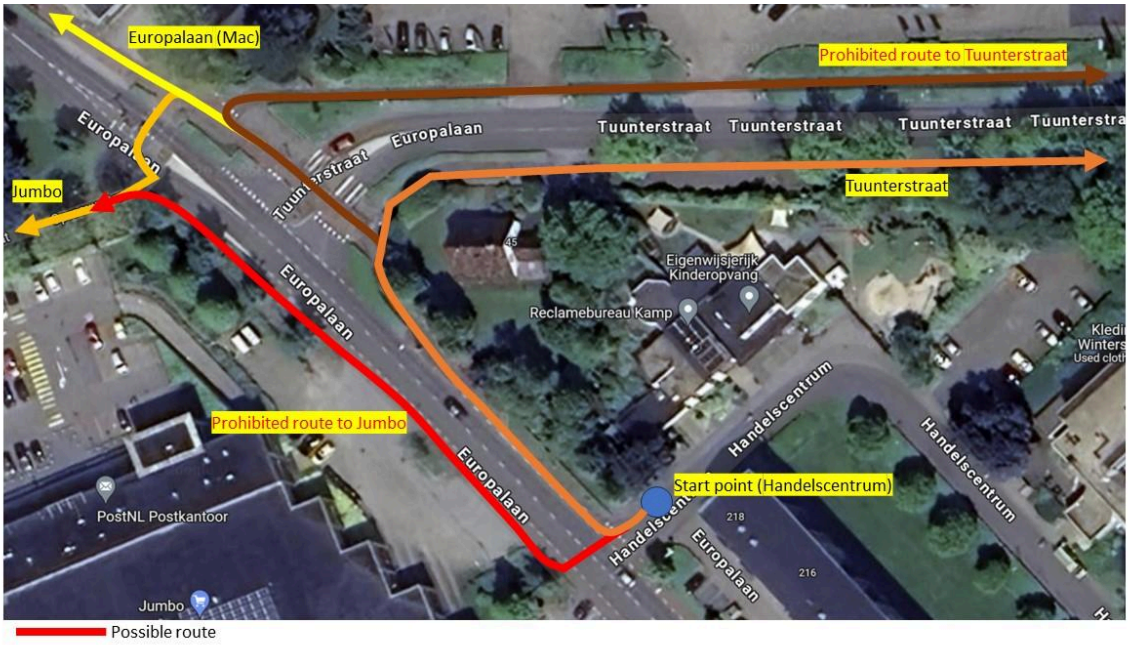


Figure B6: Possible routes cyclists from Handelscentrum

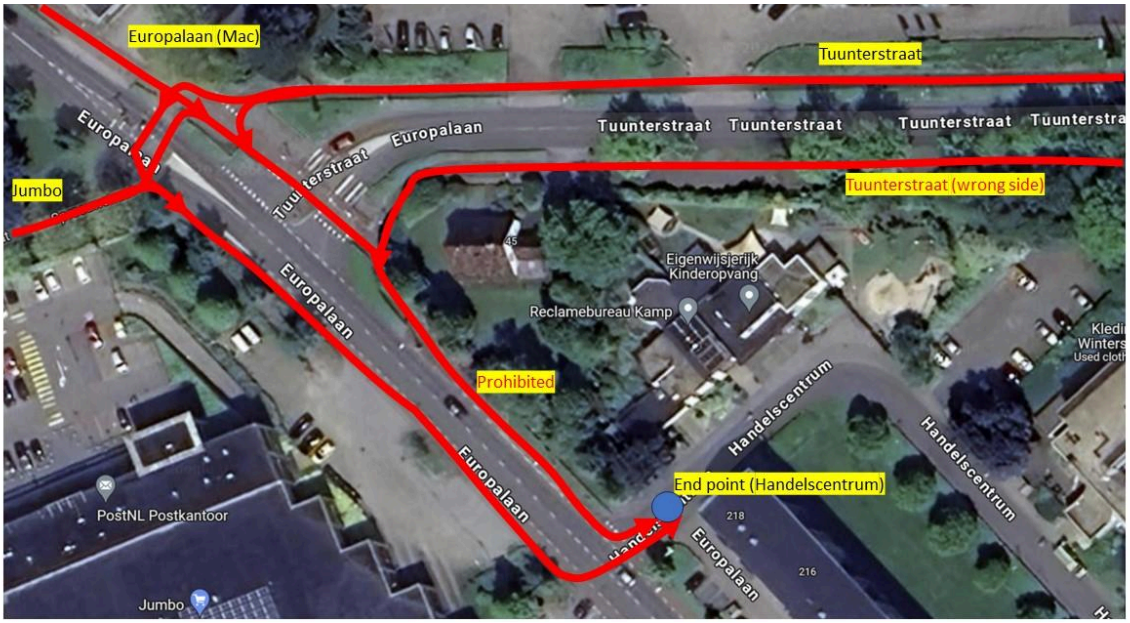


Figure B7: Possible routes for cyclists to Handelscentrum

10.3 Appendix C: Data collection results motorised traffic

Legend graphs:	
To Europalaan (West)	
To Europalaan (East)	
To Tuunterstraat	
To Handelscentrum	

Figure C1: Colour scheme for all graphs in this appendix C

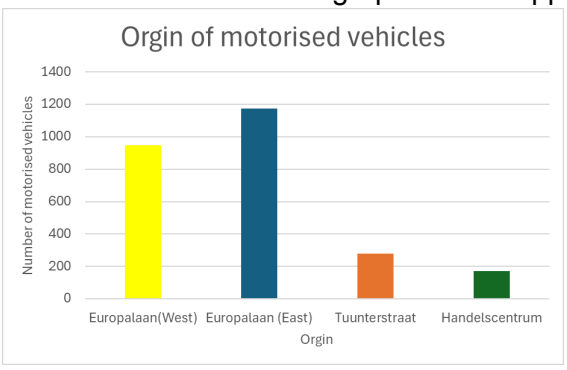


Figure C2: Origin of motorised vehicles

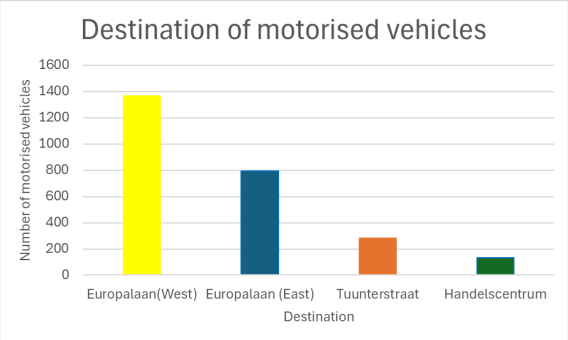


Figure C3: Destination of motorised vehicles

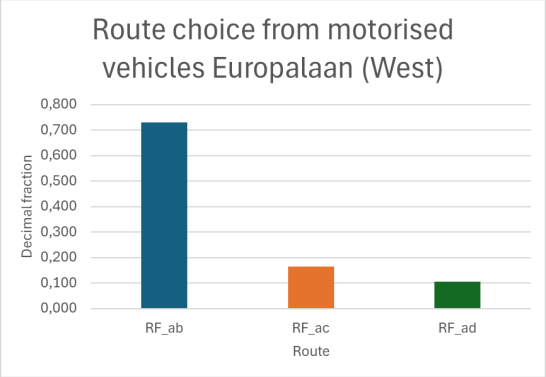


Figure C4: Route choice from motorised vehicles from the Europalaan (West)

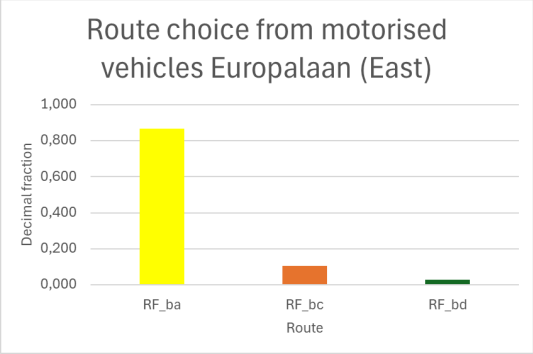


Figure C5: Route choice from motorised vehicles from the Europalaan (East)

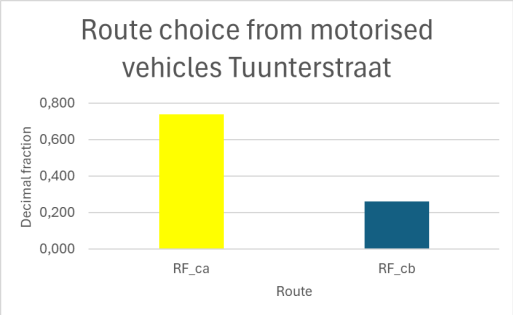


Figure C6: Route choice from motorised vehicles from the Tuunterstraat

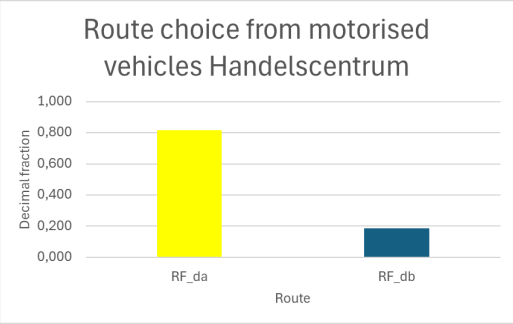


Figure C7: Route choice from motorised vehicles from the Handelscentrum

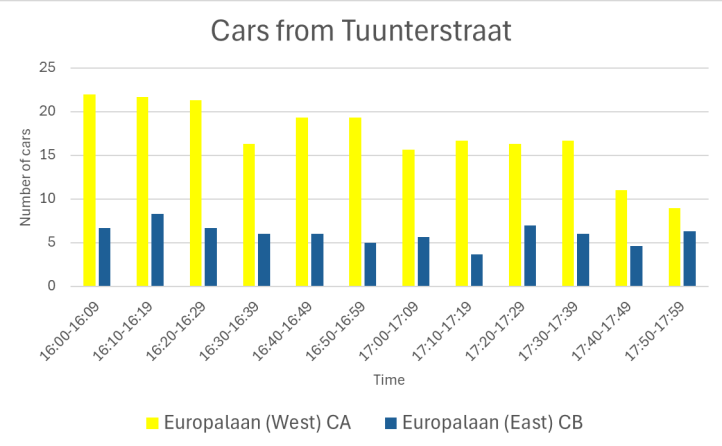


Figure C8: Detailed route choice per 10 minutes (averages from days 1, 2 and 3) from motorised vehicles from the Tuunterstraat

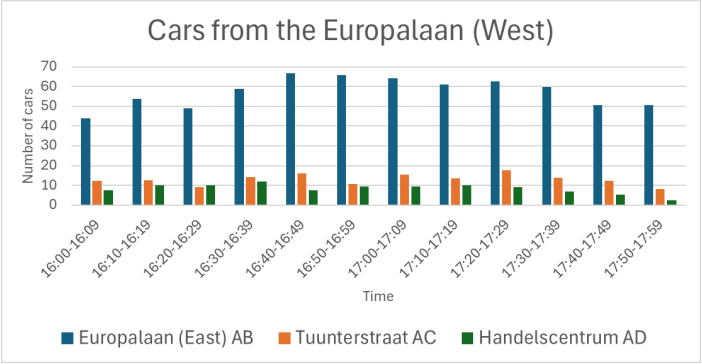


Figure C9: Detailed route choice per 10 minutes (averages from days 1, 2 and 3) from motorised vehicles from the Europalaan (West)

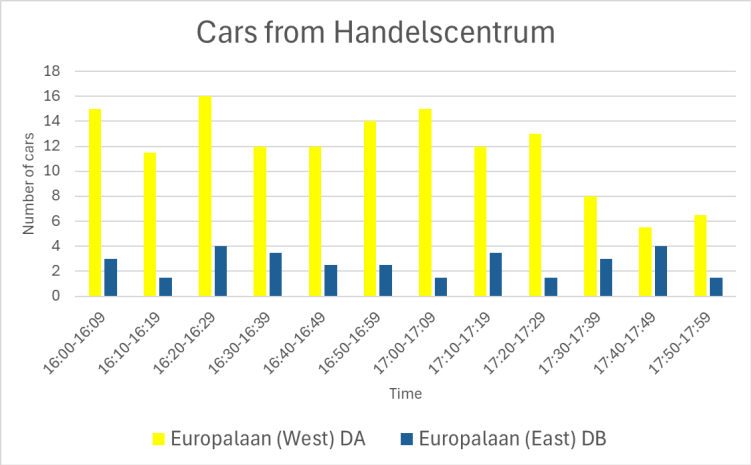


Figure C10: Detailed route choice per 10 minutes (averages from days 1, 2 and 3) from motorised vehicles from the Handelscentrum

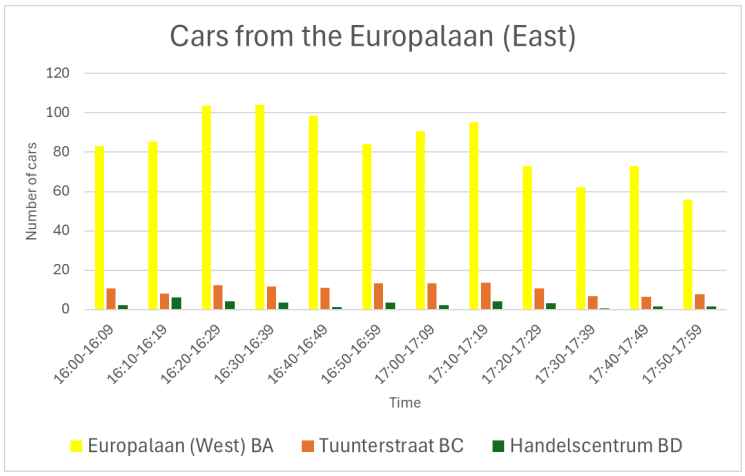


Figure C11: Detailed route choice per 10 minutes (averages from days 1, 2 and 3) from motorised vehicles from the Europalaan (East)

10.4 Appendix D: Data collection results cyclists

Legend graphs:	
To Europalaan (West)	
To Europalaan (East)	
To Tuunterstraat	
To Handelscentrum	
To Tuunterstraat (wrong side)	
To Europalaan (East, wrong side)	
To Jumbo	
To Handelscentrum (wrong side)	

Figure D1: Colour scheme for all graphs in this appendix D

Figure D2: Route choice from cyclists from the Tuunterstraat

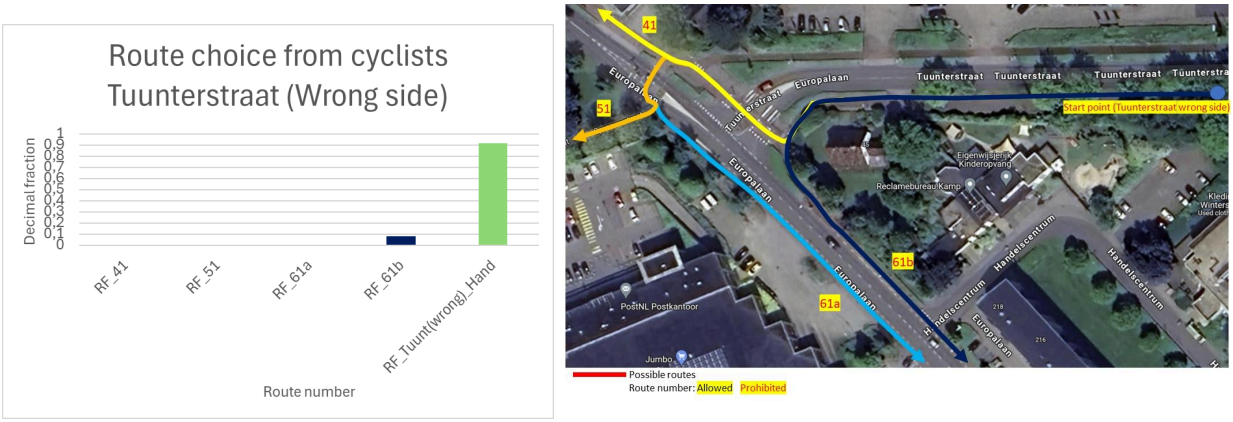


Figure D3: Route choice from cyclists from the wrong side of the Tuunterstraat

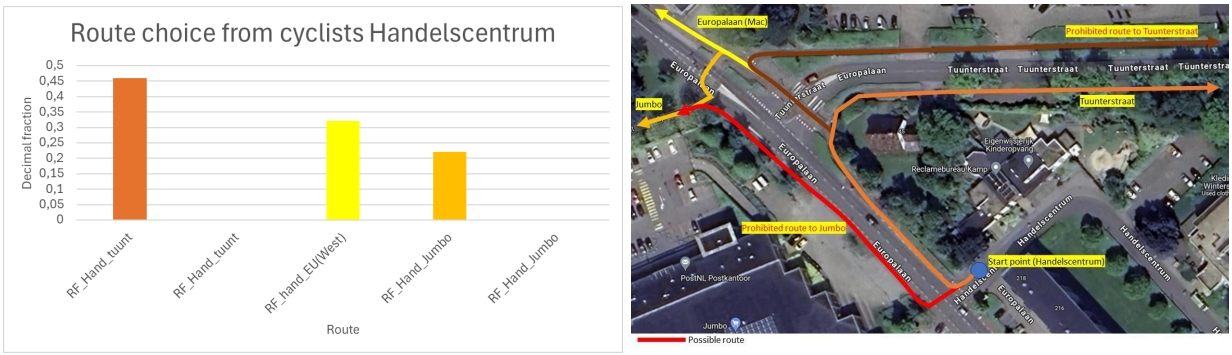


Figure D4: Route choice from cyclists from the Handelscentrum

Figure D5: Route choice from cyclists from the Europalaan (East)

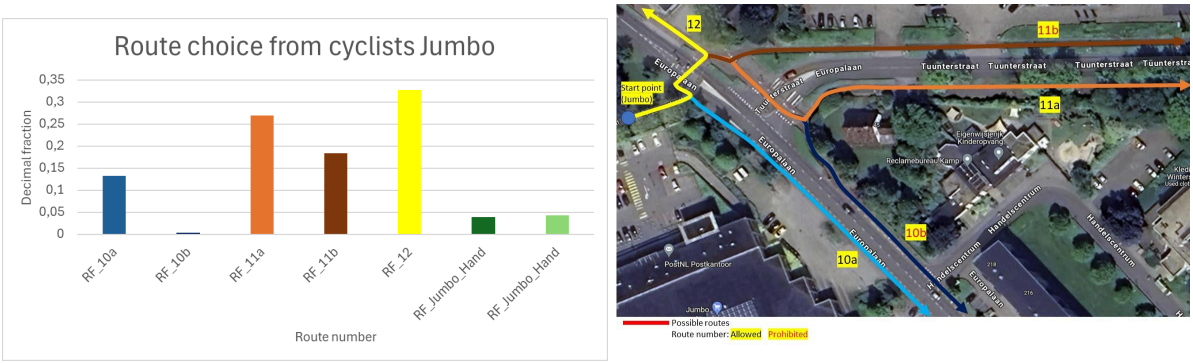
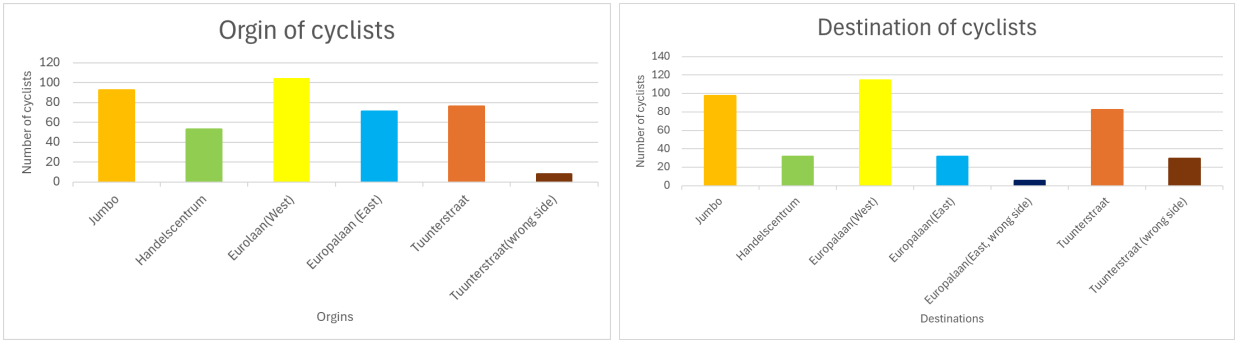


Figure D6: Route choice from cyclists from the Jumbo



Figures D7 and D8: Origin and destination of cyclists

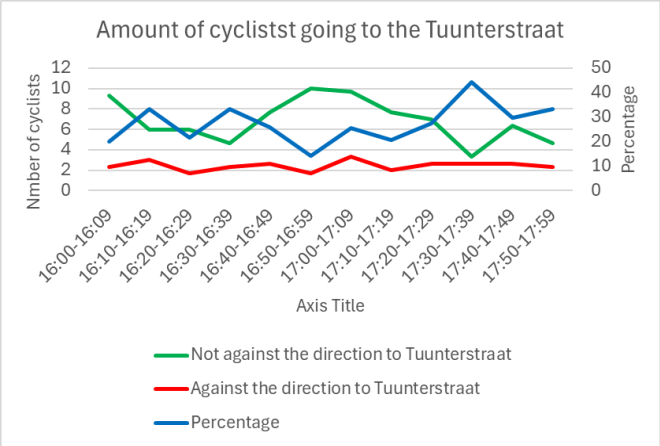


Figure D9: Amount of cyclists going against the direction to the Tuunterstraat

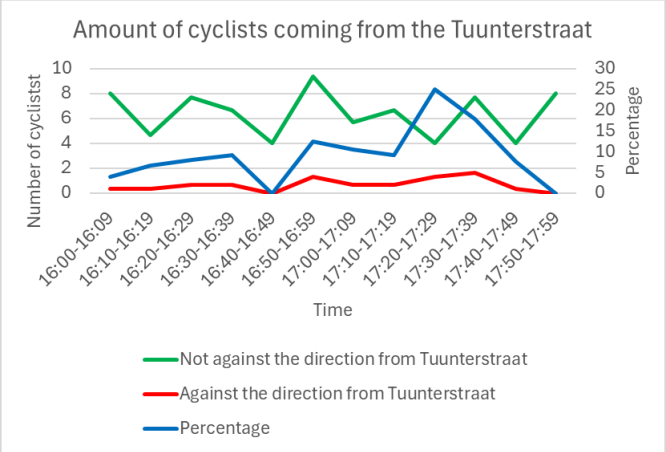


Figure D10: Amount of cyclists going against the direction from the Tuunterstraat

10.5 Appendix E: Input data current situation model

-

Time	CarSumA	CarSumB	CarSumC	CarSumD	TruckSumA	TruckSumB
16:00-16:09		64	96	29	18	0
16:10-16:19		76	99	30	13	0
16:20-16:29		68	120	28	20	1
16:30-16:39		85	119	22	16	0
16:40-16:49		90	111	25	15	0
16:50-16:59		86	101	24	17	1
17:00-17:09		89	106	21	17	0
17:10-17:19		85	113	20	16	0
17:20-17:29		89	87	23	15	0
17:30-17:39		81	69	23	11	0
17:40-17:49		69	81	16	10	0
17:50-17:59		62	65	15	8	0
	TotalA	TotalB	TotalC	TotalD	TotalAll	RF_ab
16:00-16:09		64	96	29	18	207
16:10-16:19		76	101	30	13	220
16:20-16:29		69	121	28	20	239
16:30-16:39		85	120	22	16	243
16:40-16:49		90	111	25	15	241
16:50-16:59		87	102	24	17	229
17:00-17:09		90	107	21	17	234
17:10-17:19		85	114	20	16	235
17:20-17:29		90	87	23	15	214
17:30-17:39		81	70	23	11	184
17:40-17:49		69	81	16	10	175
17:50-17:59		62	66	15	8	151
		947	**1176**	**278**	**173**	
	TotalA per hour	TotalB per hour	TotalC per hour	TotalD per hour		
16:00-16:09		385	578	172	108	
16:10-16:19		458	604	182	78	
16:20-16:29		416	728	168	120	
16:30-16:39		510	721	134	93	
16:40-16:49		541	668	152	87	
16:50-16:59		519	611	146	99	
17:00-17:09		537	640	128	99	
17:10-17:19		510	684	122	93	
17:20-17:29		538	520	140	87	
17:30-17:39		484	419	136	66	
17:40-17:49		413	487	94	57	
17:50-17:59		369	395	92	48	

Figure E1: Average intensities per 10 minutes and hour cars and trucks over days 1, 2 and 3

cycSumEurolaan(West) Per hour	CycSumTuunterstraat per hour	CycSumTuunterstraat(wrong side) per hour	CycSumHandelscentrum per hour	CycSumEuropalaan (East) per hour	CycSumJumbo per hour
50	48	2	36	46	38
50	28	2	26	28	34
54	46	4	16	32	52
60	40	4	32	44	34
48	24	0	22	60	44
56	56	8	26	44	66
46	34	4	46	26	62
74	40	4	28	52	50
54	24	8	22	38	50
58	46	10	12	18	40
38	24	2	42	10	46
34	48	0	10	28	40

Figure E2: Average intensities per hour cyclists over days 1, 2 and 3

Count: 10	No	Name	Link	Volume(0-600)	Volume(600-1200)	Volume(1200-1800)	Volume(1800-2400)	Volume(2400-3000)	Volume(3000-3600)	Volume(3600-4200)	Volume(4200-4800)	Vo
1	1		1: AB (Europalaan mac - Europalaan)	385,0	458,0	416,0	510,0	541,0	519,0	537,0	510,0	
2	2		7: Tuunterstraat C - AB	172,0	182,0	168,0	134,0	152,0	146,0	128,0	122,0	
3	3		2: BA (Europalaan - Europalaan mac)	578,0	604,0	728,0	721,0	668,0	611,0	640,0	684,0	
4	4		6: Handelscentrum	108,0	78,0	120,0	93,0	87,0	99,0	99,0	93,0	
5	5		11: Cycle lane Europalaan West	50,0	50,0	54,0	60,0	48,0	56,0	46,0	74,0	
6	6		4: Cycle lane Jumbo	38,0	34,0	52,0	34,0	44,0	66,0	62,0	50,0	
7	7		16: Cycle lane Tuunterstraat (wrong si...	2,0	2,0	4,0	4,0	0,0	8,0	4,0	4,0	
8	8		13: Cycle lane Tuunterstraat	48,0	28,0	46,0	40,0	24,0	56,0	34,0	40,0	
9	9		17: Cycle lane Europalaan East	46,0	28,0	32,0	44,0	60,0	44,0	26,0	52,0	
10	10		25: Cycle lane Handelscentrum	36,0	26,0	16,0	32,0	22,0	26,0	46,0	28,0	

Figure E3: Intensities of motorised traffic and cyclists per 10 minutes modelled in Vissim

TruckSumC	TruckSumD	RF_Car_A	RF_Tr_A	RF_Car_B	RF_Tr_B	RF_Car_C	RF_Tr_C	RF_Car_D	RD_Tr_D	
1	0	0	0,995	0,005	0,993	0,007	1,000	0,000	1,000	0,000
1	0	0	1,000	0,000	0,987	0,013	0,989	0,011	1,000	0,000
1	0	0	0,981	0,019	0,989	0,011	1,000	0,000	1,000	0,000
1	0	0	1,000	0,000	0,992	0,008	1,000	0,000	1,000	0,000
1	0	0	1,000	0,000	0,994	0,006	1,000	0,000	1,000	0,000
1	0	0	0,992	0,008	0,990	0,010	1,000	0,000	1,000	0,000
1	0	0	0,996	0,004	0,994	0,006	1,000	0,000	1,000	0,000
1	0	0	0,996	0,004	0,991	0,009	1,000	0,000	1,000	0,000
0	0	0	0,996	0,004	1,000	0,000	1,000	0,000	1,000	0,000
1	0	0	1,000	0,000	0,990	0,010	1,000	0,000	1,000	0,000
0	0	0	0,995	0,005	0,996	0,004	1,000	0,000	1,000	0,000
1	0	0	1,000	0,000	0,990	0,010	1,000	0,000	1,000	0,000

Figure E4: Mode split cars and trucks average per 10 minutes on days 1, 2 and 3

Count: 28	No	Name
1	1	A 16:00
2	2	A 16:10
3	3	A 16:20
4	4	A 16:30
5	5	A 16:40
6	6	A 16:50
7	7	A 17:00
8	8	A 17:10
9	9	A 17:20
10	10	A 17:30
11	11	A 17:40
12	12	A 17:50

Count: 2	VehType	DesSpeedDistr	RelFlow
1	100: Car	40: 40 km/h	0,995
2	200: HGV	40: 40 km/h	0,005

Figure E5: Mode split modelled in Vissim

RF_ab	RF_ac	RF_ad	RF_ba	RF_bc	RF_bd	RF_ca	RF_cb	RF_da	RF_db
0,729	0,165	0,106	0,866	0,104	0,028	0,739	0,261	0,814	0,186
72,923	16,514	10,563	86,577	10,350	2,764	73,950	26,050	81,449	18,551

Figure E6: Route choice motorised traffic days 1, 2 and 3

FROM:	Europalaan (West)							Tuunterstraat					
	RF_1	RF_2a	RF_2b	RF_3a	RF_3b	RF_Euro(East)_Hand	RF_Euro(East)_Hand	RF_4	RF_5	RF_6a	RF_6b	RF_Tuunt_Hand	RF_Tuunt_Hand
	0,305466238	0,254019293	0,028936907	0,170418006	0,118971061	0	0,122	0,314	0,546	0,066	0,022	0,000	0,052
FROM:	Tuunterstraat (wrong side)					Handelscentrum							
	RF_41	RF_51	RF_61a	RF_61b	RF_Tuunt(wrong)_Hand	RF_Hand_tuunt	RF_Hand_tuunt	RF_hand_EU(West)	RF_Hand_Jumbo	RF_Hand_Jumbo			
	0	0	0	0,083333333	0,916666667	0,459119497	0,000	0,321	0,220	0,000			
	RF_7a	RF_7b	RF_8	RF_9	RF_10a	RF_10b	RF_11a	RF_11b	RF_12	RF_Jumbo_Hand	RF_Jumbo_Hand		
	0,215962441	0	0,605633803	0,178403756	0,133093525	0,003597122	0,269784173	0,183453237	0,327338129	0,040	0,043		
FROM:	Europalaan					Jumbo							

Figure E7: Route choice cyclists days 1, 2 and 3

10.6 Appendix F: Results and verification and validation current situation

Results current situation

Table F1: Calculation of fuel consumption

Motorised vehicles	Mean StopDelay (s)	Mean Number of vehicles (per 10 min.)	Fuel consumption
Europalaan (West) to Europalaan (East) (AB)	1,4	57,8	0,80
Europalaan (West) to Handelscentrum (AD)	2,3	8,6	0,20
Europalaan (West) to Tuunterstraat (AC)	4,7	12,4	0,58
Tuunterstraat to Europalaan (West) (CA)	1,2	17,6	0,22
Tuunterstraat to Europalaan(East) (CB)	5,9	5,9	0,35
Europalaan(East) to Handelscentrum (BD)	0,1	2,7	0,00
Europalaan(East) to Tuunterstraat (BC)	0,0	10,3	0,00
Europalaan(East) to Europalaan(West) (BA)	0,0	87,0	0,00
Handelscentrum to Europalaan(West) (DA)	0,4	12,0	0,04
Handelscentrum to Europalaan(East) (DB)	2,3	2,6	0,06
Sum of all traffic flows	18,3	216,8	2,26

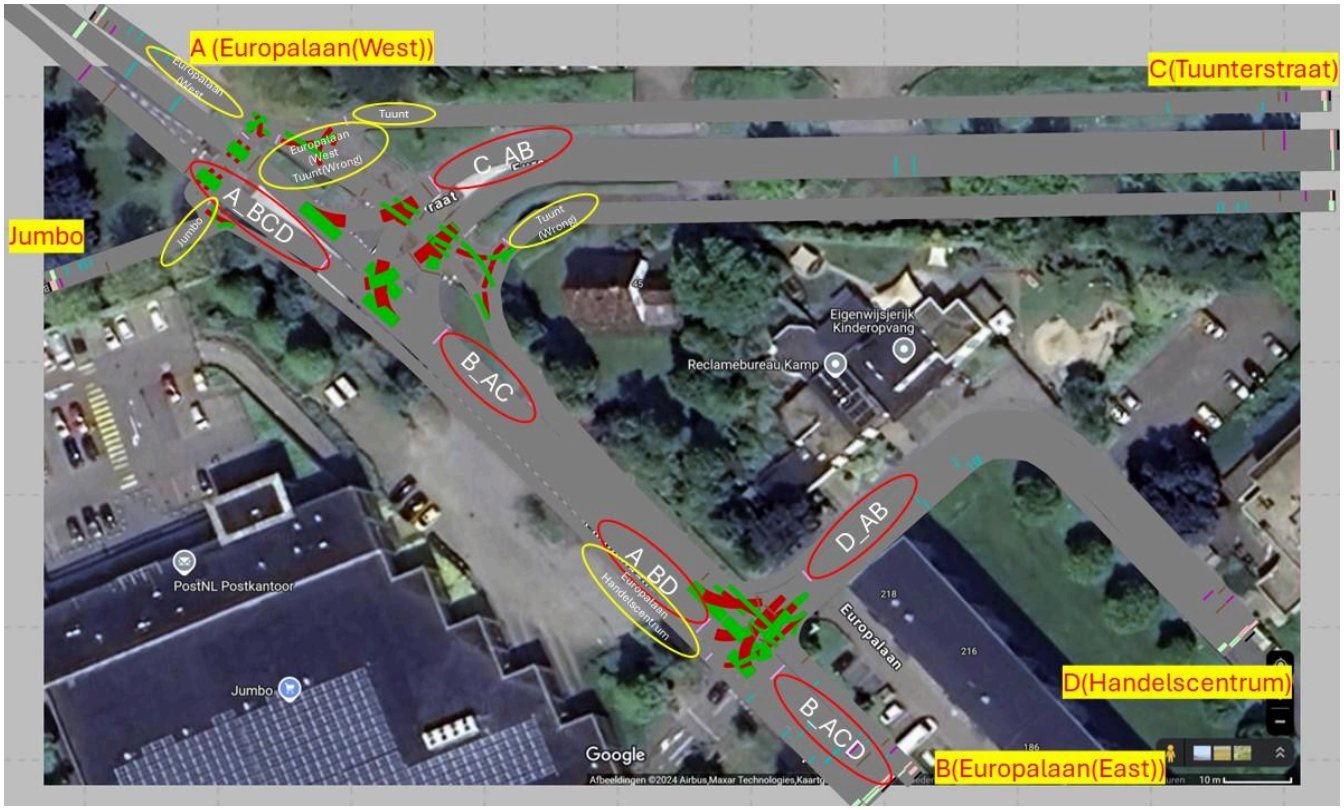


Figure F2: Places and names of queues in current situation (Red = motorised traffic queues, Yellow = Cyclists queues)

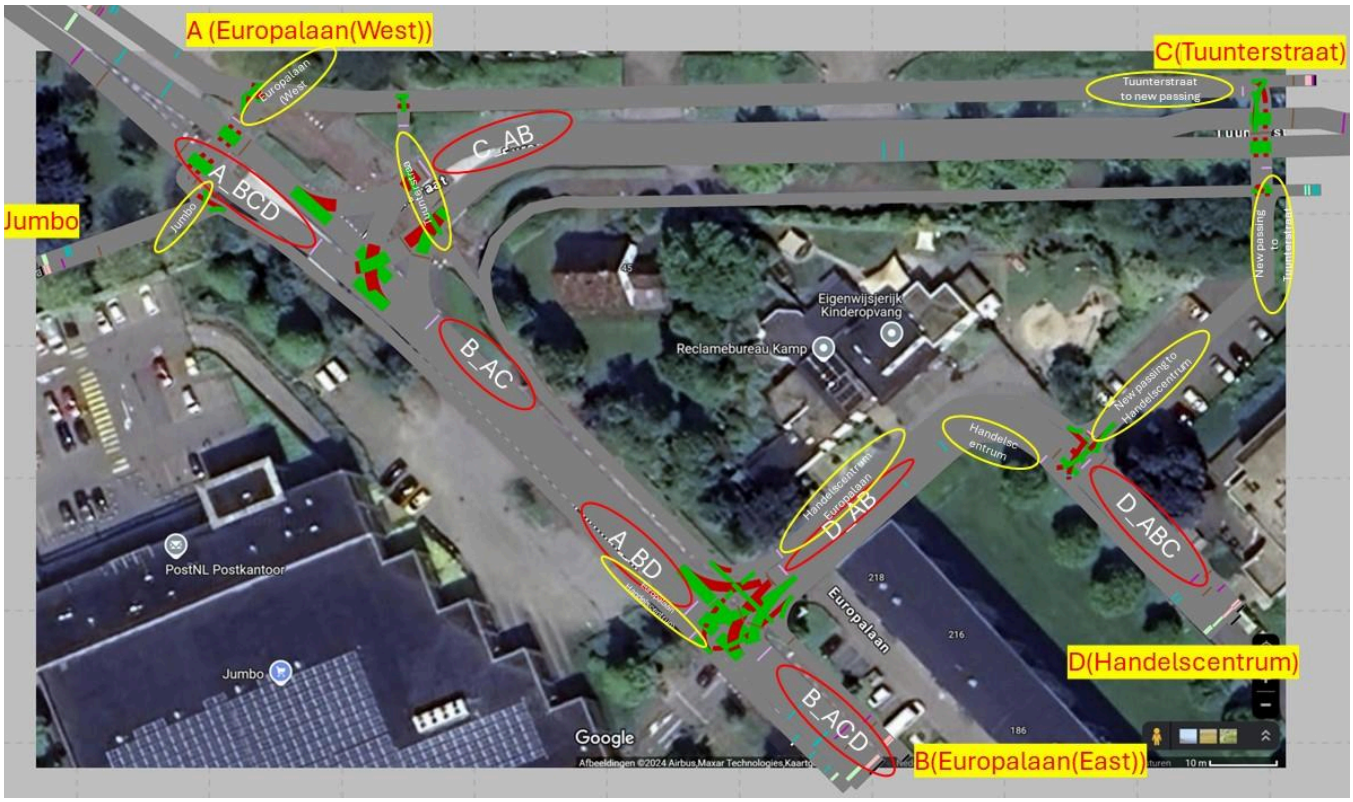


Figure F2: Places and names of queues in VVN solution (Red = motorised traffic queues, Yellow = Cyclists queues)

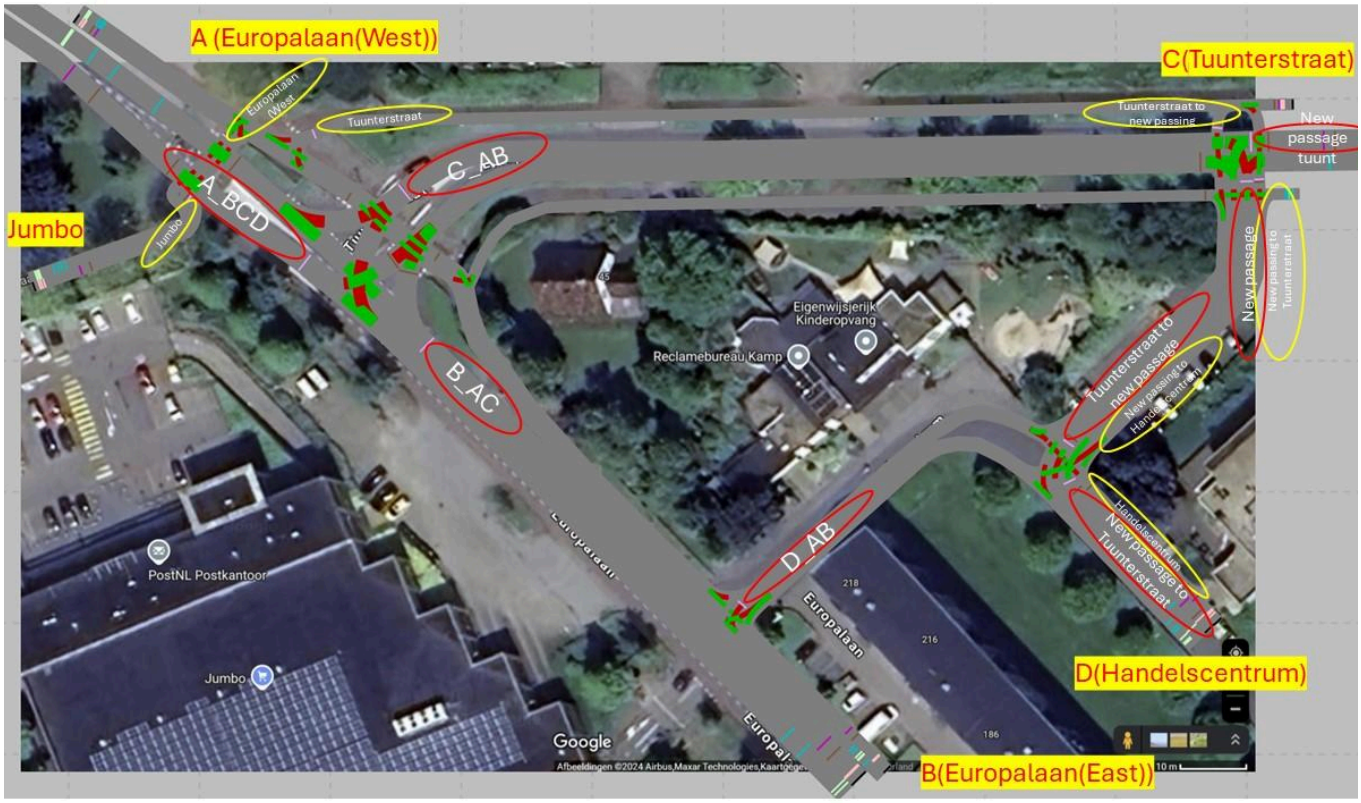


Figure F3: Places and names of queues in Municipality solution (Red = motorised traffic queues, Yellow = Cyclists queues)

Verification

Table F2: Verification input traffic

Motorised vehicles	Total vehicles generated	Total counted	Cyclists	Total cyclists generated	Total counted
Europalaan(East)	1202	1176	Europalaan(East)	69	71
Handelscentrum	175	173	Handelscentrum	51	53
Tuunterstraat	283	278	Tuunterstraat	73	76
Europalaan(West)	949	947	Tuunt(wrong)	7	8
			Europalaan(West)	101	104
			Jumbo	91	93

Table F3 Verification of static routes motorised vehicles

Motorised vehicles	Mean Number of vehicles (per 2 hour)	Number of vehicles counted (per 2 hour)
Europalaan (West) to Europalaan (East) (AB)	693	690
Europalaan (West) to Handelscentrum (AD)	103	100
Europalaan (West) to Tuunterstraat (AC)	149	156
Tuunterstraat to Europalaan (West) (CA)	211	205
Tuunterstraat to Europalaan(East) (CB)	71	72
Europalaan(East) to Handelscentrum (BD)	32	33
Europalaan(East) to Tuunterstraat (BC)	123	122
Europalaan(East) to Europalaan(West) (BA)	1044	1018
Handelscentrum to Europalaan(West) (DA)	143	141
Handelscentrum to Europalaan(East) (DB)	32	32
Sum of all traffic flows	2602	2569

Table F4: Verification of static routes cyclists

Cyclists	Mean Number of cyclists (per 2 hour)	Number of cycliststs counted
Jumbo to Europalaan(East) (10a)	10	12
Jumbo to Handelscentrum	6	8
Jumbo to Tuunterstraat (11a)	25	25
Jumbo to Tuunterstraat(wrong) (11b)	18	17
Jumbo_Europalaan(West) (12)	30	30
Europalaan(West) to Jumbo (1)	31	32
Europalaan(West) to Europalaan(East) (2a)	25	26
Europalaan(West) to Tuunterstraat (3a)	12	18
Europalaan(West) to Tuunt(wrong) (3b)	17	12
Europalaan(West) to Handelscentrum	12	13
Europalaan(East) to Tuunterstraat (7a)	43	15
Europalaan(East) to Europalaan(West) (8)	43	43
Europalaan(East) to Jumbo (9)	11	13
Handelscentrum to Tuunterstraat	23	24
Handelscentrum to Europalaan(West)	18	17
Handelscentrum to Jumbo	10	12
Tuunterstraat to Handelscentrum	4	4
Tuunterstraat to Europalaan(West) (4)	21	24
Tuunterstraat to Jumbo (5)	41	42
Tuunterstraat to Europalaan(East) (6a)	5	5
Tuunterstraat(Wrong) to Handelscentrum	7	7
Tuunt to Europalaan(East(wrong)) (6b)	1	2
Sum of all cyclists flows	412	401

Validation

Time	CarSumA	CarSumB	CarSumC	CarSumD	TruckSumA	TruckSumB	TruckSumC	TruckSumD
16:00-16:09	76,5	111,5	22,5	19,5	0	0,5	0	0
16:10-16:19	74,5	96	22,5	13,5	1	0,5	0,0	0
16:20-16:29	71	110	21	14	0	1,5	0	0
16:30-16:39	80,5	105	27	20	0,5	1,5	0	0
16:40-16:49	85,5	120	22,5	11,5	1	1,5	0	0
16:50-16:59	93,5	116	24	14,5	0	0,5	0	0
17:00-17:09	81,5	110	22	14,5	0	1	0	0
17:10-17:19	82,5	123,5	31	18	0	0	0	0
17:20-17:29	79,5	89,5	18,5	18	1	0,5	0	0
17:30-17:39	81	85	23,5	14,5	0	0,5	0	0
17:40-17:49	80	83,5	18	10	0	0	0	0
17:50-17:59	66	73,5	18,5	9,5	0	1	0	0
	TotalA	TotalB	TotalC	TotalD	TotalAll	RF_ab	RF_ac	RF_ad
16:00-16:09	76,5	112	22,5	19,5	231	0,741	0,165	0,094
16:10-16:19	75,5	96,5	22,5	13,5	208			
16:20-16:29	71	111,5	21	14	218			
16:30-16:39	81	106,5	27	20	235			
16:40-16:49	86,5	121,5	22,5	11,5	242			
16:50-16:59	93,5	116,5	24	14,5	249			
17:00-17:09	81,5	111	22	14,5	229			
17:10-17:19	82,5	123,5	31	18	255			
17:20-17:29	80,5	90	18,5	18	207			
17:30-17:39	81	85,5	23,5	14,5	205			
17:40-17:49	80	83,5	18	10	192			
17:50-17:59	66	74,5	18,5	9,5	169			
					2636,5			
	TotalA per hour	TotalB per hour	TotalC per hour	TotalD per hour				
16:00-16:09	459	672	135	117				
16:10-16:19	453	579	135	81				
16:20-16:29	426	669	126	84				
16:30-16:39	486	639	162	120				
16:40-16:49	519	729	135	69				
16:50-16:59	561	699	144	87				
17:00-17:09	489	666	132	87				
17:10-17:19	495	741	186	108				
17:20-17:29	483	540	111	108				
17:30-17:39	486	513	141	87				
17:40-17:49	480	501	108	60				
17:50-17:59	396	447	111	57				

Figure F4: Average intensities per 10 minutes and hour cars and trucks over days 4 and 5, input validation

cycSumEurolaan(West) Per hour	CycSumTuunterstraat per hour	CycSumTuunterstraat(wrong side) per hour	CycSumHandelscentrum per hour	CycSumEuropalaan (East) per hour	CycSumJumbo per hour
78	63	0	48	42	54
93	63	3	27	51	51
69	42	3	57	39	72
57	66	6	21	39	66
96	69	3	36	27	81
69	57	6	3	57	78
105	45	0	69	39	45
96	72	9	42	36	81
36	51	0	36	42	57
54	48	3	18	33	30
45	42	0	15	21	48
33	63	0	18	6	42

Figure F5: Average intensities per hour cyclists over days 4 and 5

RF_Car_A	RF_Tr_A	RF_Car_B	RF_Tr_B	RF_Car_C	RF_Tr_C	RF_Car_D	RD_Tr_D
1,000	0,000	0,996	0,004	1,000	0,000	1,000	0,000
0,987	0,013	0,995	0,005	1,000	0,000	1,000	0,000
1,000	0,000	0,987	0,013	1,000	0,000	1,000	0,000
0,994	0,006	0,986	0,014	1,000	0,000	1,000	0,000
0,988	0,012	0,988	0,012	1,000	0,000	1,000	0,000
1,000	0,000	0,996	0,004	1,000	0,000	1,000	0,000
1,000	0,000	0,991	0,009	1,000	0,000	1,000	0,000
1,000	0,000	1,000	0,000	1,000	0,000	1,000	0,000
0,988	0,012	0,994	0,006	1,000	0,000	1,000	0,000
1,000	0,000	0,994	0,006	1,000	0,000	1,000	0,000
1,000	0,000	1,000	0,000	1,000	0,000	1,000	0,000
1,000	0,000	0,987	0,013	1,000	0,000	1,000	0,000

Figure F6: Mode split cars and trucks average per 10 minutes on days 4 and 5

RF_ab	RF_ac	RF_ad	RF_ba	RF_bc	RF_bd	RF_ca	RF_cb	RF_da	RF_db
0,741	0,165	0,094	0,852	0,121	0,024	0,790	0,210	0,823	0,177

Figure F7: Route choice motorised traffic days 4 and 5

FROM:	Europalaan (West)							Tuunterstraat					
	RF_1	RF_2a	RF_2b	RF_3a	RF_3b	RF_Euro(Mac)_Hand	RF_Euro(Mac)_Hand	RF_4	RF_5	RF_6a	RF_6b	RF_Tuunt_Hand	RF_Tuunt_Hand
	0,306859	0,256318	0,014440433	0,21299639	0,104693141	0	0,105	0,300	0,498	0,079	0,026	0,000	0,097
FROM:	Tuunterstraat (wrong side)					Handelscentrum							
	RF_41	RF_51	RF_61a	RF_61b	RF_Tuunt(wrong)_Hand	RF_Hand_tuunt	RF_Hand_tuunt	RF_hand_EU(Mac)	RF_Hand_Jumbo	RF_Hand_Jumbo			
	0	0	0	0,090909091	0,909090909	0,484615385	0,000	0,323	0,192	0,000			
	RF_7a	RF_7b	RF_8	RF_9	RF_10a	RF_10b	RF_11a	RF_11b	RF_12	RF_Jumbo_Hand	RF_Jumbo_Hand		
	0,25	0	0,5625	0,1875	0,208510638	0	0,272340426	0,170212766	0,34893617	0,030	0,021		
FROM:	Europalaan				Jumbo								

Figure F8: Route choice cyclists days 4 and 5

Tables F5 and F6: Mean and peak queue lengths of motorised vehicles and cyclists

Motorised vehicles	Mean queue lenght (m)	Queue lenght max (m)
A_BCD	3,9 (192%)	150,3 (100%)
B_AC	0,0 (2320%)	73,1 (629%)
C_AB	0,1 (243%)	32,9 (121%)
C_ACD	0,0 (105%)	28,5 (102%)
A_BD	0,4 (92%)	64,2 (74%)
D_AB	0,0 (89%)	18,2 (108%)
Difference in total (%)	4,5 (174%)	367,2 (114%)

Cyclists	Mean queue lenght (%)	Queue lenght max (%)
Jumbo	0	0
Europalaan(West_	0,2 (161%)	18,1 (87%)
Europalaan(West) to Tuunt(Wrong)	0,5 (121%)	25,3 (102%)
Tuunt(Wrong)	0,0 (100%)	2,6 (90%)
Tuunterstraat	0	0
Europalaan_Handelscentrum	0	0
Sum	0,7 (128%)	45,9 (95%)

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	636	608	1110	680
Europalaan (West) to Handelscentrum (AD)	542	560	969	737
Europalaan (West) to Tuunterstraat (AC)	481	436	549	399
Tuunterstraat to Europalaan (West) (CA)	10268	17979	71974	51575
Tuunterstraat to Europalaan(East) (CB)	5824	7795	20980	13659
Europalaan(East) to Handelscentrum (BD)	530	556	4887	768
Europalaan(East) to Tuunterstraat (BC)	766	772	3543	1549
Europalaan(East) to Europalaan(West) (BA)	1088	1225	5421	4252
Difference in total (%)	2068	3130	11894	7490

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	354	360	14	38
Jumbo to Handelscentrum	366	350	608	671
Jumbo to Tuunterstraat (11a)	424	1023	1368	2358
Jumbo to Tuunterstraat(wrong) (11b)	350	355	419	344
Jumbo_Europalaan(West) (12)	380	501	534	686
Europalaan(West) to Jumbo (1)	353	296	439	285
Europalaan(West) to Europalaan(East) (2a)	352	361	432	309
Europalaan(West) to Tuunterstraat (3a)	424	1372	11113	12240
Europalaan(West) to Tuunt(wrong) (3b)	350	386	865	605
Europalaan(West) to Handelscentrum	427	1236	17543	14020
Europalaan(East) to Tuunterstraat (7a)	373	1442		
Europalaan(East) to Europalaan(West) (8)	449	1185	15821	6980
Europalaan(East) to Jumbo (9)	441	1021	1242	1963
Handelscentrum to Tuunterstraat	371	1530	36620	42334
Handelscentrum to Europalaan(West)	424	1206	32362	7775
Handelscentrum to Jumbo	427	1287	1379	3850
Tuunterstraat to Handelscentrum	396	774	5499	6660
Tuunterstraat to Europalaan(West) (4)	358	718	2622	3956
Tuunterstraat to Jumbo (5)	364	469	529	986
Tuunterstraat to Europalaan(East) (6a)	356	400	439	559
Tuunterstraat(Wrong) to Handelscentrum	361	414	1059	458
Tuunt to Europalaan(East_wrong) (6b)	368	383	4219	2491
Sum of all cyclists flows	386	787	1183	2494

Figure F9: Travel time and delay results cyclists and motorised traffic extreme condition 5 km/h test current situation

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	636	608	1110	680
Europalaan (West) to Handelscentrum (AD)	113	130	160	180
Europalaan (West) to Tuunterstraat (AC)	398	1083	758	1961
Tuunterstraat to Europalaan (West) (CA)	887	3202	371	7486
Tuunterstraat to Europalaan(East) (CB)	268	1631	151	2354
Europalaan(East) to Handelscentrum (BD)	790	3339	8197	11612
Europalaan(East) to Tuunterstraat (BC)	549	2437	4040	13366
Europalaan(East) to Europalaan(West) (BA)	631	2129	2785	10574
Difference in total (%)	385	1249	566	2500

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	783	2365	188896	104405
Jumbo to Handelscentrum	131	384	857	1082
Jumbo to Tuunterstraat (11a)	279	396	543	447
Jumbo to Tuunterstraat(wrong) (11b)	379	878	644	1589
Jumbo_Europalaan(West) (12)	467	1329	574	1612
Europalaan(West) to Jumbo (1)	764	1823	1012	2360
Europalaan(West) to Europalaan(East) (2a)	117	158	312	339
Europalaan(West) to Tuunterstraat (3a)	153	213	6380	1198
Europalaan(West) to Tuunt(wrong) (3b)	109	335	14734	3202
Europalaan(West) to Handelscentrum	86	179	5124	1560
Europalaan(East) to Tuunterstraat (7a)	216	385	-	-
Europalaan(East) to Europalaan(West) (8)	498	1278	13621	7187
Europalaan(East) to Jumbo (9)	181	1165	512	2316
Handelscentrum to Tuunterstraat	166	268	2074	1004
Handelscentrum to Europalaan(West)	234	491	7750	1807
Handelscentrum to Jumbo	136	869	187	2585
Tuunterstraat to Handelscentrum	263	962	17481	9910
Tuunterstraat to Europalaan(West) (4)	156	500	-	-
Tuunterstraat to Jumbo (5)	406	536	1253	1084
Tuunterstraat to Europalaan(East) (6a)	168	428	857	1308
Tuunterstraat(Wrong) to Handelscentrum	136	723	2258	3569
Tuunt to Europalaan(East_wrong) (6b)	89	133	4578	1422
Sum of all cyclists flows	233	649	1231	2196

Figure F10: Travel time and delay results cyclists and motorised traffic extreme condition all trucks test current situation

10.7 Appendix H: Input data VVN proposed solution model

cycSumEurolaan(West) Per hour	CycSumTuunterstraat per hour	CycSumTuunterstraat(wrong side) per hour	CycSumHandelscentrum per hour	CycSumEuropalaan (East) per hour	CycSumJumbo per hour
50	50	0	36	46	38
50	30	0	26	28	34
54	50	0	16	32	52
60	44	0	32	44	34
48	24	0	22	60	44
56	64	0	26	44	66
46	38	0	46	26	62
74	44	0	28	52	50
54	32	0	22	38	50
58	56	0	12	18	40
38	26	0	42	10	46
34	48	0	10	28	40

Figure H1: Input cyclists' intensities per hour in Vissim VVN solution

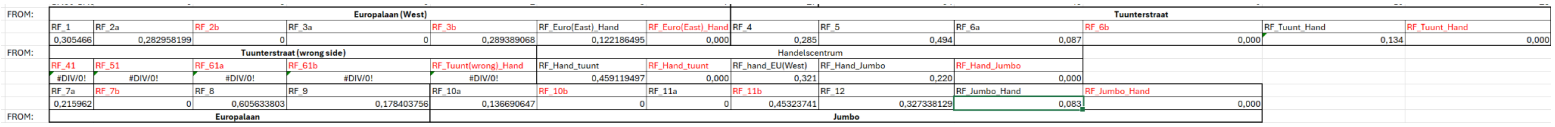


Figure H2: Input route choices cyclists in Vissim VVN solution

10.8 Appendix I: Input data Municipality proposed solution model

Time	CarSumA	CarSumB	CarSumC	CarSumD	TruckSumA	TruckSumB	TruckSumC	TruckSumD
16:00-16:0	64	94	29	15	0	1	0	0
16:10-16:1	76	93	30	12	0	1	0	0
16:20-16:2	68	116	28	16	1	1	0	0
16:30-16:3	85	116	22	12	0	1	0	0
16:40-16:4	90	110	25	12	0	1	0	0
16:50-16:5	86	97	24	14	1	1	0	0
17:00-17:0	89	104	21	15	0	1	0	0
17:10-17:1	85	109	20	12	0	1	0	0
17:20-17:2	89	84	23	13	0	0	0	0
17:30-17:3	81	69	23	8	0	1	0	0
17:40-17:4	69	79	16	6	0	0	0	0
17:50-17:5	62	64	15	7	0	1	0	0

	TotalA	TotalB	TotalC	TotalD	TotalAll	RF_ab	RF_ac	RF_ad
16:00-16:0	64	94	29	15	202	0,729	0,165	0,106
16:10-16:1	76	95	30	12	213	72,923	16,514	10,563
16:20-16:2	69	117	28	16	231			
16:30-16:3	85	117	22	12	236			
16:40-16:4	90	110	25	12	238			
16:50-16:5	87	98	24	14	223			
17:00-17:0	90	105	21	15	231			
17:10-17:1	85	110	20	12	227			
17:20-17:2	90	84	23	13	210			
17:30-17:3	81	69	23	8	181			
17:40-17:4	69	80	16	6	170			
17:50-17:5	62	64	15	7	148			

	TotalA per hour	TotalB per hour	TotalC per hour	TotalD per hour
16:00-16:0	385	566	172	90
16:10-16:1	458	568	182	69
16:20-16:2	416	704	168	96
16:30-16:3	510	700	134	72
16:40-16:4	541	662	152	72
16:50-16:5	519	590	146	84
17:00-17:0	537	628	128	90
17:10-17:1	510	660	122	72
17:20-17:2	538	502	140	78
17:30-17:3	484	416	136	48
17:40-17:4	413	478	94	33
17:50-17:5	369	386	92	39

Figure I1: Intensities motorised traffic per 10 minutes and per hour, input Municipality solution model

RF_Car_A	RF_Tr_A	RF_Car_B	RF_Tr_B	RF_Car_C	RF_Tr_C	RF_Car_D	RD_Tr_D
0,995	0,005	0,993	0,007	1,000	0,000	1,000	0,000
1,000	0,000	0,986	0,014	0,989	0,011	1,000	0,000
0,981	0,019	0,989	0,011	1,000	0,000	1,000	0,000
1,000	0,000	0,991	0,009	1,000	0,000	1,000	0,000
1,000	0,000	0,994	0,006	1,000	0,000	1,000	0,000
0,992	0,008	0,990	0,010	1,000	0,000	1,000	0,000
0,996	0,004	0,994	0,006	1,000	0,000	1,000	0,000
0,996	0,004	0,991	0,009	1,000	0,000	1,000	0,000
0,996	0,004	1,000	0,000	1,000	0,000	1,000	0,000
1,000	0,000	0,990	0,010	1,000	0,000	1,000	0,000
0,995	0,005	0,996	0,004	1,000	0,000	1,000	0,000
1,000	0,000	0,990	0,010	1,000	0,000	1,000	0,000

Figure I2: Mode split motorised traffic per 10 minutes, input Municipality solution model

RF_ab	RF_ac	RF_ad	RF_ba	RF_bc	RF_bd	RF_ca	RF_cb	RF_da	RF_db
0,729	0,165	0,106	0,890	0,110	0,000	0,739	0,261	1,000	0,000

Figure I3: Route choice motorised traffic, input Municipality solution model

cycSumEurolaan(West) Per hour	CycSumTuunterstraat per hour	CycSumTuunterstraat(wrong side) per hour	CycSumHandelscentrum per hour	CycSumEuropalaan (East) per hour	CycSumJumbo per hour
50	50	0	36	46	38
50	30	0	26	28	34
54	50	0	16	32	52
60	44	0	32	44	34
48	24	0	22	60	44
56	64	0	26	44	66
46	38	0	46	26	62
74	44	0	28	52	50
54	32	0	22	38	50
58	56	0	12	18	40
38	26	0	42	10	46
34	48	0	10	28	40

Figure I4: Input cyclists' intensities per hour in the Vissim Municipality solution

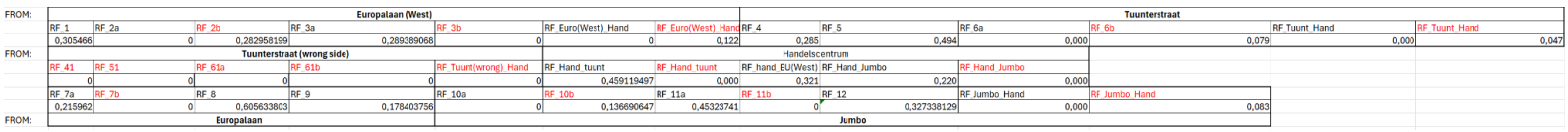


Figure I5: Input route choices cyclists in Vissim Municipality solution

10.9 Appendix J: Results VVN proposed solution

Motorised vehicles	Mean StopDelay (s)	Mean Number of vehicles (per 10 mi	Fuel consumption (L/run)
Europalaan (West) to Europalaan (East) (AB)	1,4 (95%)	57,8 (100%)	0,80 (95%)
Europalaan (West) to Handelscentrum (AD)	2,3 (95%)	8,5 (100%)	0,20 (95%)
Europalaan (West) to Tuunterstraat (AC)	4,7 (94%)	12,4 (100%)	0,58 (94%)
Tuunterstraat to Europalaan (West) (CA)	1,2 (96%)	17,6 (100%)	0,22 (96%)
Tuunterstraat to Europalaan(East) (CB)	5,9 (104%)	5,9 (100%)	0,35 (104%)
Europalaan(East) to Handelscentrum (BD)	0,1 (333%)	2,7 (100%)	0,00 (333%)
Europalaan(East) to Tuunterstraat (BC)	0,0 (109%)	10,3 (100%)	0,00 (109%)
Europalaan(East) to Europalaan(West) (BA)	0,0 (188%)	87,0 (100%)	0,00 (188%)
Handelscentrum to Europalaan(West) (DA)	0,4 (70%)	12,0 (100%)	0,04 (70%)
Handelscentrum to Europalaan(East) (DB)	2,3 (104%)	2,6 (100%)	0,06 (104%)
Sum of all traffic flows	18,3 (98%)	216,8 (100%)	2,26 (96%)

Figure J1: Fuel consumption calculation VVN proposed solution

Cyclists	Mean queue lenght (m)	Queue lenght max (m)
Jumbo crossing	0,0	0,0
Europalaan(West) crossing	0,0 (39%)	12,4 (59%)
Tuunterstraat	0,0	3,3
Europalaan to Handelscentrum	0,0	1,9
New passing to Tuunterstraat	0,0	0,0
Tuunterstraat to New passing	0,0	0,0
Handelscentrum	0,0	0,0
Handelscentrum to Europalaan	0,0	0,0
New passing to Handelscentrum	0,0	2,5
SUM	0,0	20,1

Figure J2: Mean and max queue lengths cyclists VVN proposed solution

10.10 Appendix K: Results Municipality proposed solution

Motorised vehicles	Mean StopDelay (s)	Mean Number of vehicles (per 10 min.)	Fuel consumption (L/run)
Europalaan (West) to Europalaan (East) (AB)	1,4 (96%)	57,0 (99%)	0,79 (94%)
Europalaan (West) to Handelscentrum (AD)	4,5 (180%)	8,8 (102%)	0,39 (184%)
Europalaan (West) to Tuunterstraat (AC)	4,1 (81%)	13,0 (105%)	0,53 (85%)
Tuunterstraat to Europalaan (West) (CA)	1,5 (113%)	17,6 (100%)	0,26 (113%)
Tuunterstraat to Europalaan(East) (CB)	6,1 (108%)	5,9 (100%)	0,36 (108%)
Europalaan(East) to Tuunterstraat (BC)	0,0 (62%)	10,5 (103%)	0,00 (64%)
Europalaan(East) to Europalaan(West) (BA)	0,0 (35%)	86,3 (99%)	0,00 (35%)
Handelscentrum to Europalaan(West) (DA)	1,5 (289%)	11,7 (97%)	0,18 (281%)
Sum of all traffic flows	19,0 (102%)	210,7 (98%)	2,51 (107%)

Figure K1: Fuel consumption calculation Municipality proposed solution

Motorised vehicles	Mean queue lenght (m)	Queue lenght max (m)
A_BCD	2,7 (134%)	123,5 (82%)
B_AC	0,0 (36%)	10,0 (86%)
C_AB	0,3 (528%)	47,1 (173%)
New passage	0,0	4,7
New passage	0,0	7,3
Tuunterstraat to New passage	0,0	23,7
New passage to Tuunterstraat	0,2	22,5
Difference in total (%)	3,032 (118%)	216,4 (67%)

Figure K2: Mean and max queue lengths motorised traffic Municipality proposed solution

Cyclists	Mean queue lenght (m)	Queue lenght max (m)
Jumbo crossing	0,0	3,9
Europalaan(West) crossing	0,1 (98%)	14,8 (71%)
Tuunterstraat	0,0	0,0
Handelscentrum	0,0	3,7
New passage	0,0	2,6
New passage	0,0	0,0
Sum	0,1 (18%)	25,0 (52%)

Figure K3: Mean and max queue lengths cyclists Municipality proposed solution

10.11 Appendix L: Verification and validation VVN proposed solution

Verification

Motorised vehicles	Total vehicles generated per run	Total counted	Cyclists	Total cyclists generated	Total counted
Europalaan(East)	1202	1176	Europalaan(East)	69	71
Handelscentrum	175	173	Handelscentrum	51	53
Tuunterstraat	444	278	Tuunterstraat	82	84
Europalaan(West)	704	947	Tuunt(wrong)	0	0
			Europalaan(West)	101	104
			Jumbo	91	93

Figure L1: Verification generated vehicles VVN proposed solution motorised vehicles and cyclists

Validation

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	100	119	100	138
Europalaan (West) to Handelscentrum (AD)	102	130	117	194
Europalaan (West) to Tuunterstraat (AC)	102	115	110	133
Tuunterstraat to Europalaan (West) (CA)	102	105	115	114
Tuunterstraat to Europalaan(East) (CB)	101	87	106	80
Europalaan(East) to Handelscentrum (BD)	100	94	78	42
Europalaan(East) to Tuunterstraat (BC)	100	94	101	43
Europalaan(East) to Europalaan(West) (BA)	101	101	115	105
Handelscentrum to Europalaan(West) (DA)	100	96	95	78
Handelscentrum to Europalaan(East) (DB)	99	91	94	86
Sum of all traffic flows	101	105	106	113

Figure L2: Validation travel time and delay results motorised vehicles VVN solution day 4 and 5

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	101	99	68	64
Jumbo to Handelscentrum	103	94	131	125
Jumbo to Tuunterstraat (11a)	100	101	97	121
Jumbo_Europalaan(West) (12)	100	102	104	97
Europalaan(West) to Jumbo (1)	100	65	103	50
Europalaan(West) to Europalaan(East) (2a)	101	92	112	94
Europalaan(West) to Tuunterstraat (3a)	100	86	83	66
Europalaan(West) to Handelscentrum	100	97	123	115
Europalaan(East) to Tuunterstraat (7a)	100	98	94	104
Europalaan(East) to Europalaan(West) (8)	100	102	215	241
Europalaan(East) to Jumbo (9)	99	77	90	58
Handelscentrum to Tuunterstraat	100	100	375	368
Handelscentrum to Europalaan(West)	101	101	168	63
Handelscentrum to Jumbo	101	112	117	159
Tuunterstraat to Handelscentrum	100	103	89	116
Tuunterstraat to Europalaan(West) (4)	100	101	138	101
Tuunterstraat to Jumbo (5)	102	100	115	113
Tuunterstraat to Europalaan(East) (6a)	100	88	109	63
Difference in total (%)	86	86	111	111

Figure L3: Validation travel time and delay results cyclists VVN solution day 4 and 5

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	1107	910	2712	985
Europalaan (West) to Handelscentrum (AD)	841	839	1983	1195
Europalaan (West) to Tuunterstraat (AC)	762	691	1029	703
Tuunterstraat to Europalaan (West) (CA)	11355	19790	79812	56811
Tuunterstraat to Europalaan(East) (CB)	6651	8107	24238	14063
Europalaan(East) to Handelscentrum (BD)	553	673	5958	1582
Europalaan(East) to Tuunterstraat (BC)	805	804	4098	1600
Europalaan(East) to Europalaan(West) (BA)	1135	1237	6080	4295
Handelscentrum to Europalaan(West) (DA)	1022	2029	5341	7729
Handelscentrum to Europalaan(East) (DB)	758	1510	1741	2579
Difference in total (%)	2575	3764	14286	8807

Figure L4: Extreme scenario test 5 km/h travel time and delay results motorised vehicles VVN solution

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	352	375		
Jumbo to Handelscentrum	356	322	442	303
Jumbo to Tuunterstraat (11a)	353	323	412	247
Jumbo_Europalaan(West) (12)	354	465	424	501
Europalaan(West) to Jumbo (1)	348	207	395	147
Europalaan(West) to Europalaan(East) (2a)	352	251	424	173
Europalaan(West) to Tuunterstraat (3a)	352	339	383	142
Europalaan(West) to Handelscentrum	354	358	441	224
Europalaan(East) to Tuunterstraat (7a)	351	364	740	355
Europalaan(East) to Europalaan(West) (8)	485	2331	52278	65021
Europalaan(East) to Jumbo (9)	516	1109	1880	1572
Handelscentrum to Tuunterstraat	352	371		
Handelscentrum to Europalaan(West)	463	463	28021	8863
Handelscentrum to Jumbo	441	1276	1656	5154
Tuunterstraat to Handelscentrum	365	410	799	679
Tuunterstraat to Europalaan(West) (4)	352	376	1461	1063
Tuunterstraat to Jumbo (5)	359	403	471	727
Tuunterstraat to Europalaan(East) (6a)	423	407	1071	500
Difference in total (%)	336	532	1127	1830

Figure L5: Extreme scenario test 5 km/h travel time and delay results cyclists VVN solution

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	304	381	1466	671
Europalaan (West) to Handelscentrum (AD)	264	420	1098	982
Europalaan (West) to Tuunterstraat (AC)	260	398	762	725
Tuunterstraat to Europalaan (West) (CA)	1221	2495	8174	7059
Tuunterstraat to Europalaan(East) (CB)	833	1246	2891	2152
Europalaan(East) to Handelscentrum (BD)	152	194	655	343
Europalaan(East) to Tuunterstraat (BC)	153	170	816	425
Europalaan(East) to Europalaan(West) (BA)	189	240	1993	1431
Handelscentrum to Europalaan(West) (DA)	282	882	2153	4080
Handelscentrum to Europalaan(East) (DB)	298	830	868	1516
Difference in total (%)	411	759	2142	1787

Figure L6: Extreme scenario test all trucks travel time and delay results motorised vehicles VVN solution

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	100	100	179	151
Jumbo to Handelscentrum	112	145	259	300
Jumbo to Tuunterstraat (11a)	111	118	238	179
Jumbo_Europalaan(West) (12)	130	187	278	282
Europalaan(West) to Jumbo (1)	132	83	277	72
Europalaan(West) to Europalaan(East) (2a)	116	90	272	73
Europalaan(West) to Tuunterstraat (3a)	101	101	143	135
Europalaan(West) to Handelscentrum	100	100	132	132
Europalaan(East) to Tuunterstraat (7a)	104	316	509	1647
Europalaan(East) to Europalaan(West) (8)	115	347	6063	8567
Europalaan(East) to Jumbo (9)	125	141	329	151
Handelscentrum to Tuunterstraat	100	100	100	100
Handelscentrum to Europalaan(West)	114	114	3578	2402
Handelscentrum to Jumbo	124	342	448	1396
Tuunterstraat to Handelscentrum	110	458	389	1808
Tuunterstraat to Europalaan(West) (4)	100	100	378	220
Tuunterstraat to Jumbo (5)	115	134	290	235
Tuunterstraat to Europalaan(East) (6a)	138	247	493	432
Difference in total (%)	113	170	349	422

Figure L7: Extreme scenario test all trucks travel time and delay results cyclists VVN solution

10.12 Appendix M: Verification and validation Municipality proposed solution

Verification

Motorised vehicles	Total vehicles generated per run	Total counted	Cyclists	Total cyclists generated	Total counted
Europalaan(East)	1163,6	1143	Europalaan(East)	68,9	71
Handelscentrum	140	141	Handelscentrum	50,8	53
Tuunterstraat	282,7	278	Tuunterstraat	82,4	84
Europalaan(West)	949,1	947	Tuunt(wrong)	0	0
			Europalaan(West)	101,1	104
			Jumbo	90,5	93

Figure M1: Verification generated vehicles VVN proposed solution motorised vehicles and cyclists

Validation

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	102	105	111	111
Europalaan (West) to Handelscentrum (AD)	103	112	118	123
Europalaan (West) to Tuunterstraat (AC)	104	119	117	139
Tuunterstraat to Europalaan (West) (CA)	103	105	116	109
Tuunterstraat to Europalaan(East) (CB)	103	82	109	72
Europalaan(East) to Tuunterstraat (BC)	101	108	144	206
Europalaan(East) to Europalaan(West) (BA)	102	102	153	112
Handelscentrum to Europalaan(West) (DA)	103	124	123	178
Difference in total (%)	103	107	116	115

Figure M2: Validation travel time and delay results motorised vehicles Municipality solution day 4 and 5

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	101	100	110	110
Jumbo to Handelscentrum	99	100	90	79
Jumbo to Tuunterstraat (11a)	101	101	114	65
Jumbo_Europalaan(West) (12)	105	137	132	164
Europalaan(West) to Jumbo (1)	103	99	118	94
Europalaan(West) to Europalaan(East) (2a)	100	96	60	36
Europalaan(West) to Tuunterstraat (3a)	100	100	130	148
Europalaan(West) to Handelscentrum	100	101	85	86
Europalaan(East) to Tuunterstraat (7a)	98	91	45	96
Europalaan(East) to Europalaan(West) (8)	100	102	147	100
Europalaan(East) to Jumbo (9)	101	98	111	65
Handelscentrum to Tuunterstraat	99	90	14	18
Handelscentrum to Europalaan(West)	100	109	133	214
Handelscentrum to Jumbo	101	96	114	114
Tuunterstraat to Handelscentrum	100	87	72	73
Tuunterstraat to Europalaan(West) (4)	101	100	260	184
Tuunterstraat to Jumbo (5)	101	108	117	121
Tuunterstraat to Europalaan(East) (6a)	100	100	95	95
Difference in total (%)	100	101	109	95

Figure M3: Validation travel time and delay results cyclists Municipality solution day 4 and 5

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	1103	1570	2694	2512
Europalaan (West) to Handelscentrum (AD)	758	1405	1686	2733
Europalaan (West) to Tuunterstraat (AC)	938	1643	1857	2670
Tuunterstraat to Europalaan (West) (CA)	11529	16901	56502	35108
Tuunterstraat to Europalaan(East) (CB)	7422	8468	24521	13153
Europalaan(East) to Tuunterstraat (BC)	957	3032	12950	35327
Europalaan(East) to Europalaan(West) (BA)	1197	1197	13982	6981
Handelscentrum to Europalaan(West) (DA)	6792	12870	44644	41494
Difference in total (%)	3723	5965	19315	13507

Figure M4: Extreme scenario test 5 km/h travel time and delay results motorised vehicles Municipality solution

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	410	974	1161	2203
Jumbo to Handelscentrum	410	1368	1168	4379
Jumbo to Tuunterstraat (11a)	458	1261	1790	2850
Jumbo_Europalaan(West) (12)	370	1711	504	3342
Europalaan(West) to Jumbo (1)	332	551	313	700
Europalaan(West) to Europalaan(East) (2a)	405	1681	16599	8936
Europalaan(West) to Tuunterstraat (3a)	492	1473	11449	9406
Europalaan(West) to Handelscentrum	406	816	15884	7134
Europalaan(East) to Tuunterstraat (7a)	402	2034	2165	8398
Europalaan(East) to Europalaan(West) (8)	420	2103	116134	47291
Europalaan(East) to Jumbo (9)	402	1446	910	2999
Handelscentrum to Tuunterstraat	471	9381	37833	50689
Handelscentrum to Europalaan(West)	483	5108	17848	83659
Handelscentrum to Jumbo	489	2986	1970	1970
Tuunterstraat to Handelscentrum	537	1170	4348	4314
Tuunterstraat to Europalaan(West) (4)	357	439	1800	1733
Tuunterstraat to Jumbo (5)	348	426	341	665
Tuunterstraat to Europalaan(East) (6a)	423	1641	2497	6563
Difference in total (%)	425	1858	1825	6458

Figure M5: Extreme scenario test 5 km/h travel time and delay results cyclists Municipality solution

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)
Europalaan (West) to Europalaan (East) (AB)	303	418	1327	798
Europalaan (West) to Handelscentrum (AD)	243	306	789	590
Europalaan (West) to Tuunterstraat (AC)	274	342	836	578
Tuunterstraat to Europalaan (West) (CA)	938	1914	4330	3921
Tuunterstraat to Europalaan(East) (CB)	663	1014	2036	1555
Europalaan(East) to Tuunterstraat (BC)	169	278	2102	2424
Europalaan(East) to Europalaan(West) (BA)	208	208	4915	1907
Handelscentrum to Europalaan(West) (DA)	2482	6335	16736	20818
Difference in total (%)	717	1424	3741	3284

Figure M6: Extreme scenario test all trucks travel time and delay results motorised vehicles Municipality solution

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	126	291	421	652
Jumbo to Handelscentrum	114	126	289	190
Jumbo to Tuunterstraat (11a)	159	293	864	642
Jumbo_Europalaan(West) (12)	129	202	264	293
Europalaan(West) to Jumbo (1)	131	136	276	160
Europalaan(West) to Europalaan(East) (2a)	118	292	5106	1394
Europalaan(West) to Tuunterstraat (3a)	158	705	4631	4975
Europalaan(West) to Handelscentrum	109	221	2762	1660
Europalaan(East) to Tuunterstraat (7a)	101	132	135	271
Europalaan(East) to Europalaan(West) (8)	119	285	29955	5038
Europalaan(East) to Jumbo (9)	127	233	365	398
Handelscentrum to Tuunterstraat	100	92	33	19
Handelscentrum to Europalaan(West)	120	232	2757	2418
Handelscentrum to Jumbo	119	281	318	318
Tuunterstraat to Handelscentrum	136	228	879	730
Tuunterstraat to Europalaan(West) (4)	100	102	255	246
Tuunterstraat to Jumbo (5)	112	124	248	232
Tuunterstraat to Europalaan(East) (6a)	138	370	1078	1330
Difference in total (%)	123	248	548	727

Figure M7: Extreme scenario test all trucks travel time and delay results cyclists Municipality solution

10.13 Appendix N: Effects assumptions and increase volume

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	120	166	265	241	403
Europalaan (West) to Handelscentrum (AD)	112	92	222	274	315
Europalaan (West) to Tuunterstraat (AC)	105	82	183	233	239
Tuunterstraat to Europalaan (West) (CA)	194	323	195	280	319
Tuunterstraat to Europalaan(East) (CB)	126	156	205	213	299
Europalaan(East) to Handelscentrum (BD)	100	99	104	71	68
Europalaan(East) to Tuunterstraat (BC)	98	98	129	105	115
Europalaan(East) to Europalaan(West) (BA)	92	101	175	140	317
Handelscentrum to Europalaan(West) (DA)	101	106	129	136	174
Handelscentrum to Europalaan(East) (DB)	100	87	102	77	119
Sum of all traffic flows	115	127	188	203	315

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	101	100	64	58
Jumbo to Handelscentrum	103	109	132	202
Jumbo to Tuunterstraat (11a)	104	140	164	226
Jumbo_Europalaan(West) (12)	114	135	138	186
Europalaan(West) to Jumbo (1)	108	110	143	113
Europalaan(West) to Europalaan(East) (2a)	107	142	185	277
Europalaan(West) to Tuunterstraat (3a)	101	98	195	130
Europalaan(West) to Handelscentrum	100	362	269	227
Europalaan(East) to Tuunterstraat (7a)	98	100	70	16
Europalaan(East) to Europalaan(West) (8)	100	99	212	210
Europalaan(East) to Jumbo (9)	107	132	168	150
Handelscentrum to Tuunterstraat	100	100	3	4
Handelscentrum to Europalaan(West)	100	88	129	55
Handelscentrum to Jumbo	106	142	174	242
Tuunterstraat to Handelscentrum	100	98	40	66
Tuunterstraat to Europalaan(West) (4)	101	98	56	29
Tuunterstraat to Jumbo (5)	104	119	157	218
Tuunterstraat to Europalaan(East) (6a)	101	113	101	144
Sum of all cyclists flows	102	127	149	172

Figure N1: Current situation +20% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	125	189	277	287	441
Europalaan (West) to Handelscentrum (AD)	119	204	244	409	364
Europalaan (West) to Tuunterstraat (AC)	121	170	201	256	271
Tuunterstraat to Europalaan (West) (CA)	113	134	194	199	303
Tuunterstraat to Europalaan(East) (CB)	128	143	208	181	298
Europalaan(East) to Handelscentrum (BD)	100	111	103	51	85
Europalaan(East) to Tuunterstraat (BC)	101	95	114	70	141
Europalaan(East) to Europalaan(West) (BA)	103	105	151	137	282
Handelscentrum to Europalaan(West) (DA)	104	109	143	144	232
Handelscentrum to Europalaan(East) (DB)	101	89	106	83	125
Sum of all traffic flows	114	145	197	217	342

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	99	98	30	37
Jumbo to Handelscentrum	97	113	98	180
Jumbo to Tuunterstraat (11a)	108	148	164	206
Jumbo_Europalaan(West) (12)	119	132	142	174
Europalaan(West) to Jumbo (1)	111	134	156	155
Europalaan(West) to Europalaan(East) (2a)	106	98	186	107
Europalaan(West) to Tuunterstraat (3a)	105	108	326	112
Europalaan(West) to Handelscentrum	126	158	499	760
Europalaan(East) to Tuunterstraat (7a)	64	157	2572	1047
Europalaan(East) to Europalaan(West) (8)	104	77	93	58
Europalaan(East) to Jumbo (9)	113	127	184	136
Handelscentrum to Tuunterstraat	30	30	0	1
Handelscentrum to Europalaan(West)	103	78	738	391
Handelscentrum to Jumbo	108	129	142	164
Tuunterstraat to Handelscentrum	33	42	131	265
Tuunterstraat to Europalaan(West) (4)	99	97	38	50
Tuunterstraat to Jumbo (5)	105	124	164	218
Tuunterstraat to Europalaan(East) (6a)	63	79	162	173
Sum of all cyclists flows	89	103	162	201

Figure N2: VVN solution +20% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	143	267	369	440	539
Europalaan (West) to Handelscentrum (AD)	167	265	356	520	563
Europalaan (West) to Tuunterstraat (AC)	135	200	235	310	271
Tuunterstraat to Europalaan (West) (CA)	128	208	253	443	326
Tuunterstraat to Europalaan(East) (CB)	128	166	194	232	265
Europalaan(East) to Tuunterstraat (BC)	102	100	83	75	278
Europalaan(East) to Europalaan(West) (BA)	99	92	104	150	451
Handelscentrum to Europalaan(West) (DA)	171	213	453	477	795
Sum of all traffic flows	138	203	269	363	415

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	131	172	21749	4641
Jumbo to Handelscentrum	110	136	132	310
Jumbo to Tuunterstraat (11a)	107	113	174	98
Jumbo_Europalaan(West) (12)	118	139	154	193
Europalaan(West) to Jumbo (1)	117	159	194	197
Europalaan(West) to Europalaan(East) (2a)	83	67	3	20
Europalaan(West) to Tuunterstraat (3a)	103	102	216	165
Europalaan(West) to Handelscentrum	101	97	73	69
Europalaan(East) to Tuunterstraat (7a)	66	82	2395	196
Europalaan(East) to Europalaan(West) (8)	98	75	45	73
Europalaan(East) to Jumbo (9)	106	133	163	146
Handelscentrum to Tuunterstraat	30	29	8	6
Handelscentrum to Europalaan(West)	103	113	729	323
Handelscentrum to Jumbo	105	136	155	37
Tuunterstraat to Handelscentrum	34	35	241	123
Tuunterstraat to Europalaan(West) (4)	101	107	359	131
Tuunterstraat to Jumbo (5)	105	131	167	241
Tuunterstraat to Europalaan(East) (6a)	50	46	29	37
Sum of all cyclists flows	86	97	148	151

Figure N3: Municipality solution +20% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	289	607	1444	1150	3629,9
Europalaan (West) to Handelscentrum (AD)	113	91	986	1299	2183,0
Europalaan (West) to Tuunterstraat (AC)	105	83	759	1264	1406,3
Tuunterstraat to Europalaan (West) (CA)	403	1286	1487	3077	4010,9
Tuunterstraat to Europalaan(East) (CB)	312	652	913	1195	1799,3
Europalaan(East) to Handelscentrum (BD)	100	97	138	59	314,6
Europalaan(East) to Tuunterstraat (BC)	100	99	171	101	238,8
Europalaan(East) to Europalaan(West) (BA)	95	108	257	212	3086,6
Handelscentrum to Europalaan(West) (DA)	112	144	263	317	711,1
Handelscentrum to Europalaan(East) (DB)	119	144	196	183	393,9
Sum of all traffic flows	176	329	837	1069	2530,3

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	102	100	349	147
Jumbo to Handelscentrum	116	190	294	655
Jumbo to Tuunterstraat (11a)	122	159	419	271
Jumbo_Europalaan(West) (12)	166	362	392	650
Europalaan(West) to Jumbo (1)	144	226	349	310
Europalaan(West) to Europalaan(East) (2a)	122	187	375	366
Europalaan(West) to Tuunterstraat (3a)	102	102	313	130
Europalaan(West) to Handelscentrum	101	403	415	691
Europalaan(East) to Tuunterstraat (7a)	99	99	139	27
Europalaan(East) to Europalaan(West) (8)	104	110	682	289
Europalaan(East) to Jumbo (9)	125	214	345	361
Handelscentrum to Tuunterstraat	100	100	54	99
Handelscentrum to Europalaan(West)	108	353	3608	2234
Handelscentrum to Jumbo	116	162	302	373
Tuunterstraat to Handelscentrum	101	111	177	210
Tuunterstraat to Europalaan(West) (4)	102	146	462	608
Tuunterstraat to Jumbo (5)	124	188	393	507
Tuunterstraat to Europalaan(East) (6a)	113	162	282	393
Sum of all cyclists flows	112	182	354	463

Figure N4: Current situation +50% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	268	693	1234	1335	3266,2
Europalaan (West) to Handelscentrum (AD)	213	519	935	1322	2077,1
Europalaan (West) to Tuunterstraat (AC)	225	578	704	1150	1317,3
Tuunterstraat to Europalaan (West) (CA)	334	1271	1832	3538	5091,4
Tuunterstraat to Europalaan(East) (CB)	329	765	1003	1308	1978,5
Europalaan(East) to Handelscentrum (BD)	101	96	123	46	114,7
Europalaan(East) to Tuunterstraat (BC)	102	98	160	93	420,3
Europalaan(East) to Europalaan(West) (BA)	107	115	237	236	1774,1
Handelscentrum to Europalaan(West) (DA)	115	154	296	386	944,5
Handelscentrum to Europalaan(East) (DB)	123	194	209	290	411,0
Sum of all traffic flows	205	515	854	1193	2510,3

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	100	98	93	39
Jumbo to Handelscentrum	104	124	194	268
Jumbo to Tuunterstraat (11a)	122	136	359	171
Jumbo_Europalaan(West) (12)	159	170	341	252
Europalaan(West) to Jumbo (1)	153	294	391	433
Europalaan(West) to Europalaan(East) (2a)	123	149	395	259
Europalaan(West) to Tuunterstraat (3a)	105	108	407	135
Europalaan(West) to Handelscentrum	127	123	780	339
Europalaan(East) to Tuunterstraat (7a)	63	62	978	49
Europalaan(East) to Europalaan(West) (8)	106	88	358	147
Europalaan(East) to Jumbo (9)	125	226	307	411
Handelscentrum to Tuunterstraat	30	29	0	1
Handelscentrum to Europalaan(West)	105	79	958	296
Handelscentrum to Jumbo	125	185	358	444
Tuunterstraat to Handelscentrum	34	39	240	165
Tuunterstraat to Europalaan(West) (4)	100	132	208	325
Tuunterstraat to Jumbo (5)	124	165	390	388
Tuunterstraat to Europalaan(East) (6a)	70	117	252	334
Sum of all cyclists flows	96	122	330	304

Figure N5: VVN solution +50% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	319	426	1593	767	3525,3
Europalaan (West) to Handelscentrum (AD)	292	409	1245	924	2650,4
Europalaan (West) to Tuunterstraat (AC)	267	384	843	709	1367,1
Tuunterstraat to Europalaan (West) (CA)	319	1053	1477	3207	3105,5
Tuunterstraat to Europalaan(East) (CB)	277	605	758	1093	1240,5
Europalaan(East) to Tuunterstraat (BC)	105	146	155	474	3383,6
Europalaan(East) to Europalaan(West) (BA)	103	96	186	188	264,8
Handelscentrum to Europalaan(West) (DA)	405	1681	3231	7406	12104,1
Sum of all traffic flows	272	587	1164	1416	2725,3

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	150	253	48871	9105
Jumbo to Handelscentrum	121	120	277	242
Jumbo to Tuunterstraat (11a)	126	445	442	1156
Jumbo_Europalaan(West) (12)	155	181	341	263
Europalaan(West) to Jumbo (1)	149	220	373	295
Europalaan(West) to Europalaan(East) (2a)	84	88	10	75
Europalaan(West) to Tuunterstraat (3a)	112	466	1714	4394
Europalaan(West) to Handelscentrum	103	101	307	363
Europalaan(East) to Tuunterstraat (7a)	66	80	2261	190
Europalaan(East) to Europalaan(West) (8)	100	132	266	483
Europalaan(East) to Jumbo (9)	120	181	295	288
Handelscentrum to Tuunterstraat	30	29	13	13
Handelscentrum to Europalaan(West)	104	121	1555	356
Handelscentrum to Jumbo	118	147	325	78
Tuunterstraat to Handelscentrum	35	38	351	168
Tuunterstraat to Europalaan(West) (4)	101	100	358	161
Tuunterstraat to Jumbo (5)	123	135	393	273
Tuunterstraat to Europalaan(East) (6a)	52	52	45	66
Sum of all cyclists flows	94	148	319	421

Figure N6: Municipality solution +50% volume increase compared to the current situation without an increase

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	97	99	106	101	93,3
Europalaan (West) to Handelscentrum (AD)	113	91	103	101	95,2
Europalaan (West) to Tuunterstraat (AC)	104	80	98	168	96,2
Tuunterstraat to Europalaan (West) (CA)	163	260	104	178	102,4
Tuunterstraat to Europalaan(East) (CB)	103	122	120	145	102,6
Europalaan(East) to Handelscentrum (BD)	99	100	100	101	109,4
Europalaan(East) to Tuunterstraat (BC)	98	96	111	86	91,9
Europalaan(East) to Europalaan(West) (BA)	90	94	135	92	164,5
Handelscentrum to Europalaan(West) (DA)	98	100	97	106	78,0
Handelscentrum to Europalaan(East) (DB)	97	98	89	99	87,0
Tuunterstraat to Handelscentrum (CD)					
Handelscentrum to Tuunterstraat (DC)					
Sum of all same traffic flows	107	110	105	126	95,9

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	100	100	53	44
Jumbo to Handelscentrum	99	104	93	208
Jumbo to Tuunterstraat (11a)	101	98	108	98
Jumbo_Europalaan(West) (12)	106	103	96	109
Europalaan(West) to Jumbo (1)	100	91	99	83
Europalaan(West) to Europalaan(East) (2a)	99	85	93	80
Europalaan(West) to Tuunterstraat (3a)	100	100	104	100
Europalaan(West) to Handelscentrum	100	362	88	97
Europalaan(East) to Tuunterstraat (7a)	99	99	126	26
Europalaan(East) to Europalaan(West) (8)	100	77	75	76
Europalaan(East) to Jumbo (9)	103	116	124	121
Handelscentrum to Tuunterstraat	100	100	42	72
Handelscentrum to Europalaan(West)	100	88	164	108
Handelscentrum to Jumbo	100	107	98	117
Tuunterstraat to Handelscentrum	100	100	70	100
Tuunterstraat to Europalaan(West) (4)	100	116	144	230
Tuunterstraat to Jumbo (5)	100	100	103	93
Tuunterstraat to Europalaan(East) (6a)	100	89	93	83
Sum of all cyclists flows	100	112	101	106

Figure N7: Current situation with traffic CD and DC compared to current situation without traffic CD and DC

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%)
Europalaan (West) to Europalaan (East) (AB)	98	98	98	97	96
Europalaan (West) to Handelscentrum (AD)	99	95	97	93	96
Europalaan (West) to Tuunterstraat (AC)	100	100	96	100	95
Tuunterstraat to Europalaan (West) (CA)	107	118	95	140	98
Tuunterstraat to Europalaan(East) (CB)	109	146	114	186	105
Europalaan(East) to Handelscentrum (BD)	100	100	99	103	238
Europalaan(East) to Tuunterstraat (BC)	102	105	106	126	88
Europalaan(East) to Europalaan(West) (BA)	100	99	115	96	257
Handelscentrum to Europalaan(West) (DA)	99	101	85	103	58
Handelscentrum to Europalaan(East) (DB)	99	128	95	153	95
Tuunterstraat to Handelscentrum (CD)					
Handelscentrum to Tuunterstraat (DC)					
Sum of all traffic flows	102	104	98	106	94

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	98	98	27	23
Jumbo to Handelscentrum	96	89	81	116
Jumbo to Tuunterstraat (11a)	105	108	115	69
Jumbo_Europalaan(West) (12)	110	93	97	86
Europalaan(West) to Jumbo (1)	104	106	119	102
Europalaan(West) to Europalaan(East) (2a)	101	110	124	142
Europalaan(West) to Tuunterstraat (3a)	105	113	319	185
Europalaan(West) to Handelscentrum	126	129	514	230
Europalaan(East) to Tuunterstraat (7a)	62	62	534	89
Europalaan(East) to Europalaan(West) (8)	104	78	44	23
Europalaan(East) to Jumbo (9)	104	93	96	62
Handelscentrum to Tuunterstraat	30	30	3	4
Handelscentrum to Europalaan(West)	102	77	196	88
Handelscentrum to Jumbo	106	118	111	156
Tuunterstraat to Handelscentrum	34	34	189	138
Tuunterstraat to Europalaan(West) (4)	99	97	13	19
Tuunterstraat to Jumbo (5)	100	99	99	106
Tuunterstraat to Europalaan(East) (6a)	58	80	82	175
Sum of all cyclists flows	86	87	106	108

Figure N8: VVN solution with traffic CD and DC compared to the current situation without traffic CD and DC

Motorised vehicles	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak delay (%)	Fuel consumption (%
Europalaan (West) to Europalaan (East) (AB)	106	84	113	63	92,3
Europalaan (West) to Handelscentrum (AD)	140	132	162	140	182,0
Europalaan (West) to Tuunterstraat (AC)	106	110	99	113	84,0
Tuunterstraat to Europalaan (West) (CA)	110	121	138	162	111,7
Tuunterstraat to Europalaan(East) (CB)	108	121	120	138	103,4
Europalaan(East) to Tuunterstraat (BC)	101	96	60	55	114,4
Europalaan(East) to Europalaan(West) (BA)	97	91	66	97	58,3
Handelscentrum to Europalaan(West) (DA)	155	169	276	268	297,7
Tuunterstraat to Handelscentrum (CD)					
Handelscentrum to Tuunterstraat (DC)					
Sum of all traffic flows	117	117	131	125	107,6

Cyclists	Mean travel time (%)	Travel time peak (%)	Mean delay (%)	Peak Delay (%)
Jumbo to Europalaan(East) (10a)	124	142	13455	2892
Jumbo to Handelscentrum	107	103	97	145
Jumbo to Tuunterstraat (11a)	103	117	119	145
Jumbo_Europalaan(West) (12)	106	93	98	91
Europalaan(West) to Jumbo (1)	100	87	99	76
Europalaan(West) to Europalaan(East) (2a)	83	70	3	22
Europalaan(West) to Tuunterstraat (3a)	103	106	237	190
Europalaan(West) to Handelscentrum	101	95	70	111
Europalaan(East) to Tuunterstraat (7a)	66	77	2078	160
Europalaan(East) to Europalaan(West) (8)	98	74	7	10
Europalaan(East) to Jumbo (9)	100	119	109	130
Handelscentrum to Tuunterstraat	30	32	165	201
Handelscentrum to Europalaan(West)	102	93	357	51
Handelscentrum to Jumbo	101	97	106	25
Tuunterstraat to Handelscentrum	33	40	169	130
Tuunterstraat to Europalaan(West) (4)	100	99	130	65
Tuunterstraat to Jumbo (5)	100	108	110	126
Tuunterstraat to Europalaan(East) (6a)	50	47	22	45
Sum of all cyclists flows	84	85	97	98

Figure N9: Municipality solution with traffic CD and DC compared to current situation without traffic CD and DC

10.14 Appendix M: Safety assessment

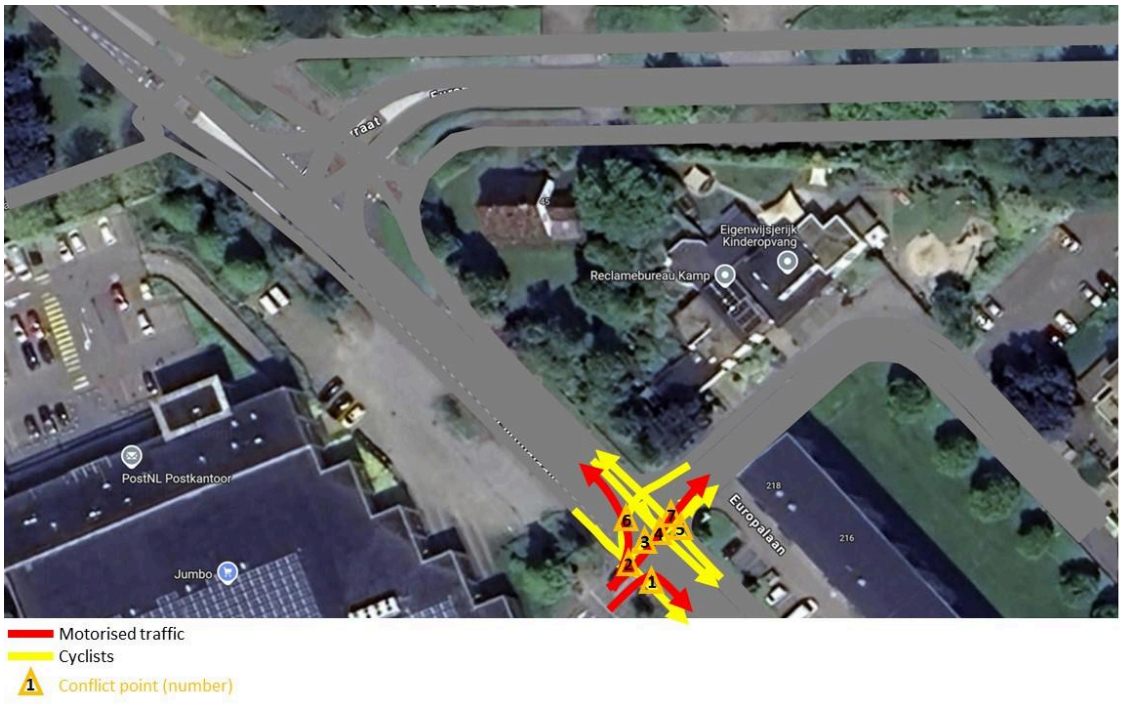


Figure M1: Extra conflict points cyclists with motorised traffic from the exit of the Jumbo in the current situation

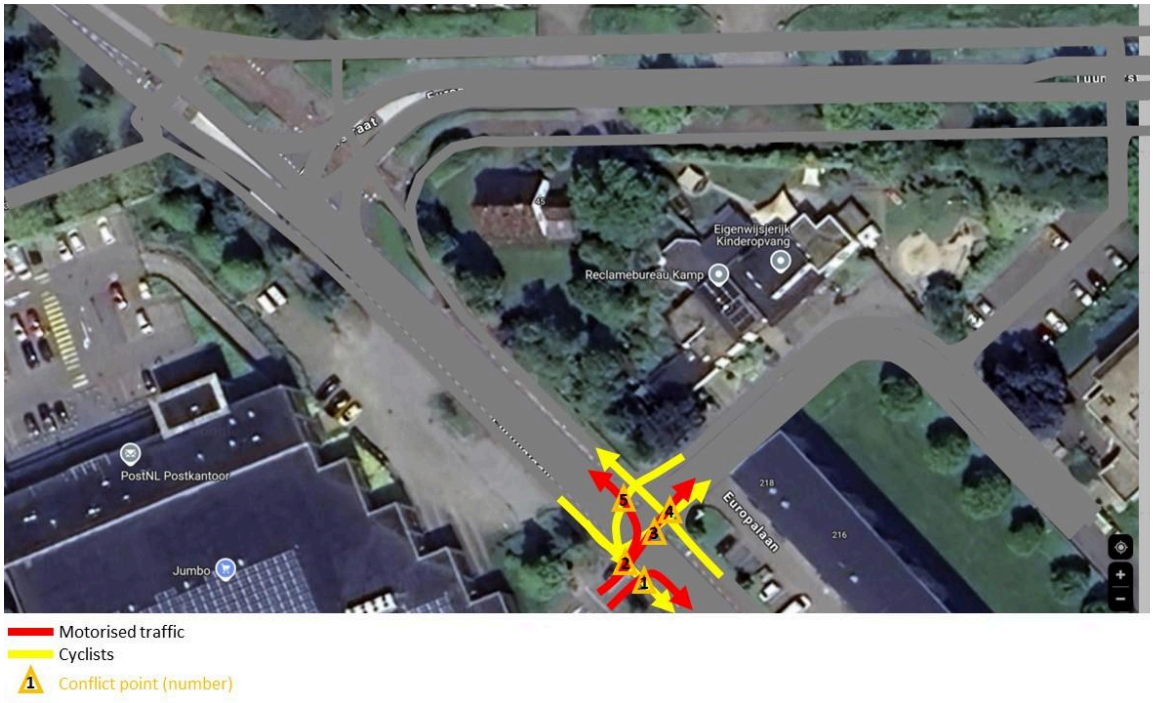


Figure M2: Extra conflict points cyclists with motorised traffic from the exit of the Jumbo in the solution of VVN

Conflict point	Conflict angle (degrees)	Speed motorised traffic (km/h)	Speed cyclists	Speed difference	Number of vehicles passing per 10 min.
1	90	39,1	10,7	28,3	79
2	90	39,1	12,9	26,2	79
3	90	40,3	12,9	27,4	117
4	90	40,3	10,7	29,5	117
5	90	25,6	17,6	8,0	24
6	90	25,6	17,6	8,0	24
7	90	19,1	17,6	1,5	23
8	90	19,1	17,6	1,5	23
9	90				66
10	0				58
11	45-90				100
12	90	12,3	17,2	-4,8	60
13	45-90				109
14	90	12,3	18,7	-6,4	11
15	90	13,9	18,7	-4,8	15
16	90	14,7	17,2	-2,5	15
Sum of all conflict points	1170	301,4	189,4	112,0	917

Figure M3: Safety assessment of the current situation

Conflict point	Conflict angle	Mean speed motorised traffic (km/h)	Speed cyclists (km/h)	Speed difference	Number of vehicles passing
1	90	39,0	10,8	28,2	79
2	90	39,0			79
3	90	40,3			117
4	90	40,3	10,8	29,4	117
5	90-180	26,9	17,6	9,3	24
6	45-90	19,2	17,6	1,6	23
7	90				11
8	45-90				11
9	45-90	12,3		12,3	100
10	45-90				109
11	90	12,3	17,5	-5,2	11
12	90	13,5	17,5	-4,1	15
13	90	22,7	16,5	6,2	11
14	90	22,7			11
15	90	34,1			15
16	90	34,1	16,5	17,6	15
17	90		17,6		23
18	90				23
19	90				24
20	90		17,6		24
Sum of all conflict points	1350	356,6	160,2	95,4	838

Figure M4: Safety assessment of the VVN proposed solution

Conflict point	Conflict angle	Speed motorised vehicles (km/h)	Speed cyclists (km/h)	Speed difference	Number of vehicles passing
1	90	37,0	11,3	25,7	79
2	90	37,0			79
3	90	38,9			116
4	90	38,9	11,3	27,5	116
5	90	25,4	17,5	7,9	35
6	90	25,4	17,3	8,1	35
7	90	18,6	17,3	1,3	24
8	90	18,6	17,5	1,1	24
9	90	20,8	17,0	3,8	9
10	45	20,8			9
11	90	31,9			12
12	90	31,9	17,0	14,9	12
13	90		16,6		9
14	90		16,6		12
15	90	36,3	14,3	22,0	28
16	90	36,3			24
17	90	31,9			24
18	90	31,9	14,3	17,6	35
Sum of all conflict points	1575	481,7	188,0	130,1	677

Figure M5: Safety assessment of the Municipality proposed solution