Bachelor assignment

Redesign of the intersection of the N343, De Aanleg and Gunnerstraat in Weerselo

(Google maps, 2024)

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Preface

This bachelor thesis has been made as part of the Civil Engineering program at the University of Twente in Enschede. The research is executed at Buro TWIN who got the assignment from the municipality Dinkelland. The research has taken place from November 2024 to Januari 2025.

The question from the municipality is to come up with a possible redesign of the N343 through Weerselo. A plan already exists for making a bypass around Weerselo, however there are doubts if this is possible. Therefore, a new plan will be made for the road laying in its current position.

This research will focus on one intersection in Weerselo, which is the most problematic intersection. The intersection will be simulated in simulation program VISSIM and the redesign will also be simulated. The simulations, combined with determining stakeholders wishes and requirements and keeping them in mind has always been in my interest. Therefore, this research project was a proper fit for me.

I want to thank Ing. Roy Nieuwe Weme, my external supervisor from Buro TWIN, and Dr. Ir. Oskar Eikenbroek, my internal supervisor from the University of Twente, for assisting me and giving me support whenever I needed help or had questions.

Further, I want to thank everyone who has helped me during my research. So, all employees of Buro TWIN for giving me a pleasant time and giving me the opportunity to do my research there. Also, I want to thank my friends who wanted to help me collect the data in the early morning cold and for supporting me.

At last, I want to thank my friends and family for supporting me the last few years while studying at the university.

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Executive summary

Overall, this research is about the intersection between the N343, De Aanleg and De Gunnerstraat in Weerselo. Here there are three main issues regarding flow of traffic, safety and social cohesion. The flow of traffic gets interrupted for the main link, the N343, by crossing traffic and too small pre-sorting bays and therefore blocking the road partly. For the roads, Gunnerstraat and De Aanleg the flow is severely disturbed, with a significant problem at De Aanleg with large queues. The vehicles of these roads are not able to cross or join the traffic on the N343.

Furthermore, cyclists and pedestrians are not able to cross the N343 due to the significant flow. This causes safety issues with cyclists for example crossing the road when there is too little space because they do not want to wait any longer. This is the same case for the vehicles trying to cross or join the N343.

For the social cohesion there is also the problem of not being able to cross the road. This divides Weerselo into two parts which is negatively for the social cohesion. Furthermore, there are two restaurants and a meeting point at the intersection which are hardly connected due to the intersection which is hard to cross.

This report focusses on the re-design of this intersection in the form of an oval roundabout. To simulate both models in simulation program VISSIM, data is gathered via data collection by counting the traffic in a 2-hour period during the busiest moment on the intersection, the morning rush.

Using this data the models can be generated and the travel time, vehicle delays and number of stops can be determined per model. These are the main points where the model is evaluated upon. Further there are several design evaluation points such as space and a safety assessment with the number of conflict areas and the complexity of them.

Overall is the result from this report that there are positive and negative points for both solutions. There is a positive point for the vehicle delays which are mostly solved for De Aanleg the main problem point. However, a smaller queue is present for the traffic of the N343 coming from the north. However, the safety issues for the small pre-sorting bays in between the roads are solved.

For the cyclists the problems are solved regarding crossing and traffic flow as the travel times and delays have improved significantly. Therefore, the social cohesion also has improved due to the better accessibility for cyclists and pedestrians on the intersection, connecting Weerselo and the restaurants and the meeting point.

The main limitation for this project was the amount of data available. The models are based on one data set of one count and are validated with another dataset based on one 2-hour period of counting vehicles. Another problem is that the model was only able to run at 90% of the intensity of vehicles as otherwise the model stopped working according to reality. A recommendation is to discuss the results with all stakeholders. If there are overall positive reactions the suggestion is to investigate gathering more data and fine-tuning the model and design. If there are overall negative reactions to the design and results another design must be evaluated, such as a signalized intersection.

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1. Introduction

Figure 1: Overview of the intersection

There are many unregulated intersections in the region of Twente and several of them are located between a provincial road and side roads connecting the towns with the provincial road. These unregulated intersections however lead to numerous issues, when a high volume of vehicles is present, including suboptimal traffic flow and safety concerns. Figure 1 shows one of these intersections that is present in the center of Weerselo.

In Weerselo, the N343 between Oldenzaal and Fleringen divides the town in two which gives a large degree of nuisance and unsafe situations specifically on this intersection with the roads De Aanleg and Gunnerstraat. For over two decades there have been plans to make a ring road around the town, however it has not been realised due to several reasons including high construction and maintenance cost and an increase in travel time. These problems will be further discussed in this paper and are mentioned in Ecorys (17-12-2015).

Therefore, the municipality asked Buro Twin, a civil engineering firm, to explore what is possible with the road, laying in its current position, to make the center of Weerselo safer for all road users and to reduce nuisance, so that the residents are comfortable crossing and living close to the provincial road dividing the town. As such, in this research project a plan will be made to determine what a possible solution for this intersection is. Consequently, the solution must be sustainable so that the problems are solved once and for all. Next to that, the solution must comply with all the wishes of the users of the road and the citizens of Weerselo, so complying with the stakeholders wishes.

This project will focus on the specific intersection. The aim of this project is to design an improved version of this intersection, overcoming the safety and traffic flow issues that currently exist. Here, practical considerations, such as the availability of space and stakeholders' concerns are considered.

To accommodate this the current situation will get analyzed and data will be gathered to make a micro simulation in VISSIM, a simulation program. Based on this simulation a

proposed solution of an oval roundabout will get modeled and evaluated. Both positive and negative points will be analyzed to give a general conclusion if a roundabout is a suitable solution for this intersection, considering safety, traffic flow and stakeholder wishes.

2. Project definition

The project definition includes the general context of the project, the problem statement, the research objective and the research questions. These four points give a general overview of the project from which research can start off.

2.1 Context

This chapter consists of three parts giving more context to the situation and the background of the research project. In the first part the background and reasons leading towards this research are stated. In the second part a general overview of the study area will be given, so the placement and the roads connected to the intersection. The third part of this chapter gives an overview of the involved parties in this research project, so the actual stakeholders and their power and interests.

2.1.1 Reasons and background of study

Research has been done towards the effects of the bypass in comparison to the current situation and what will happen with the current N343 through Weerselo if the bypass is made. This research is done as a social cost-benefit analysis where the social perceptions and actual data with for example noise nuisance is monetized to make it measurable (Ecorys, 17-12-2015).

The outcomes of this research can be found in annex I where the conclusion is drawn that the costs of making the bypass in comparison to the current situation has a negative effect of €13.5 million and therefore the conclusion of the cost-benefit analysis is that it is better to not construct the bypass. The main reason for this is that the costs of making the bypass and maintaining the bypass and the current road will cost a significant amount of money while not enough positive effects are present for the citizens living next to the current road.

The problem with this situation is that citizens of Weerselo do not agree with this conclusion as they feel that the road being as it is, is having more negative effects than is currently considered and is monetized in that way. For example, in looking at the data the main road has a flow of 700 cars per hour, per direction, with a capacity of 1200 cars per hour, per direction, theoretically which gives that the way the intersection and the crossing points are sufficient designed. However, this is not the feeling the stakeholders have and therefore data does not reflect the actual situation. Stakeholders feel there is a lack of safety and that the flow of the intersection is not smooth and gets interrupted by stopping vehicles. This is one of the more general problems of monetizing perceptions of people as it is hard to measure the actual perception of a person towards things like safety or the perception of flow on the intersection.

This is one of the problems that is present in the current society where everything must be monetized, and everything is considered as a “dead” object instead which will take the most rational logical decisions which is not always the case. Society is a “living” and dynamic thing where everything interacts with each other and where mistakes are made. By not taking this into account, stakeholders’ wishes and requirements are neglected due to other larger effects.

This is also the paradigm in current traffic engineering, the assumption is that cars are a non-living object and that they travel from A to B in the most logical way. (Filippi, 2022) Therefore, current traffic engineering is mostly focused on motorized traffic and mostly on cars. The roads and intersections are made mostly efficient for cars and are ignoring the cyclists and pedestrians. (Kreps, 2024)

As a conclusion, this project right now is focusing on finding a more workable solution for the intersection in the current layout of the road as the possibility of the bypass is out of the picture. However, the paradigm shift should be considered that the traffic situation is a living and dynamic system and therefore not the overall priority has to be given to the motorized traffic but also towards the non-motorized traffic and the stakeholders living next to the intersection and the citizens who are feeling the effects the intersection has on the city of Weerselo.

As an addition to the conclusion for making a more workable solution for this intersection and improving the intersection another possibility is present. This is making the intersection worse and therefore having less demand for the intersection as it takes more time to drive over the intersection or it is less convenient to do so. This is possible as there are routes around Weerselo to get from A to B in the same time or within 5 minutes extra. (Google maps, 2024) However the focus of this project is to look if there is enough improvement with the current situation and having the same demand. In this way, there is still a lot of traffic traveling through Weerselo which is good for, for example, the companies in Weerselo. If less vehicles travel through the town, less possible customers appear at the stores. Therefore, the focus will be on improving the situation and not making it less attractive to drive through.

2.1.2 The study area

The study area is the intersection of the provincial road, the N343, and the two side roads, De Aanleg coming from the North-East and the Gunnerstraat coming from the South-West as can be seen in figure 2.

Figure 2: Overview of the Intersection (AutoCAD, 2024)

The research is scoped to this intersection because there is only a limited amount of time of 10 weeks for doing this research assignment and then researching the whole N343 running through Weerselo and finding a solution would not be possible. Therefore, the decision has been made to focus the assignment towards the most troublesome intersection, according to the municipalities and experiences of road users, in the road and try to find a solution for improving this intersection.

Figure 3: Placement of the intersection (Google Maps, 2024)

Now looking at the roads leading to and going from the intersection, figure 3, it can visually be seen that the provincial road, the N343 is the priority road making the connection towards the larger city of Oldenzaal and therefore also a connection to the highway A1. Going the

other way towards the North-West there is the connection towards the intersection with the N349 leading towards the larger city of Almelo.

The side road De Aanleg comes from the town Ootmarsum and smaller town Groot Agelo, which results in traffic coming and going to those towns for, for example, work.

The side road Gunnerstraat comes from the town Saasveld, but this road is also a road to go to or come from the larger towns Borne and Hengelo and therefore this road is also used quite often for, for example, traveling to and from work.

The intersection is most busy in the morning during the morning rush. It is especially busy for traffic coming from De Aanleg to cross or turn on to the provincial road, as they must yield for crossing traffic. Particularly since traffic on the provincial road has priority over traffic on the side roads.

2.1.3 Involved parties

The involved parties are based on previous knowledge of intersection redevelopment, knowledge of the situation from Buro TWIN and the Municipality and talking with users of the intersection. In this way a complete overview can be made from the involved parties and their interests.

The question for Buro Twin to find a solution for redesigning the provincial road came from the municipality and the province that Weerselo is part of, which are the municipality of Dinkelland and the province of Overijssel. The reason the municipality and the province have asked this is because both instances see the problems with the road and the problems of the intersection where the local roads intersect with the provincial road. The local road is the responsibility of the municipality to take care of and the provincial road is the responsibility of the province of Overijssel. Therefore, they both are large stakeholders in this project as they together are responsible for the intersection and improving it.

As this research assignment focusses on one specific intersection and not on the complete road section in Weerselo there are also more specific stakeholders present in this situation. The reason for only focusing on this intersection is explained in section “The study area”. So, looking at the intersection the stakeholders are all road users that make use of the intersection. These will be motorists, cyclists and pedestrians coming from all directions and going to all possible directions.

The other stakeholders are the people living in the neighborhood of the intersection, restaurant owners and in general the residents of Weerselo who have to deal with the road being there as it is and having the road as a general barrier in the town. This leads to less social cohesion and less possibilities to form a center in the town which is accessible for

the whole town. The reason for this is the provincial road which has a significant amount of traffic, and which has safety issues making it hard to cross and therefore making it a barrier in the town.

In the remainder of this section, an overview of the stakeholders is given with their power and interest.

Province of Overijssel

The province of Overijssel is responsible for the N343 and is the road authority. Therefore, the province is an important stakeholder with a significant amount of interest in having a save road and having a road with a sufficient flow and capacity. Having a road with a sufficient flow can get measured in several ways which will be discussed in the methodology and is linked to the Measures of Effectiveness. (FHWA, 21-03-2021) These measures of effectiveness will get discussed further in chapter 3 and in appendix A.

Municipality of Dinkelland

The municipality of Dinkelland is responsible for the livability of all citizens in the municipality, so also the citizens living next to the N343 and the intersection. Next to this, the municipality is responsible for the roads connecting with the N343, so the roads De Aanleg and the Gunnerstraat are under the jurisdiction of the municipality. Therefore, the municipality has a significant amount of interest in improving the intersection and for improving the live ability and the safety of the intersection. Next to this the municipality wants the traffic crossing the N343 having a safe and easy crossing where they can easily blend in with the traffic of the N343.

These wishes can be linked towards MOE points like speed. Speed can give an estimation of the safety of the intersection, the lower the speed of the vehicles the more overview is possible as there is more time to react with a lower driving speed.

Motorized traffic

The motorized traffic is driving towards all directions, but the main traffic flow is on the N343 going straight ahead. Their interest is that they do not want to get disturbed in their driving and have a smooth travel from A to B.

For motorized traffic coming from and going towards the side roads, De Aanleg and Gunnerstraat, their interests are different. They want to have a save and easy crossing on the intersection and being able to get through the main traffic on the N343. Right now, this is relatively hard as the gaps between cars, so the headways, are small. Therefore, it is in the interest of these motorists to have an easier and more safe crossing.

Next to the private motorized traffic, there are two bus lines running through the intersection on the N343. The bus lines go through the intersection each halve hour per direction. The busses are 1 minute apart from each other. (Rrreis, 2025) The bus lines should not be neglected, and the design of the new intersection should be made in such a way that busses still can drive over the intersection.

These gaps can be linked to the MOE point, the density of the road N343 which is relatively high and therefore the gaps between the vehicles are too small and the number of sufficient gaps is not sufficient.

Cyclists

Cyclists are cycling parallel with the N343 and the cycling path has priority over the traffic coming from the side roads. This makes that these cyclists have a safe crossing and an easy flow which is in their interest. However, their flow gets interrupted when motorists are standing on the cycling path while they are waiting to cross the N343. This is a problem for the flow of the cyclists and a safety issue and therefore it is in the interest of the cyclists to solve this.

There are also cyclists coming from the side roads which do not have a problem with the N343 when turning towards the right as there is a cycling path there and there is no need to cross the road. However, the problems are present when cyclists want to cross the N343 to go straight ahead or to turn towards the left. There are bicycle crossings, however these are not in the direct line of cycling and therefore these are neglected as can be seen in figure 4. In this way cyclists are in the same position as the motorists which is not safe and, in this way, cyclists have the same problems as the motorists of not being able to get in between the traffic on the N343. Therefore, the interests of these cyclists should not be neglected.

Figure 4: Cyclist using the middle sorting bay

Pedestrians

There are no actual crossings solely for pedestrians, the pedestrians must share the crossing with the cyclists which is all right as there is enough space available. This leads therefore to the same problems of the cyclists and motorists of not being able to cross the road due to the small headways between cars on the N343.

For the pedestrians walking parallel with the N343 there is not an actual crossing, and the pedestrians do not have priority over the cars which can lead to unsafe situations. Therefore, this should be something to be considered which is also in the interest of the pedestrians.

Citizens living next to the intersection

Citizens living next to the intersection have mostly problems with the nuisance the N343 gives. There is noise pollution due to the motorists driving on the intersection and mostly the number of motorists on the N343 is high. Next to this seeing an unsafe intersection is nerve wracking which gives stress (Lazaro et al., 2022)

Restaurant owners

The same points as for the citizens living next to the intersection apply for the restaurant owners and the guests. The intersection can scare customers away from the meeting point and the two restaurants on the corners of the intersection. This is not ideal for the restaurant owners and therefore the owners have high interest in a safe and nuisance free intersection. However, they do not have much power as there are only two restaurants which is not a significant amount.

Residents of Weerselo

The residents of Weerselo have interest in changing the intersection towards a safer intersection which is comfortable to cross. It is mostly that the residents want the N343 to be rerouted as the road is dividing the town the two parts and creating nuisance and unsafe situations which divides the town. Therefore, the interest of the residents is important, however changing the whole N343 is not in the scope of this project and therefore for that problem no solution will be given in this project. However, for the safety and having an easier crossing, the interests will be taken seriously, and these improvements do help with the perception of the N343 and the feelings of the residents.

2.2 Problem statement

There are overall problems that are present which are based on the stakeholders wishes. These are for example the safety and disturbances in the traffic flow which are problems that must be considered in the research project.

From the stakeholder analysis and a site visit the following main problems can be determined as can be seen in figure 5.

Problem 1, the blue stars, relate to the problems with the restaurant owners and the connection with the meeting point that the intersection divides these three points with each other. This leads to less social cohesion in the town.

Problem 2, the orange stars, relates to the vehicle presorting bays. Those are too small for a larger car or van to stand on without blocking other traffic.

Problem 3, the green stars, relate to the problem of pedestrians and cyclists not having a safe and convenient place to cross the N343.

Problem 4, the yellow stars, relate the problems of the crossing roads that are not able to get on the N343 or cross it because they must yield for oncoming traffic. Especially because the N343 has priority over the other side roads.

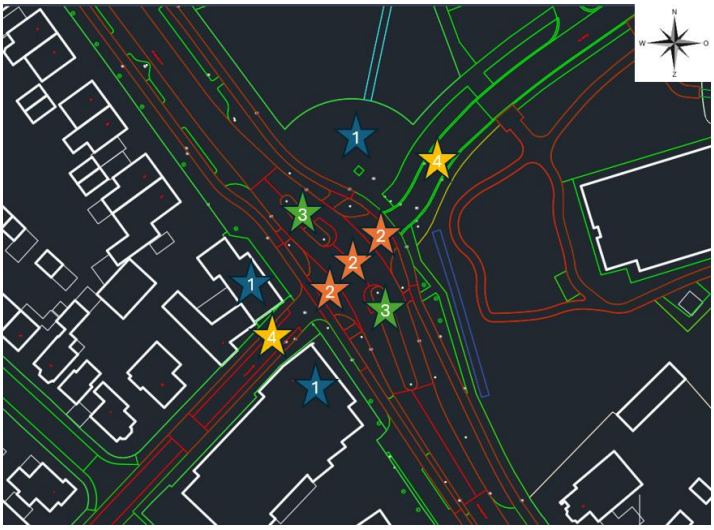

Figure 5: Overview of problems (AutoCAD, 2024)

In this problem statement an overview is made where the stakeholders' interests, measures of effectiveness are compared with the problems on the intersection as can be seen in table 1.

Table 1: Overview interests, MOE and problems

Stakeholder interests	**Measure of Effectiveness**	**Problems**	**Explanation**
Improvement in social cohesion	Traffic flow, safety and social cohesion	Problem 1 and 3	The social cohesion can be measured by all three points as it is influenced by all points. For example, having a safer intersection leads to easier use of the intersection creating a better connection in the town.
Improvement in safety	Safety	Problem 3 and 4	
Improvement in crossing of intersection (pedestrians and cyclists)	Traffic flow, safety and social cohesion	Problem 1,2,3 and 4	Improvement in the crossing relates to all aspects as this influences all points.
Improvement in inserting/crossing the main traffic flow (motorized vehicles)	Traffic flow and safety	Problem 2 and 4	Improving the size of the pre-sorting bays means less blockage of other traffic. Further the traffic from the side roads is not able to get on the main road.
Improvement in the overall flow/travel time of the main traveling link	Traffic flow and safety	Problem 2	The vehicle pre-sorting bays are too small and blocking other traffic. This causes safety problems and a disruption in the flow of traffic.

2.3 Research Objective

The reason for choosing a roundabout design is because a roundabout gives relatively more space for vehicles to maneuver on compared to the cramped-up design right now where multiple flows go overlap in a small space. Further, a roundabout gives a relatively steady flow for vehicles coming from all directions compared to, for example, a signalized intersection. With a signalized intersection the vehicles must cross the intersection in batches during the green time and must wait for their turn. With a roundabout design the flow is slowly but steady and more consistent.

The research objective of this study is therefore to analyze if the use of a roundabout improves the traffic situation, focusing on the measures of effectiveness such as the traffic flow, the safety and pollution for the town due to the intersection, so a problem with the social cohesion. Next to this a comparison of the results of the new solution and the current situation must be made to give a clear overview of the solution and the positive and negative points.

2.4 Research questions and hypothesis

In this chapter the research questions are mentioned which need to be answered during the research. The research questions are based on problem statement and the research objective.

The main research question is the following:

Is a roundabout a suitable solution for resolving the issues such as large interruptions in the flow of traffic, safety and social cohesion of the current traffic situation?

With the following sub-questions:

- *What are the current issues at the intersection and the improvements in the intersection re-design while analyzing the traffic flows?*
- *What are the current issues at the intersection and the improvements in the intersection re-design while analyzing the safety for crossing of the intersection?*
- *What are the current issues at the intersection and the improvements in the intersection re-design while analyzing social cohesion in the village?*

All these sub-questions focus on key performance areas such as safety, social cohesion and traffic, with the following performance indicators: vehicle delay, travel time and stops. These parameters are measurable in real life and mostly in VISSIM which makes them usable parameters to determine an answer for the sub-questions and the main research question. For example, all performance indicators are related to the traffic flow of the intersection. However, these points are an indicator of the safety, if there are more stops for

example, people get annoyed easily and accept higher risks in traffic. For the social cohesion these indicators also work as a main point is to have an improved crossing. An indicator for this is the vehicle delay for the cyclists and pedestrians for example. If this has decreased this can be an indicator that the crossing has been made easier.

Furthermore, there are several less quantifiable measures to determine the issues and improvements. These are related to the perception of stakeholders such as the improvement in safety and the social cohesion of the village.

Hypothesis

The hypothesis for the main research question is that the roundabout will be a significant improvement for the large interruptions in the flow of traffic. Mostly for the traffic coming from the side streets where there is a larger possibility to join the main flow of traffic. This is because of the design of the roundabout having only one major flow from one direction and therefore not having to consider other flows coming from other directions.

This also means an improvement in the safety as there are less complicated conflict points with vehicles coming from multiple directions. Another improvement in safety will be the cyclists and pedestrians having an easier way to cross the traffic if they are in priority.

Furthermore, it is expected that the social cohesion will improve as there are easier ways to cross the roads which leads to a better connection between all parts of Weerselo. Especially the improvement of the connection with the restaurants and the meeting point is important to create a cozier center of Weerselo.

3. Research Methods

This chapter will consist of four main parts, which can also be seen schematically in figure 6. The first part will be about data collection, analysis and having the data available to use in VISSIM. The second part is making the initial traffic situation in VISSIM and validating and making a verification that the model is in line with the current situation. The third part is making the proposed solution of a roundabout in VISSIM and validating and making a verification that the model should work the same in the real-life situation. The fourth part consists of evaluating the proposed solution and the data from the solution and comparing that with the current situation and to see if the proposed solution solved the problems.

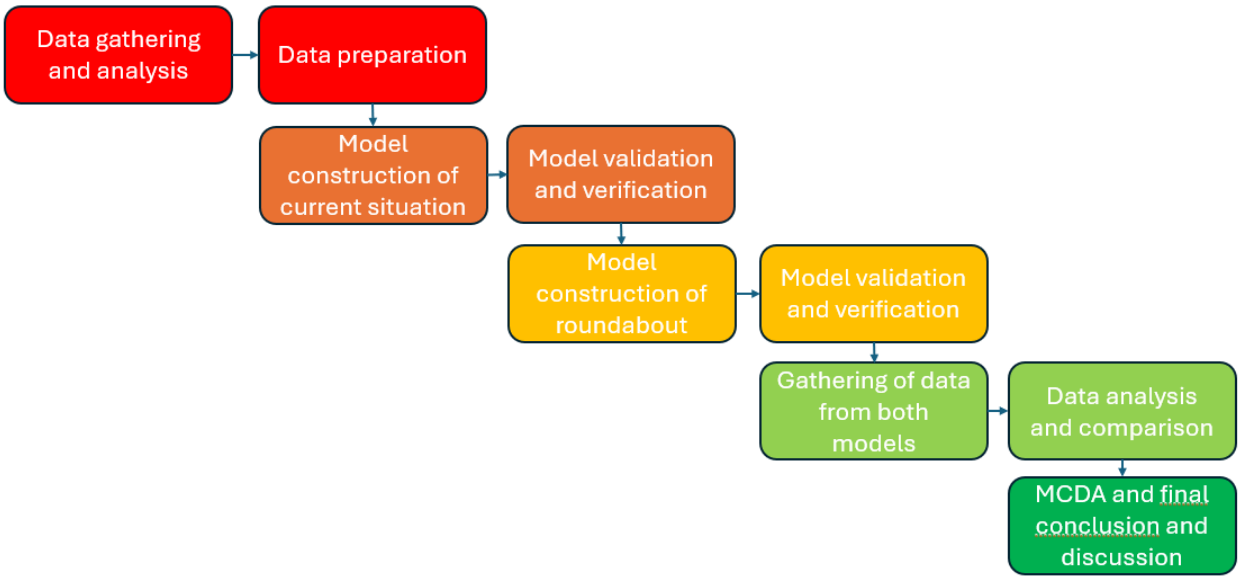

Figure 6: Research method

3.1 Data collection, analysis and preparation

According to the province of Overijssel there is no recent data available for the traffic intersection. However, the municipality of Dinkelland does have some data available from 2020 for the 2-hour rush window. While this data is outdated, it can give an estimation of what should be expected for intensities. Next to this in table 4.2 an overview of the expected growth of traffic is given for the intersection, which should be considered for the data input of the models.

However, having no recent data present, the data must be gathered via counting and being on the intersection taking notice of all the traffic. The data collection will happen when the intersection is the busiest, so during the morning rush. (Ecorys, 17-12-2015) The reason for this is that most problems are present during the morning rush with the highest peak in traffic for the day. The data for the morning rush will be gathered over a few days to account

for the day-to-day variation in demand. The reason for not considering the traffic during other hours of the day, for example during low demand hours, is the following. A roundabout design is still suitable for low demand hours as an important indication for the travel time is the demand. If there is a low demand the travel time will get a bit lower and the other way around and there are no real hindrances. For a signalized intersection for example, there is still hindrance from the traffic light, even if "smart" traffic lights are installed. A vehicle does have to stop almost al times for the red light even when it is no busy. Therefore, the roundabout is still a suitable solution even during low demand hours. Furthermore, the evening peak is not considered as the assumption is, based on Ecorys (2015) and Rijkswaterstaat Verkeersinformatie (2023), that the evening peak is lower than the morning rush hours. Therefore, the same reasons as during the other low demand hours apply that the roundabout design will still work sufficiently.

The data is collected in the following way as can be seen in figure 7.

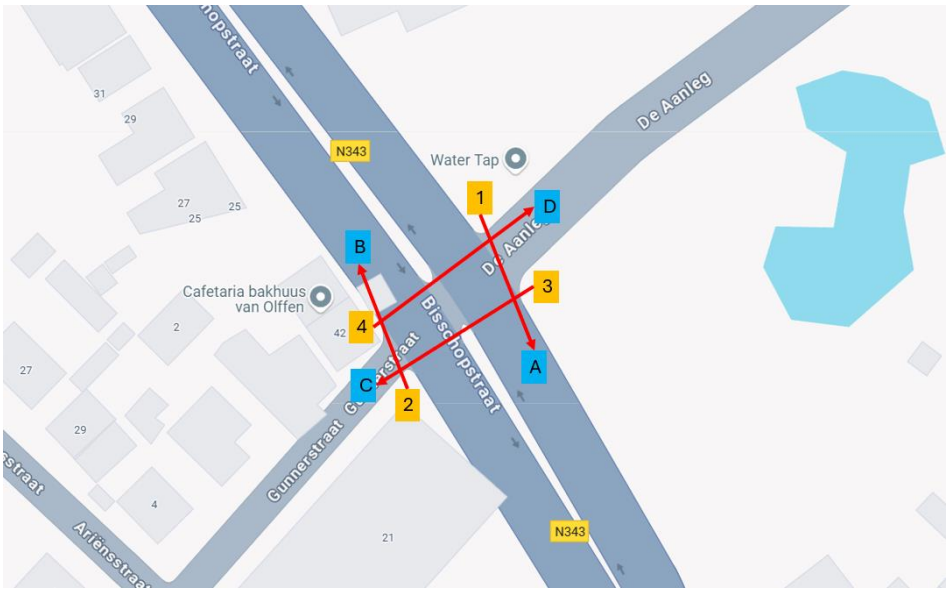

Figure 7: Data collection method

There are 4 data collection points with a person counting the motorized traffic, cyclists and pedestrians for each point. For example, person 1 counts all traffic coming from A which is the N343. That means that person 1 counts how many vehicles are going straight ahead or turning left or right. Next to this person 1 also counts the cyclists and pedestrians coming from the direction of point A. This way of collecting data was the case for each data collection point. The counting of the data happened continuously throughout the two hours with the help of the following tool: Traffic Logger (2024). In this way a sufficient dataset is made where the deviations in amount of traffic can be visualized.

The data is visualized in an excel sheet which can be implemented in the microsimulation program VISSIM. An example of this excel sheet can be found in table 2 and a complete overview can be found in appendix B.

Table 2: Example of excel sheet used to count traffic for person 1

N343 South													
Time		Cars and motorcyclists			Vans and trucks			Cyclists			Pedestrians		
Start	End	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)
7.10	7.19												
7.20	7.29												
7.30	7.39												
7.40	7.49												

In this way an overall view is made of the whole intersection. The reason why vans and trucks are specifically mentioned is because they are overall a slower moving vehicle and are larger and longer than an average car. These vans and trucks therefore need a larger headway between cars to get between them and the vans and truck need more space to be able to pre-sort which is a problem right now as has been stated in chapter 3.1. The busses from the bus lines are also part of the vans and trucks due to the low number of busses and the busses not significantly disturbing the traffic flows.

3.2 Initial traffic situation

When the data from the initial situation is found the model can be made in VISSIM. Here the roads are made, and the priority rules are added to the model in such a way that it complies with the actual situation. Next to this, first dataset from the traffic count is added so that the model works the same as the real-life situation. The second dataset will be used for validating the model as otherwise there is not enough data available for validating the model.

The first step of verification for the model is to verify that the input and output of traffic is the same as the counted traffic in the actual situation. If this is not the case, then input variables must be changed to make the model work according to the actual situation.

The second phase of the verification of the model is done by looking at the model's behavior and comparing that with the actual situation and the experiences from standing next to the intersection. If the model does not comply with the real-life situation, the model needs to be changed so that it is the same.

For the validation of the model the second dataset, will be used to see if the model still runs the same as for the larger dataset. The measurements are for example based on travel time and delays to compare with each other if they are in line. If this is not the case, the coding of the program is not correct, or the input points are not placed correctly and then that must be changed.

Another part of validating the model is performing an extreme conditions test where the model runs for much slower speeds such as 5 km/h. It is expected that the intersection will get stuck completely and that not all data could be loaded in the given time. However, the model should still work for these input variables, and it should not crash or give errors.

Once the model is verified and validated the redesign can be done with the same input values.

3.3 The re-design

For the re-design the initial input data and variables are used from the first model. However, the intersection will be changed towards an oval roundabout which changes the road layout and the priority rules on the intersection. The roundabout size and measures will get based on Crow (2019) where the average dimensions of a roundabout are mentioned. After the roundabout is modeled and the priority rules for the cyclists and pedestrians are also added the model can be verified and validated. The verification of the model can only be done by looking at the simulation and seeing if the model runs correctly and that there are not errors in the model. What also will be done is comparing the roundabout with an actual roundabout in a similar situation and determining if the model is correct.

The validation of the model is the same as for the initial situation with the 50% of the remaining data and the extreme conditions test.

3.4 Comparing the re-design with the initial situation

The last step of this study is comparing the proposed solution, the roundabout, with the current traffic situation. The comparison will be done on different aspects, for example the flow of the traffic. The flow of traffic will get measured in amount of traffic per hour, to analyze if the roundabout still has enough flow and capacity for the main link, the N343. Next to this the flow of the side roads will get analyzed and the conclusion will get drawn if there are more possibilities for the traffic to join the roundabout than in the current situation. This will also be measured in travel time and vehicle delay for the motorized traffic waiting to enter the roundabout.

For the cyclists and pedestrians, the same procedure will be done. So, there will be looked at if there are more possibilities for the traffic to continue their way. Further, the travel time and the vehicle delay on the roundabout will get determined. This will be compared with the current situation and then a percentage of improvement can be determined.

Another aspect was safety and an option for improving the safety is adding priority for cyclists and pedestrians. However, this should be determined with the traffic flow if the flow will be sufficient and that it does not cause safety issues for motorized traffic, as they must

stop abruptly on the roundabout for a passing cyclist. This option should be determined when designing the model and analyzing the traffic flows for both options and comparing that with the current situation.

As last point there is the point of the N343 dividing the town into two parts which is not something the roundabout is going to solve. However, if the driving speeds are lower and there are more and safer possibilities to cross the road the N343 is less of a problem. This is specifically an improvement for the catering businesses situated next to the intersection and the connecting with the field on the other side of the N343 as can be seen in figure 8.

Figure 8: Overview catering and meeting point (Googlemaps, 2024)

Now that all these problems are stated, and a comparison has been made all these distinctions can be compared with each other and general conclusions can be drawn per topic. A general conclusion can not be given due to the large number of comparisons and positive and negative points. However, a recommendation can be written for what a next step could be in re-designing this intersection.

4. Data collection

4.1 Data collection

The data collection is done in the same way as described in chapter 3.1. The data collection has taken place on two days: Wednesday 20 November 2024 and Tuesday 26 November 2024. The data was collected between 7.10 and 9.00 in the morning from each direction. In that way a complete overview of the number of cars, trucks, cyclists and pedestrians per 10 minutes is made and which direction they go towards.

4.2 Data preparation and analysis

The data has been collected as one dataset per direction with a time stamp and what kind of transportation method is used. For the data to be analyzed and prepared for the VISSIM models the data first must be divided into blocks of 10 minutes and a division between each direction the mode of transportation goes must be made. From this an overview has been made of what the intensities are at the intersection and what the busiest directions are.

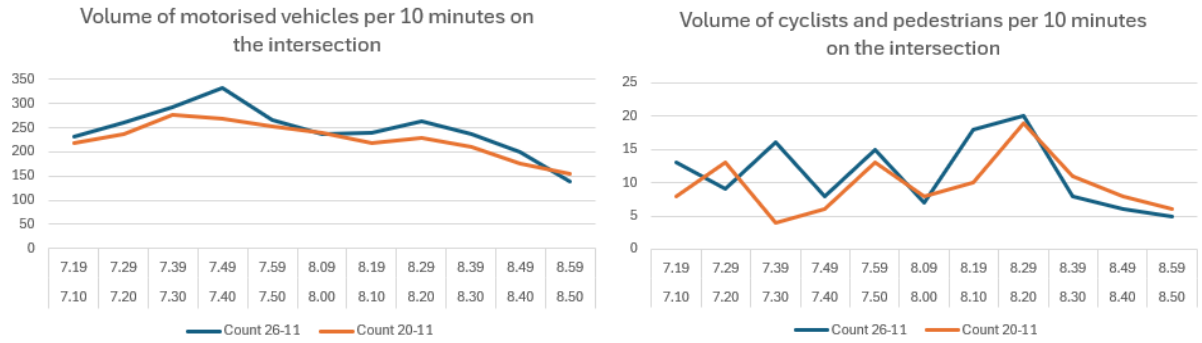

Figure 9: Volume of cyclists and pedestrians

Figure 10: Volume of vehicles

In figure 9 and figure 10 a comparison between both datasets is made of the total amount of vehicles on the intersection per 10 minutes. For the motorized vehicles the dataset from the count on 26 November is overall larger as was expected. There are two small peaks present in the dataset, the first one between 7.40 and 7.49 and the second one between 8.20 and 8.29. Overall, the graph is increasing from the start of the graph and is decreasing towards the end, meaning that the dataset indeed includes the morning rush of traffic.

For the cyclists the graphs fluctuate more as the total number of cyclists is a small number. The chance that it looks like there is more fluctuation is therefore higher, as one person makes a larger difference in the graphs than with a higher amount, such as with motorized vehicles. Therefore, there are more peaks in the graphs, with the highest peak

between 8.20-8.29. Overall, there are more cyclists and pedestrians present during the count on 26 November.

Next to the comparison between the two datasets, a comparison can be made between the two datasets and a dataset provided by the municipality Dinkelland. This dataset was formed in 2020 based on traffic counts from 2020 and therefore the corona virus had an influence on the dataset figure 12. Figure 12 gives an overview of the total number of vehicles coming from each direction and going to each direction for the two-hour morning rush. Less people needed to travel as they needed to stay at home. Therefore, the dataset is useful, however it is expected that the intensity of the traffic is less, as can be seen in figure 11. The intensities in figure 11 are based on the total number of vehicles coming from each direction for the two-hour period.

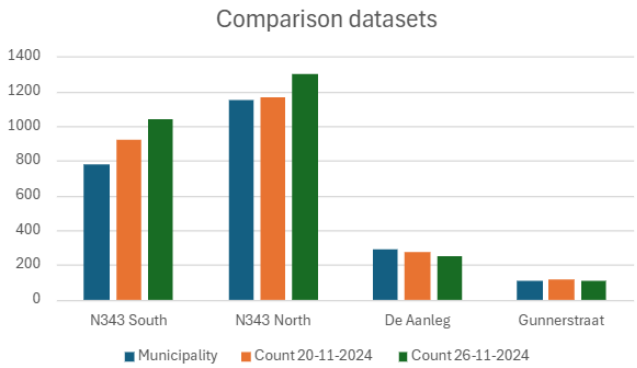

Figure 11: Comparison datasets

Figure 12: Data from municipality

As can be seen in figure 11 the datasets that were counted in 2024 overall have a larger number of vehicles than the dataset from 2020. This is under the influence of the corona virus and the point that it was expected that more vehicles would be present on the intersection according to Ecorys (17-12-2015).

Next to the total number of vehicles coming from each direction an overview has been made of which direction each vehicle goes per 10 minutes for the dataset from the count of 26-11-2024. In that way an accurate model can be made which represents the actual situation. An example of the distribution of the traffic per direction can be found in figure 13 and 14. A complete overview of all distributions can be found in appendix C.

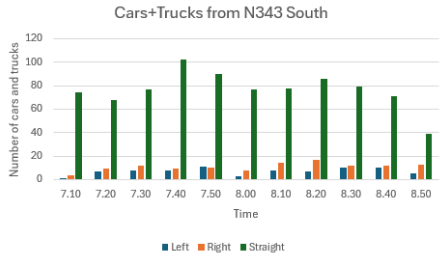

Figure 13: Route choices

Figure 14: Distribution of vehicle routes

4.3 Data collection conclusions and limitations

A conclusion regarding the use of the data is that the dataset from 26-11-2024 will get used as the main dataset. The reason for the is that overall, the intensities are higher for vehicles coming from all directions compared to the dataset from 20-11-2024. Therefore, the dataset from 20-11-2024 gets used as the dataset for validation and verification.

An overall conclusion is that the main flow of traffic on the intersection is on the N343 going straight in both directions. Next to this, there is a significant number of vehicles coming from the side road De Aanleg which mostly want to turn towards the left, so towards the South going in the direction of Oldenzaal. This gives the problem with large queues on De Aanleg and delay times of several minutes to cross the major flow of the N343.

In general, there is a significant number of cars with trailers and trucks driving on the intersection which is something to consider in making the oval roundabout. The corners should not be too sharp and there should be enough space available to turn on or from the oval roundabout.

An overall conclusion with the focus on cyclists and pedestrians is that the total number of cyclists and pedestrians is relatively small compared to the motorized vehicles. Therefore, the cyclists and pedestrians do not play a significant role in the intersection. However, the problem is still present that the waiting times to cross the N343 are high. This should be considered in the re-design of the intersection.

There were some limitations with the data collection method. For one point, the data collection method is time consuming and takes 4 people willing to stand 2 hours on the intersection in the cold. That is one of the reasons why only two datasets are used in this research as it was difficult to find enough people willing to count.

Next to this the input times of each vehicle entering the network can be slightly different in the actual situation. That is because it is hard to count all vehicles entering the network especially when there is a queue. This can lead to small deviations in the data.

Further, the headways between the vehicles are determined from the data collection, however there is no real use for this data as it can not be implemented in VISSIM. VISSIM only uses input variables per time interval and there is no possibility to implement vehicles by their actual input times. Therefore, the data collection of headways is neglected.

As a last point, the cyclists and pedestrians sometimes cross the intersection in a different way than is allowed. This is something that will not be considered in the model as it happens sporadically and will otherwise result in many independent routes which is difficult to model correctly.

5. Initial traffic situation

5.1 Overview model and input data

The model that has been made in VISSIM can be viewed in figure 15. The model uses a background map from AutoCAD (2024), having a representable background and scale for the model.

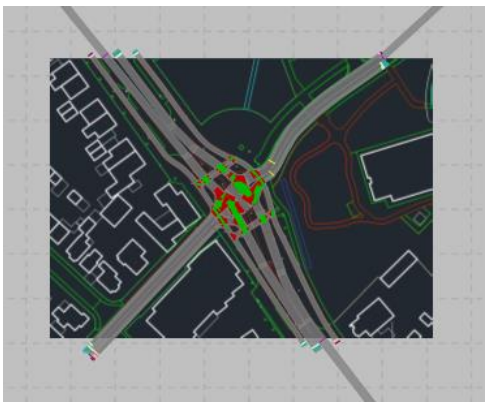

Figure 15: Overview of initial model

For the model to run three main input variables are needed: Vehicle inputs, mode splits and routing decisions. Starting of with the vehicle inputs. The vehicle inputs are placed at the start of a link, so on all four branches of the model for the motorized traffic and all four branches for the cyclists and pedestrians.

The data is put in the model per 10 minutes and the intensity must be in vehicles per hour. Therefore, the data obtained from the counting must be multiplied by 6 to go from number of vehicles per 10 minutes to vehicles per hour. For the motorized traffic the input value is cars, trucks and busses combined, as the mode split will decide the percentage of trucks and busses. For the cyclists and pedestrians, the input point is the same and the model only considers cyclists. The reason for this is because the number of pedestrians and cyclists is that low that they can easily be combined if the average speed is lowered. (Crow, 2022) This makes the total model more readable and easier to understand and evaluate while still having an accurate model. All the input variables can be found in appendix D.

After the vehicle inputs are put in the model the mode splits can be added per ten minutes. The mode splits are added for the motorized traffic to make the distinction between cars and trucks. These values are put in the model as percentages. There is no difference in mode split with the cyclists as input as no other traffic mode is considered here. The mode splits can be found in appendix D.

At last, the route choices must be added per 10 minutes and per link. These route choices determine the routes the vehicles take on the intersection and which percentage of the vehicle input goes which direction. In this way with all these three points combined and having set the vehicle speeds and allowed speed on the intersection correctly a complete model is created. These input variables can be found in appendix D.

5.2 Results

The model is run 10 times as has been stated in Fries et al, 2017 to obtain an average, representable result from the model. The results from the model that are used are the following: Vehicle delay, stops, travel time. These results can be found in chapter 6 where the comparison is made with the roundabout results.

Having these results a proper comparison can be made between the models, and the model can be verified and validated. The results include the means of all ten runs and the means values over the entire period. Furthermore, the results include the total number of stops for example. At last, the results include the maximum, so for example the maximum vehicle delay measured. For example, the maximum is interesting to know as if the maximum is high it can lead to unsafe situations, as vehicles do not want to wait anymore and accept smaller gaps between vehicles. Overall, these values are all interesting to compare with each other in both models as these are the points the models can be evaluated on.

For the results the following points are given: the totals, averages and maximums are based on the average of all simulation runs. The reason for using the averages over all simulations is because this is more representative for a regular day.

An observation can be made from the results that the vehicle delay is the highest at De Aanleg which complies with the actual situation. Furthermore, the cyclists also have a large waiting time to cross the N343.

A more in-depth analysis of the results will be provided in chapter 7 where the comparison between this model and the redesign is given. This gives a better insight of the results instead of just looking at numbers and having nothing to compare to.

5.3 Verification and validation

The second phase of the verification of the model is done by looking at the model's behavior and comparing that with the actual situation and the experiences from standing next to the intersection. Visually it can be determined that the model runs correctly and that there are no situations in the model which could not happen in real life. However, this is only the case when the model runs at 90% of the input data. When the model runs at 100% of the input

data the model still runs, however vehicles collide with each other which results in a standstill of the whole model. Next to this the queue length and waiting time for De Aanleg becomes unrealistically long and therefore it has been chosen to let the model run at 90% of the input data. In that way the model runs more realistically and there are no collisions between vehicles. A further explanation of the reason for letting the model run at 90% of the input data can be viewed in chapter 8.1 discussion.

The second step of verification for the model is to verify that the input and output of traffic is the same as the counted traffic in the actual situation. Therefore, the vehicles generated by the model are compared with the vehicles counted. This comparison is made based on the difference in percentage and in values as can be found in figure 16.

	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343 South	897	935	-4,074430542	-38
De Aanleg	225	229	-1,57480315	-4
N343 North	1220	1172	4,11332992	48
Gunnerstraat	99	97	1,851851852	2
C N343 south	28	34	-18,12865497	-6
C De Aanleg	22	29	-23,61111111	-7
C N343 North	25	26	-4,214559387	-1
C Gunnerstraat	27	23	15,38461538	4

Figure 16: Verification initial model

As can be determined from the figure, there are differences in what the model has generated in comparison with what is counted. A part of this is that the input data from the model is stochastic and therefore there are slight differences. Overall, the differences are relatively small. There are a few larger differences percentage wise, however when looking at the actual differences in values, these differences can be neglected.

The model is also evaluated on the difference in route choices and this figure can be found in appendix F. It can be determined that there are some differences and some of them are relatively large percentage wise. However, the same applies as with the total number generated, the differences are relatively small value wise. Therefore, the model in general is verified that it runs correctly.

For the validation there are again two steps taken as has been explained in chapter 3.2. The first step is using a different dataset to determine if the model still runs correctly and that there are no large differences. The dataset from the counting at 20-11-2024 is used for this. The input values can be found in appendix E. The validation is evaluated on three main components: Vehicles simulated, difference in travel time, difference in delay. The vehicles simulated component can be found in figure 17, this is more a verification step to determine that the model still runs correctly for this dataset. As can be seen, there are some differences however these are not significant.

	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343 South	805	868	-7,215306593	-63
De Aanleg	239	266	-9,981167608	-27
N343 North	1071	1091	-1,815181518	-20
Gunnerstraat	111	113	-1,333333333	-2
C N343 south	27	33	-18,91891892	-6
C De Aanleg	22	25	-12,6984127	-3
C N343 North	22	23	-5,982905983	-1
C Gunnerstraat	22	16	35,80246914	6

Figure 17: Verification validation data

Now the evaluation takes place on the difference in travel time and delay which can be found in figure 18. As can be determined, there are some differences in travel time and delays per input data. However the input data is in general different, the input for the validation is smaller for the main flow on the N343. This leads to lower travel times for De Aanleg for example as there are more possibilities to cross the main flow on the N343, as less vehicles drive there.

Validation	Travel time average	Travel time MAX	Delay average	Delay MAX
N343-south straight	4,11%	57,67%	10,83%	111,30%
N343 South Left	-2,18%	12,57%	-7,51%	18,14%
N343 South Right	3,00%	40,67%	4,61%	81,96%
De Aanleg Straight	-40,00%	-35,65%	-47,75%	-37,71%
De Aanleg Left	-27,33%	-35,79%	-33,21%	-38,03%
De Aanleg Right	-39,83%	-39,83%	-48,33%	-42,19%
N343 North Straight	6,32%	41,87%	50,69%	156,18%
N343 North Left	-1,60%	41,67%	-1,68%	90,89%
N343 North Right	9,27%	22,81%	159,68%	150,92%
Gunnerstraat Straight	-13,00%	-33,82%	-21,45%	-42,20%
Gunnerstraat Left	45,16%	158,14%	104,89%	250,52%
Gunnerstraat Right	5,10%	24,16%	17,59%	46,87%
C N343 South Straight	8,72%	36,01%	0,00%	0,00%
C N343 South Left	16,77%	19,91%	210,76%	76,21%
C N343 South Right	0,20%	-1,28%	-100,00%	-100,00%
C De Aanleg Straight	-15,02%	-27,23%	-86,70%	-91,42%
C De Aanleg Left	0,61%	2,25%	-16,70%	5,45%
C De Aanleg Right	0,00%	0,00%	0,00%	0,00%
C N343 North Straight	5,19%	1,15%	0,00%	0,00%
C N343 North Left	-1,96%	-9,68%	13,23%	-25,81%
C N343 North Right	-41,61%	-54,71%	-100,00%	-100,00%
C Gunnerstraat Straight	5,42%	9,10%	44,64%	56,87%
C Gunnerstraat Left	19,70%	19,15%	262,21%	184,27%
C Gunnerstraat Right	-1,86%	-8,52%	0,00%	0,00%

>40%
20%-40%
-20%-20%
-40%--20%
<-40%

Figure 18: Comparison travel time and delay

The second phase of validation is the extreme conditions test. This means that the speed of all vehicles will be set to 5 km/h to determine if the model still runs. The results from this test can be found in appendix F.

As can be determined from this figure, the travel times and delays are extremely high for all motorized traffic. This is the case because of the slow speed and the point that at a certain point no motorized vehicles are moving, because there are too many vehicles present at the intersection at the same time, and they are blocking all roads.

While the motorized vehicles have a large increase in travel time and delays, the cyclists and pedestrians overall have a large decrease in travel time and delay. This is because the whole

motorized traffic is brought to a standstill. The cyclists and pedestrians can still get between the motorized traffic and cross the roads without having to wait.

As a conclusion the model gives no errors and still runs and therefore the validation of the model is complete and all right.

6. The re-design

6.1 Overview model and input data

For the re-design the choice has been made to design an oval roundabout. The design has been made in AutoCAD and is in line with the safety and design requirements given by Crow, 2012. In AutoCAD the same base layer has been used as the original design of the intersection so that the whole drawing is scaled correctly. The design has a separated cycling and footpath with 5 meters distance from the oval roundabout making sure there is enough distance between the two traffic flows. The model can be viewed in figure 19, where the VISSIM model is already implemented.

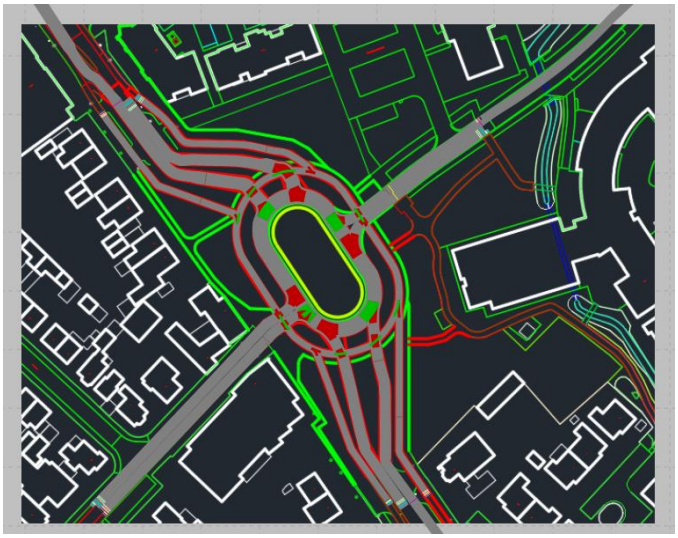

Figure 19: Oval roundabout model

The same input variables are used as for the initial model which can be found in appendix D. Further there are some differences in this design compared to the initial situation. The first one is that as with every roundabout, the traffic on the roundabout has priority over the traffic wanting to join the roundabout. This is different compared to the initial situation where the N343 has priority over all other roads.

Next to this the cyclists and pedestrians have priority over the motorized traffic making crossings easier, faster and safer. This is possible due to the low number of cyclists and pedestrians and therefore there is not a large problem with queues due to the cyclists and pedestrians.

Overall, the design is completely different and takes up a lot more space than the original situation. However, there are less conflict areas in this situation and the angles of the conflict areas are still the same as the original intersection which theoretically makes the roundabout safer.

6.2 Verification and validation

The verification and validation have been done via the same method as for the initial model with the same input variable as can be seen in appendix E. The results from the verification and validation are slightly different than for the initial situation, however they are comparable with each other. There mostly is a difference in the extreme conditions test because in the extreme conditions test the intersection is not blocked. In that way the vehicles keep moving and therefore the travel times for the cyclists are also longer as they sometimes must wait for a car or for another cyclist. The results can be viewed in appendix G.

7. Comparison of the models

7.1 Comparison of results

The models will be compared on multiple results from the models. The first one is the travel time through the model. This can be viewed in figure 20, where the travel time can be found from the initial situation and the comparison with the oval roundabout.

	Current travel time Total	Roundabout travel time Total	Current travel time Average	Roundabout travel time Average	Current travel time MAX	Roundabout travel time MAX
N343-south straight	531,75	782,73(47%)	48,34	71,16(47%)	69,48	91,82(32%)
N343 South Left	818,20	825,39(1%)	74,38	75,04(1%)	122,47	106,71(-13%)
N343 South Right	579,64	629,54(9%)	52,69	57,23(9%)	79,17	87,31(10%)
De Aanleg Straight	2991,98	493,75(-83%)	299,20	70,54(-76%)	828,75	79,8(-90%)
De Aanleg Left	2965,12	856,47(-71%)	269,56	77,86(-71%)	819,27	106,6(-87%)
De Aanleg Right	2694,43	637,98(-76%)	269,44	70,89(-74%)	819,69	94,65(-88%)
N343 North Straight	377,77	2204,71(484%)	34,34	200,43(484%)	41,10	247,5(502%)
N343 North Left	577,23	2399,41(316%)	52,48	218,13(316%)	72,54	263,64(263%)
N343 North Right	325,27	1667,37(413%)	36,14	185,26(413%)	41,21	243,24(490%)
Gunnerstraat Straight	619,91	544,11(-12%)	56,36	49,46(-12%)	115,65	105,96(-8%)
Gunnerstraat Left	200,05	315,79(58%)	40,01	63,16(58%)	54,64	89,19(63%)
Gunnerstraat Right	200,25	426,97(113%)	20,03	42,7(113%)	27,07	89,23(230%)
C N343 South Straight	88,76	97,94(10%)	44,38	48,97(10%)	45,04	51,83(15%)
C N343 South Left	183,22	196,65(7%)	61,07	65,55(7%)	67,59	75,96(12%)
C N343 South Right	246,98	207,2(-16%)	41,16	34,53(-16%)	43,59	42,12(-3%)
C De Aanleg Straight	379,59	322,1(-15%)	63,27	53,68(-15%)	76,34	57,27(-25%)
C De Aanleg Left	301,63	257,69(-15%)	60,33	51,54(-15%)	85,74	58,74(-31%)
C De Aanleg Right	0,00	0	0,00	0	0,00	0
C N343 North Straight	121,85	113,31(-7%)	40,62	37,77(-7%)	43,51	42,7(-2%)
C N343 North Left	128,27	117,51(-8%)	64,14	58,76(-8%)	69,62	60,34(-13%)
C N343 North Right	437,44	217,33(-50%)	72,91	43,47(-40%)	94,00	44,13(-53%)
C Gunnerstraat Straight	109,15	55,1(-50%)	54,58	55,1(1%)	54,85	55,1(%)
C Gunnerstraat Left	119,26	126,76(6%)	59,63	63,38(6%)	59,91	65,76(10%)
C Gunnerstraat Right	155,79	183,37(18%)	38,95	36,67(-6%)	42,71	42,24(-1%)

Figure 20: Comparsison travel time

The comparison is made based on the differences in travel time total, average and the maximum. As can be determined from the figure, the travel time of De Aanleg has decreased significantly compared with the initial situation. However, the travel time from the N343 North has increased significantly. The reason for this is that the traffic on the roundabout has priority over the traffic on the N343 North. Therefore, there are less opportunities to continue the way without a stop compared to the initial situation, which results in a larger travel time.

The same reason for a higher travel time applies for the Gunnerstraat. The traffic coming from the Gunnerstraat must wait for all the other traffic.

Part of the reason why some travel times are slightly higher than the initial situation is because the distance traveled is larger. This is due to the oval roundabout taking up more space than the initial situation and making vehicle routes longer distance wise. A comparison between the distances can be found in appendix H.

For the cyclists and pedestrians there is a almost no difference in travel time. The reason for this is that the distance of the route is larger most of the time, especially for vehicles coming

from the N343 and wanting to turn left. They must cycle three quarters of the roundabout which is a larger distance than the initial situation. This can also be found in appendix H.

Now the vehicle delays are presented in figure 21 which gives extra information of where queues are present. As can be determined from figure 21 the queues are present at the expected points based on figure 20. The vehicle delays consist mainly of the queues and a relatively small part is based on the longer distance traveled.

	Current vehicle delay total	Roundabout vehicle delay total	Current vehicle delay average	Roundabout vehicle delay average	Current vehicle delay maximum	Roundabout vehicle delay maximum
N343-south straight	161,43	191,15(18%)	14,68	17,38(18%)	35,85	39,74(11%)
N343 South Left	374,88	173,7(-54%)	34,08	15,79(-54%)	82,15	50,64(-38%)
N343 South Right	147,92	147,59(%)	13,45	13,42(%)	39,97	45,75(14%)
De Aanleg Straight	2523,99	77,58(-97%)	252,4	11,08(-96%)	780,36	24,28(-97%)
De Aanleg Left	2432,82	203,44(-92%)	221,17	18,49(-92%)	771,19	48,22(-94%)
De Aanleg Right	2225,83	151,46(-93%)	222,58	16,83(-92%)	773,75	42,65(-94%)
N343 North Straight	47,49	1719,03(3520%)	4,32	156,28(3518%)	11,09	201,67(1718%)
N343 North Left	157,04	1841,44(1073%)	14,28	167,4(1072%)	34,01	212,28(524%)
N343 North Right	22,35	1281,52(5634%)	2,48	142,39(5642%)	7,03	201,62(2768%)
Gunnerstraat Straight	388,17	232,66(-40%)	35,29	21,15(-40%)	95,72	80,26(-16%)
Gunnerstraat Left	89,88	107,48(20%)	17,98	21,5(20%)	34,94	53,35(53%)
Gunnerstraat Right	29,02	208,84(620%)	2,9	20,88(620%)	9,73	67,65(595%)
C N343 South Straight	0	1,66	0	0,83	0	1,66
C N343 South Left	14,21	0,23(-98%)	4,74	0,08(-98%)	11,73	0,15(-99%)
C N343 South Right	0,04	2,12(5200%)	0,01	0,35(3400%)	0,04	1,87(4575%)
C De Aanleg Straight	46,05	5,82(-87%)	7,67	0,97(-87%)	20,63	3,48(-83%)
C De Aanleg Left	51,8	3,39(-93%)	10,36	0,68(-93%)	34,67	2,72(-92%)
C De Aanleg Right	0	0	0	0	0	0
C N343 North Straight	0	0,35	0	0,12	0	0,17
C N343 North Left	13,31	1,55(-88%)	6,65	0,77(-88%)	10,15	1,55(-85%)
C N343 North Right	105,79	0,91(-99%)	17,63	0,18(-99%)	39,85	0,25(-99%)
C Gunnerstraat Straight	5,6	0(-100%)	2,8	0(-100%)	4,15	0(-100%)
C Gunnerstraat Left	8,67	1,71(-80%)	4,34	0,85(-80%)	5,53	1,23(-78%)
C Gunnerstraat Right	0	0,49	0	0,1	0	0,22

Figure 21: Comparsion delay

The number of stops is provided in figure 22. This complies with the vehicle delays and vehicle travel times. The number of stops has increased significantly for the N343 North and the number of stops has decreased considerable for De Aanleg. For the cyclists the number of stops mostly has decreased because of the priority over de motorized traffic.

	CURRENT STOPS(ALL)	ROUNDABOUT STOPS(ALL)	CURRENT STOPS(AVERAGE)	ROUNDABOUT STOPS(AVERAGE)	CURRENT STOPS(MAX)	ROUNDABOUT STOPS(MAX)
1: N343-south straight	7,98	10,21(28%)	0,73	0,93(28%)	1,52	1,97(30%)
2: N343 South Left	35,55	7,67(-78%)	3,23	0,7(-78%)	9,83	3(-69%)
3: N343 South Right	8,45	9,37(11%)	0,77	0,85(11%)	2,5	3,2(28%)
4: De Aanleg Straight	135,29	9(-93%)	13,53	1,29(-90%)	39,33	3,5(-91%)
5: De Aanleg Left	133,77	17,85(-87%)	12,16	1,62(-87%)	35,65	2,7(-92%)
6: De Aanleg Right	101,96	16,04(-84%)	10,20	1,78(-83%)	25,1	3,67(-85%)
7: N343 North Straight	1,92	172,7(8895%)	0,17	15,7(8895%)	0,4	21,29(5223%)
8: N343 North Left	14,56	185,22(1172%)	1,32	16,84(1172%)	3,17	23(626%)
9: N343 North Right	0,79	120,39(15139%)	0,09	13,38(15139%)	0,4	21,67(5318%)
10: Gunnerstraat Straight	51,5	36,83(-28%)	4,68	3,35(-28%)	15	19(27%)
11: Gunnerstraat Left	12	6(-50%)	2,40	1,2(-50%)	7	2,5(-64%)
12: Gunnerstraat Right	3,76	24,3(546%)	0,38	2,43(546%)	1,5	6,28(319%)
13: N343 South Straight	0	0	0	0	0	0
14: N343 South Left	1,5	0(-100%)	0,50	0(-100%)	1	0(-100%)
15: N343 South Right	0	0	0	0	0	0
16: De Aanleg Straight	4,42	0(-100%)	0,74	0(-100%)	1,75	0(-100%)
17: De Aanleg Left	5,5	0(-100%)	1,10	0(-100%)	3	0(-100%)
18: De Aanleg Right	0	0	0	0	0	0
19: N343 North Straight	0	0	0	0	0	0
20: N343 North Left	2,33	0(-100%)	1,17	0(-100%)	1,33	0(-100%)
21: N343 North Right	13,5	0(-100%)	2,25	0(-100%)	4	0(-100%)
22: Gunnerstraat Straight	0,5	0(-100%)	0,25	0(-100%)	0,5	0(-100%)
23: Gunnerstraat Left	1,57	0(-100%)	0,79	0(-100%)	1	0(-100%)
24: Gunnerstraat Right	0	0	0	0	0	0

Figure 22: Comparison stops

Now that all data has been evaluated, a complete reflection of the data can take place by comparing the results with the stakeholder interests, measures of effectiveness and the

problems as can be seen in table 3. In this table also an overview is given if the problems are solved or not. The improvement section is based on the data analysis and model reflection, figure 20-22, with for example vehicle delays.

Table 3: Reflection of the roundabout compared with the problems

Stakeholder interests	**Measure of Effectiveness**	**Problems**	**Improvement**	**Explanation**
Improvement in social cohesion	Traffic flow, safety and social cohesion	Problem 1 and 3	Improved	The social cohesion is mostly improved due to easier and safer possibilities for crossing.
Improvement in safety	Safety	Problem 3 and 4	Improved	The safety is improved due to less complex conflict areas and improved crossings, this will be further explained in chapter 7.
Improvement in crossing of intersection (pedestrians and cyclists)	Traffic flow, safety and social cohesion	Problem 1,2,3 and 4	Improved	The cyclists and pedestrians have priority over the motorized vehicles. This makes an easier crossing. As can be seen in figures 20-22 where there is an overall improvement for the cyclists.
Improvement in inserting/crossing the main traffic flow (motorized vehicles)	Traffic flow and safety	Problem 2 and 4	Improved and made worse	For De Aanleg inserting the main problems are solved with waiting times. For the

				Gunnerstraat the vehicle delay has increased a small amount.
Improvement in the overall flow/travel time of the main traveling link	Traffic flow and safety	Problem 2	Improved and made worse	For the N343 South there is an improvement in travel time vehicle delay. For the N343 North there is a small increase in vehicle delay and travel time which is worse than initial.

7.2 Safety assessment

For the safety assessment a comparison will be made between the two models on a few aspects: The number of conflict points, the angle between the flows, the distance between the conflict points.

7.2.1 Current situation

For the current situation there are 12 conflict points in total, not including conflict points between cyclists only as can be seen in figure 23. There are 8 conflict points between motorized vehicles and cyclists and pedestrians. Further, there are 4 main conflict points between motorized traffic only. These 4 main conflict points include vehicles coming from 3 different directions which makes it difficult to keep an overview of when to cross for example. It does make it safer that the conflict angles are mostly 90 degrees. This is the ideal conflict angle as this gives the most overview of what the other vehicle will do.

For the 8 conflict points between motorized traffic and cyclists and pedestrians the angle between the traffic flows is 90 degrees. Further, for conflict points 1,2,3,6,7,10 there are only two traffic flows that must be considered, cyclists coming from one side and motorized vehicles coming from one side. For conflict areas 11 and 12 three traffic flows must be considered, cyclists coming from both sides and motorized traffic coming from one side.

Overall, for the conflict areas the distance between the conflict areas is short which leads to a chaotic and unsafe intersection. In this situation traffic drives from one conflict area to the next without time to prepare for the next situation.

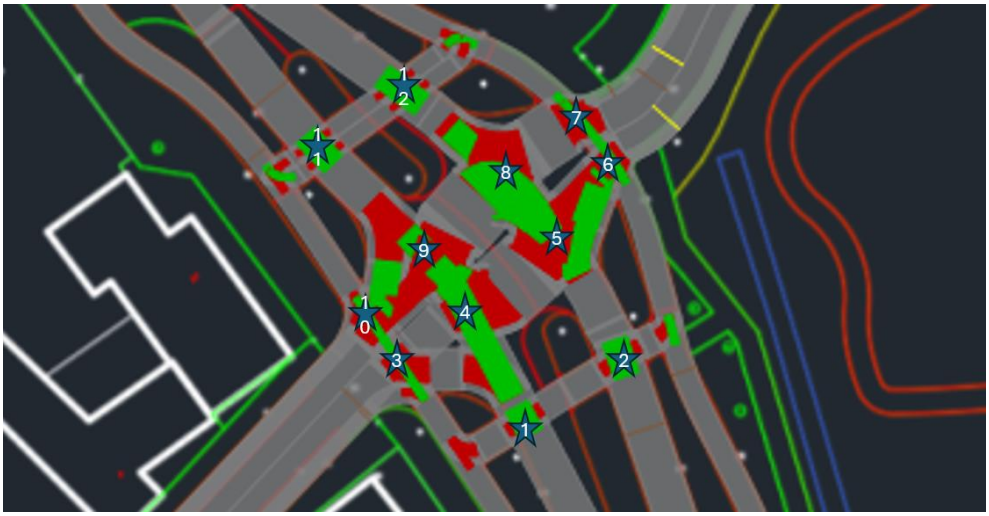

Figure 23: Conflict area's initial model

7.2.2 Oval roundabout

For the oval roundabout, the number of conflict area's is the same as for the initial situation as can be seen in figure 24. The difference s that the conflict points now only consider two traffic flows at the time with an angle of approximately 90 degrees. This leads to a less chaotic intersection. Next to this, the distance between the conflict area's is larger which makes the intersection easier to oversee and the different modes of transport can prepare for the next conflict area.

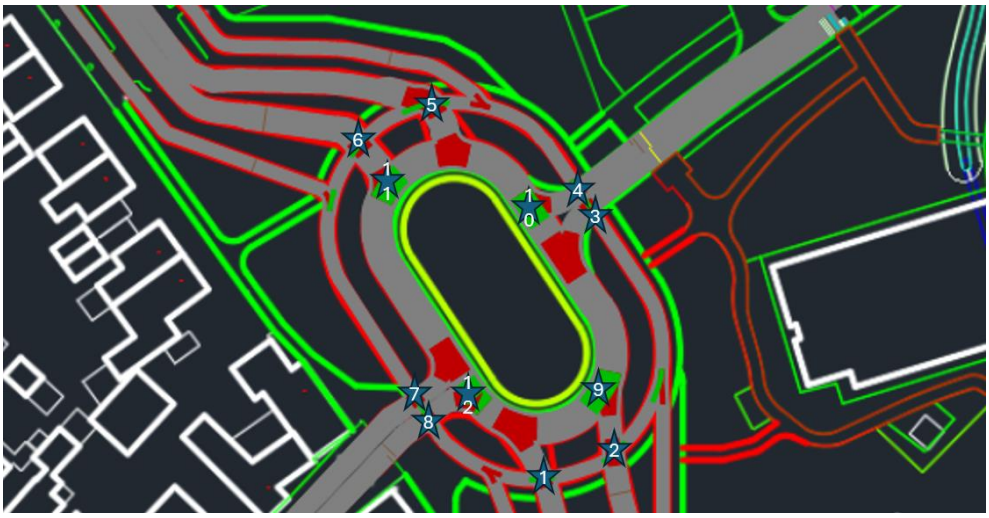

Figure 24: Conflict areas roundabout

7.3 Design reflection

In general, there are multiple positive and negative points regarding both designs, a few of them will be discussed in this chapter, to give a general overview of both designs.

Space and social cohesion

The roundabout design takes up a significant amount of space compared to the initial traffic situation. In numbers, the initial situation takes up approximately 1835 m2 compared to the oval roundabout taking up 8042 m2 which is 338,26 % more. The oval roundabout design takes up almost halve of the green patch on the north side of the intersection and it takes up a part of the small forest on the East side of the intersection.

The forest is part of the nursing home, and they would lose a part of that due to the roundabout. This is a negative side effect for the nursing home as they lose a small path to walk through with the residents. Next to that, the intersection is now relatively closer to the house with a smaller buffer zone for noise and sight nuisance.

The negative effect of losing a part of the green patch and losing the meeting point is a problem for the social cohesion in the town. Losing a meeting point and water tap creates for less space for people to talk with each other and meet with each other. However, this meeting point and water tap could be re-situated further to the North and therefore this is not a large problem in the redesign.

Furthermore, the terraces from the restaurants can remain the same as the roundabout does not take up space there. The cycling and pedestrian paths are almost at the same place and the main road is even further away than in the initial situation which makes for a more enjoyable terrasse experience.

A negative effect of the roundabout taking up more space is that parking spaces will be lost, which is a negative effect for the residents in the neighborhood. However, there still is a parking space towards the northeast which can be used for the residents. This is less convenient, although it is an option.

Feeling of safety

One problem with the current design of the intersection is that the feeling of safety is missing. Vehicles are flying past on the N343 and as a vehicle, cyclist or pedestrian standing to cross the N343 or even worse standing in the middle between the two lanes, gives a unnerving feeling. This feeling can not be taken away completely; however, the oval roundabout makes that vehicles drive past with a slightly lower speed. Next to that, no motorized vehicle must stand in the middle of the two roads due to the roundabout design.

The pedestrians and cyclists do have to stand in between the two lanes, however there is more space available to stand which gives a saver feeling dan being cramped up on a small space. Furthermore, the cyclists and pedestrians have right of way over the motorized vehicles, which gives a safer feeling, not having cars flying past and finding a suitable gap.

Small pre-sorting bays

The problem with the small pre-sorting bays can not be solved due to rules and regulations (Crow, 2012) that the sorting lane for motorized vehicles should be exactly 5 meters. This means that normal sized vehicles can stand there but longer vehicles like trucks cannot. This was the is the same situation as for the initial design, so the problem remains that vehicles can block the cycling and pedestrian crossing.

The problem of the small pre-sorting bay in the middle of the road is solved as that is not present anymore with a roundabout. However, it can be the case with the roundabout that vehicles are blocking the traffic on the roundabout when having to wait for a crossing cyclist or pedestrians. This is only for a few seconds and therefore this will give less problems than the initial design where the vehicle was slightly blocking one lane creating unsafe situations for a significant amount of time.

8. Discussion, conclusion and recommendations

This chapter includes a few points of discussion of this research, a general conclusion and recommendations for further research.

8.1 Discussion

There are a few points of discussion in this research which will be discussed in this chapter.

The first point being that the model is run based on only one dataset of one count and is verified and validated by one other dataset. The datasets have been compared with data from 2020 provided by the municipality, however a larger dataset with counts over more days should be used for the actual model to consider possible errors or differences in intensities. The reason for only having 2 datasets is due to the large amount of people necessary for counting the data and the not ideal weather in November. The choice has been made to do one count at a Wednesday which theoretically has the lowest intensity of traffic and one count on a Tuesday which theoretically has the highest intensity of traffic. (Rijkswaterstaat Verkeersinformatie, 2023)

Next point is that the model is only run at 90% intensity of the dataset because otherwise the initial situation intersection stops running due to the vehicles blocking the intersection. This is not the actual counted situation; therefore, the model is not completely representable. However, the model does run almost the same way as the real-life situation, only the queues are sometimes larger than in real life. That is partly because VISSIM simulates vehicles following a Poisson distribution. Simulating vehicles within the 10-minute time period with one peak, while in the real-life situation multiple small peaks are more representative. A solution could be to use smaller time periods for input data, however this problem occurred at a late state in the project and therefore this could not be addressed completely.

Furthermore, the model does not include a warm-up period for each run. The warm-up period lets the model run for 15-30 minutes pre-loading the network and therefore having a more representable situation to collect the data from. This has been overlooked in the making of the models and therefore the models start and at the same time the data collection starts. This leads to a less representable results list as for example the travel times are smaller as there are no other vehicles to take into account or previous queues.

For the data collection and analysis there are points that can not be quantified as they are related to stakeholders' opinions or interests. It would be better to be in more direct contact with stakeholders to be able to create a better understanding of their feelings. In that way

the feelings can be quantified, and the different points can be determined of which is more important over the other points.

8.2 Conclusion

As can be determined from the previous chapters, there are positive and negative points for each design. An overview of the points will be given in this chapter, and an answer will be given towards the research questions.

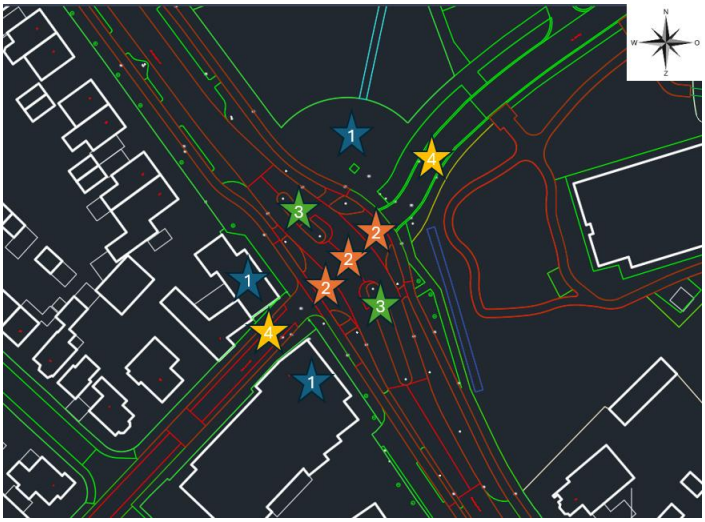

Figure 25: Problem points

In general, there were several problems stated mostly in figure 25. The problems will get run through if the problem has been taken care of or if the problem still exists.

Problem 1, the blue stars, is related to the restaurant owners and the connection with the meeting point. In the current situation crossing the N343 is difficult and therefore getting to the restaurants or going to the meeting point is difficult. This leads to less social cohesion in the town. The new oval roundabout keeps in mind the restaurant owners and the terraces by not interfering with their businesses and their space. The main intersection is further away from the restaurants, creating a pleasurable situation on the terraces. The meeting point does have to be resituated further away from the restaurant which is a negative point. However, the connection between all three points has improved due to the cyclists and pedestrians having right of way on the oval roundabout.

Problem 2, the orange stars, relate to the vehicle presorting bays that are too small and blocking other traffic. This is not solved in the new design due to the rules and regulations given by SWOV, 2012. However, the problem of the small presorting bays has been solved for the bays in between the roads as there are no sorting bays necessary for the roundabout design.

Problem 3, the green stars, relates to the problem pedestrians and cyclists not having a safe and convenient place to cross the N343. This problem is solved by giving cyclists and pedestrians right of way over the motorized vehicles. Further, there is more distance between the motorized vehicles and the cyclists and pedestrians which creates a safer feeling for both parties.

Problem 4, the yellow stars, relate the problems of the crossing roads that are not able to get on the N343 or cross it because they must yield for oncoming traffic. Especially because the N343 has priority over the other side roads. This problem is solved for De Aanleg as can be determined from the data analysis in chapter 7. However, now the problems exist for traffic coming from the N343 North not being able to get on the roundabout and creating queues. These queues are shorter but have an impact on relatively more traffic as the intensity of the traffic is higher on the N343 North than on De Aanleg.

Overall looking at the design of both intersections, the roundabout design takes up a significant amount of space in comparison to the initial design. This goes at the cost of the green space and the small forest of the nursing home. Next to that, the roundabout design also takes up parking spaces. The people using these parking spaces can park their car further to the north at a parking lot, however this is less convenient.

To give an overall view of all points table 4 can be looked upon where the results are compared with the stakeholder interests, measures of effectiveness and the problems. In this table also an overview is given if the problems are solved or not. The solved or not solved section is based on the data analysis and model reflection, figure 20-22 in chapter 6, with for example vehicle delays.

Table 4: Overview positive and negative points

Stakeholder interests	**Measure of Effectiveness**	**Problems**	**Improvement**	**Explanation**
Improvement in social cohesion	Traffic flow, safety and social cohesion	Problem 1 and 3	Improved	The social cohesion is mostly improved due to easier and safer possibilities for crossing.
Improvement in safety	Safety	Problem 3 and 4	Improved	The safety is improved due to less complex conflict areas and improved

				crossings, this will be further explained in chapter 7.
Improvement in crossing of intersection (pedestrians and cyclists)	Traffic flow, safety and social cohesion	Problem 1,2,3 and 4	Improved	The cyclists and pedestrians have priority over the motorized vehicles. This makes an easier crossing. As can be seen in figures 20-22 where there is an overall improvement for the cyclists.
Improvement in inserting/crossing the main traffic flow (motorized vehicles)	Traffic flow and safety	Problem 2 and 4	Improved and made worse	For De Aanleg inserting the main problems are solved with waiting times. For the Gunnerstraat the vehicle delay has increased a small amount.
Improvement in the overall flow/travel time of the main traveling link	Traffic flow and safety	Problem 2	Improved and made worse	For the N343 South there is an improvement in travel time vehicle delay. For the N343 North there is a small increase in vehicle delay and travel time which is worse than initial.

To give answer to the main research question, first the sub questions needed to be answered, which were answered during the report and the results can also be found in this conclusion.

The main research question was: *Is an oval roundabout a suitable solution for resolving the issues such as traffic flow disturbance, safety, social cohesion of the current traffic situation?*

The answer to the question is complex as can be seen in table 4, there are positive and negative points regarding the points of interest. The issues for traffic flows are solved for De Aanleg, however new problems are created for the N343 North. For the cyclists the problems are solved regarding crossing and having an easier flow.

For safety, the situation is improved with the roundabout design and giving the cyclists and pedestrians right of way. The amount of conflict area's is the same in both situations, but the conflict areas are less complex for the roundabout design and are placed further apart. This gives the road users more time to adjust for the new situation, creating less unsafe situations.

For the social cohesion the roundabout design has improvements, creating safer and more convenient crossings. Keeping in mind the restaurants and still having the meeting point. In this way the intersection is less of a hindrance for the town and partly solves the problem of the N343 dividing the town in two.

Overall, the answer to the main question will be that an oval roundabout can be a suitable solution if the positive effects outweigh the negative effects which only the stakeholders can determine.

8.3 Recommendations

As a recommendation, the suggestion would be to be in contact with the stakeholders and discussing the report and solution with them to try to discover the arguments of the stakeholders for and against this design.

If the arguments against are small points which can be solved easily the suggestion will be to change the design in such a way that the problems are solved, and the design could be workable.

Still the suggestion would be to recalculate the waiting times and queues et cetera with a larger representative dataset so that there are no differences and the design works.

If the stakeholders are against the whole design, then a new design must be made which can be, for example, a regulated intersection with traffic lights. This should be new research, where positive and negative points from this research are considered.

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10. Appendix

10.1 Appendix A: Limitations MOE

In this appendix the limitations of the MOE values are given.

MOE Building Blocks of Performance Measurement Systems	Limitations
Travel Time	• Treatment of delays and travel time for incomplete trips or trips that cannot start within the analysis period is an issue. • Difficult for a decision-maker to interpret (no value of time is obviously too high or too low without knowing more about the trip characteristics).
Speed	• Treatment of incomplete or unbegun trips is an issue, as for travel time. • Interpretation is facility-specific. Low speed may be quite acceptable on an arterial, but not on a freeway. • Once all vehicles come to a stop, the mean speed conveys no further information on the severity of congestion (speed cannot go below zero). • Speed is a poor indicator of how close the facility is to breakdown (capacity).
Delay	• Treatment of incomplete trips or trips that have not started is an issue. • Definition of free-flow speed, against which delay is measured, is a problem. Some use the posted speed limit for the free-flow speed; others use the mean speed under very low-flow conditions (can be higher or lower than the posted speed limit).
Queue	• Definition of when vehicle joins a queue and when it leaves a queue is a problem. • Interpretation is road segment and facility-specific. Queues are normal for signals, but queues that overflow turn bays or block cross streets are not desirable. • Tallying of queued vehicles unable to enter the road segment is an issue for many tools. Many tools cannot report a queue longer than the storage capacity of the road segment or turn bay. • Tallying of vehicles, which have not been able to enter the road network during the analysis period, is an issue.
Stops	• Definition of what minimum speed is a stop is an issue. (One reviewer recommended that stop speed be defined as zero so that model results can be better compared to two-fluid models of traffic flow.) • Since tallying of stops is normally suspended while a vehicle is moving up within a queue, the definition of a queue is an issue. • Once all vehicles are queued on a road segment, further increases in congestion have no effect on stops.
Density	• Once all vehicles are queued, then further increases in congestion have no effect on density.
Travel-Time Variance	• Rarely used due to difficulty of computation. Prediction tools are close to nonexistent. • Once all vehicles are queued on a road segment, the variation in travel time tends to drop towards zero. Variance will tend to peak when the volume is around capacity.

Figure A-1: Limitations of the MOE (FHWA, 21-03-2023)

10.2 Appendix B: Traffic count

In this appendix the tables for the traffic count are given.

Table B-1: Table with directions counted for all travel measures for each direction

N343 South													
Time		Cars and motorcyclists			Vans and trucks			Cyclists			Pedestrians		
Start	End	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)	AC (Left)	AD (Right)	AB (Straight)
7.10	7.19												
7.20	7.29												
7.30	7.39												
7.40	7.49												
7.50	7.59												
8.00	8.09												
8.10	8.19												
8.20	8.29												
8.30	8.39												
8.40	8.49												
8.50	8.59												

N343 North													
Time		Cars and motorcyclists			Vans and trucks			Cyclists			Pedestrians		
Start	End	BD (Left)	BC (Right)	BA (Straight)	BD (Left)	BC (Right)	BA (Straight)	BD (Left)	BC (Right)	BA (Straight)	BD (Left)	BC (Right)	BA (Straight)
7.10	7.19												
7.20	7.29												
7.30	7.39												
7.40	7.49												
7.50	7.59												
8.00	8.09												
8.10	8.19												
8.20	8.29												
8.30	8.39												
8.40	8.49												
8.50	8.59												
Gunnerstraat													
Time		Cars and motorcyclists			Vans and trucks			Cyclists			Pedestrians		
Start	End	CB (Left)	CA (Right)	CD (Straight)	CB (Left)	CA (Right)	CD (Straight)	CB (Left)	CA (Right)	CD (Straight)	CB (Left)	CA (Right)	CD (Straight)
7.10	7.19												
7.20	7.29												
7.30	7.39												
7.40	7.49												
7.50	7.59												
8.00	8.09												
8.10	8.19												
8.20	8.29												
8.30	8.39												
8.40	8.49												
8.50	8.59												
De Aanleg													
Time		Cars and motorcyclists			Vans and trucks			Cyclists			Pedestrians		
Start	End	DA (Left)	DB (Right)	DC (Straight)	DA (Left)	DB (Right)	DC (Straight)	DA (Left)	DB (Right)	DC (Straight)	DA (Left)	DB (Right)	DC (Straight)
7.10	7.19												
7.20	7.29												
7.30	7.39												
7.40	7.49												
7.50	7.59												
8.00	8.09												
8.10	8.19												
8.20	8.29												
8.30	8.39												
8.40	8.49												
8.50	8.59												

10.3 Appendix C: Data collection results

In this appendix an overview of the collected data from 26-11-2024 is given with comparisons with all directions.

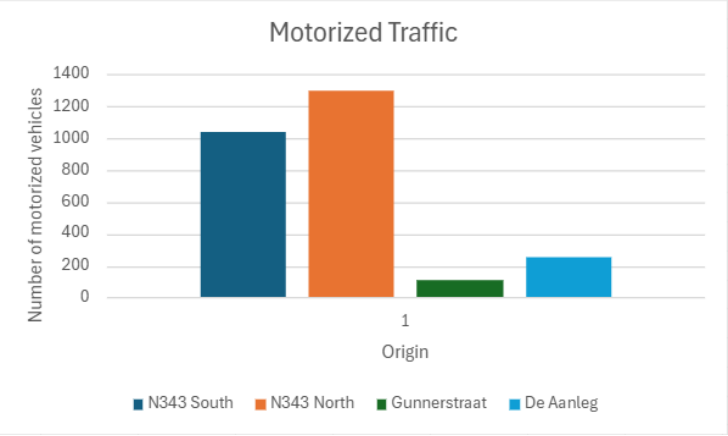

Figure C-1: Overview of motorized traffic on the intersection for the period 7.10-8.59

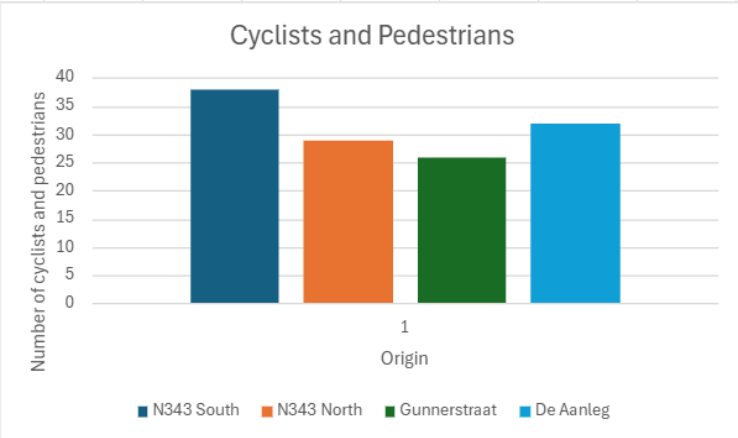

Figure C-2: Overview of cyclists and pedestrians on the intersection for the period 7.10-8.59

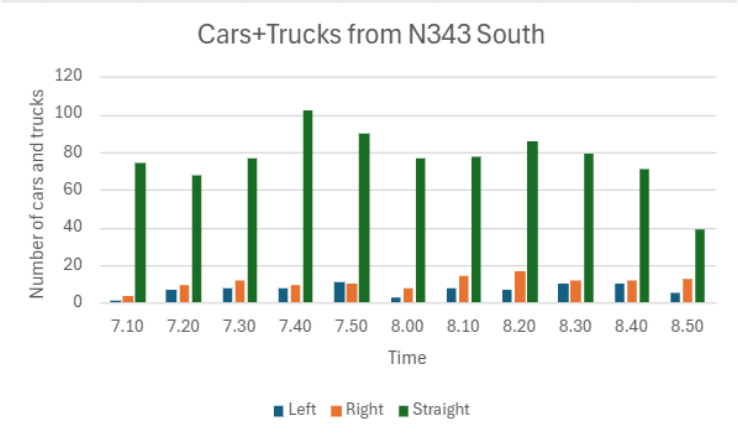

Figure C-3: Overview of motorized traffic on the intersection for the period 7.10-8.59 from N343 South

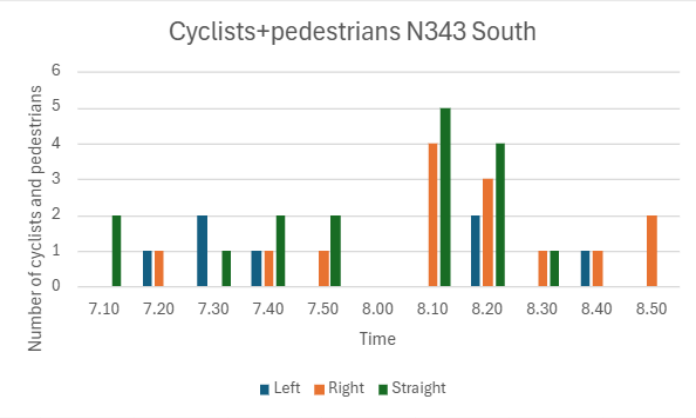

Figure C-4: Overview of cyclists and pedestrians on the intersection for the period 7.10-8.59 from N343 South

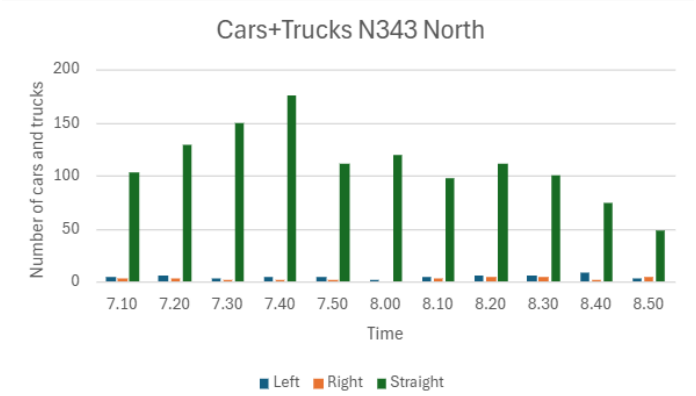

Figure C-5: Overview of motorized traffic on the intersection for the period 7.10-8.59 from N343 North

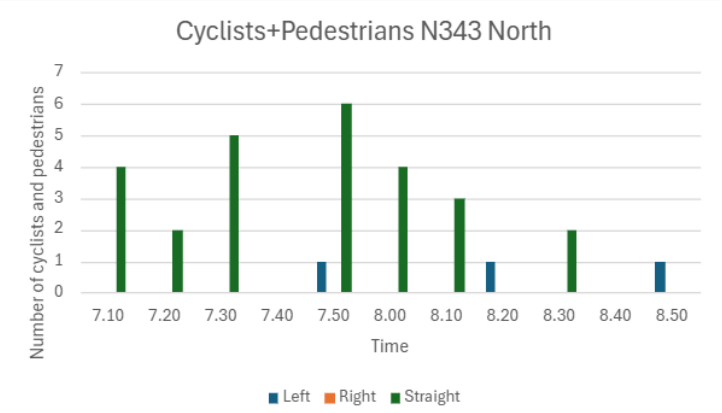

Figure C-6: Overview of cyclists and pedestrians on the intersection for the period 7.10-8.59 from N343 North

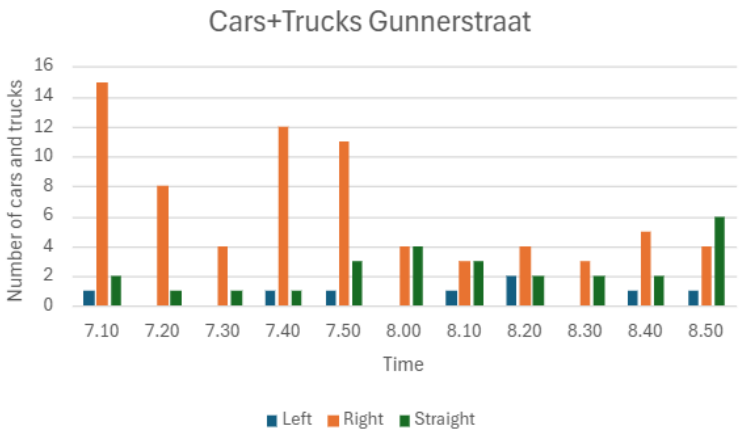

Figure C-7: Overview of motorized traffic on the intersection for the period 7.10-8.59 from Gunnerstraat

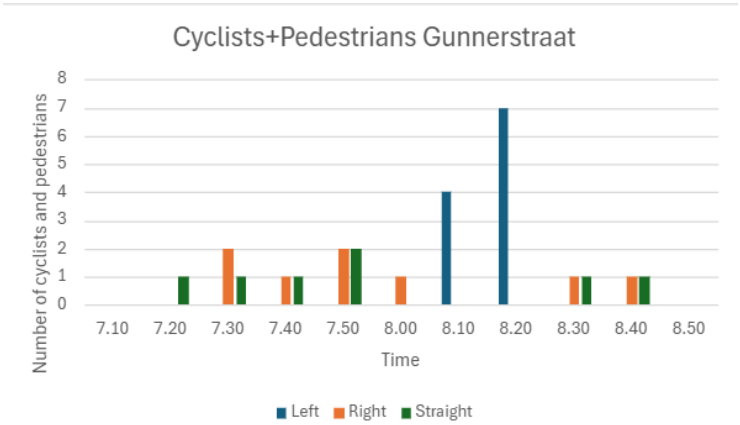

Figure C-8: Overview of cyclists and pedestrians on the intersection for the period 7.10-8.59 from Gunnerstraat

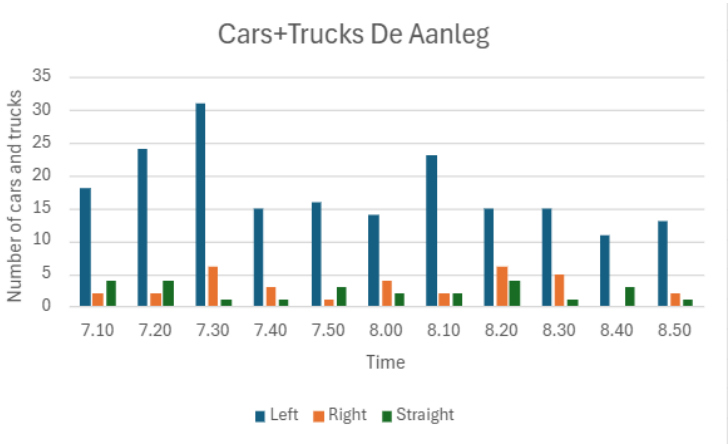

Figure C-9: Overview of motorized traffic on the intersection for the period 7.10-8.59 from De Aanleg

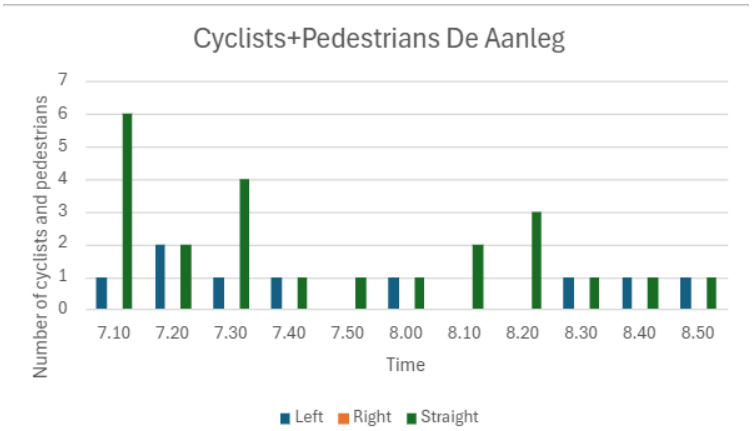

Figure C-10: Overview of cyclists and pedestrians on the intersection for the period 7.10-8.59 from De Aanleg

10.4 Appendix D: Input data 26-11-2024

Here an overview of all input data is given for the dataset of 26-11-2024.

Table D-1: Vehicle inputs in vehicles per hour

Input variables 26-11-2024					
Motorized vehicles					
Start	**End**	**N343 South**	**N343 North**	**Gunnerstraat**	**De Aanleg**
7.10	7.19	427	594	97	130
7.20	7.29	454	745	49	162
7.30	7.39	524	832	27	205
7.40	7.49	643	977	76	103
7.50	7.59	599	643	81	108
8.00	8.09	475	659	43	108
8.10	8.19	540	567	38	146
8.20	8.29	594	653	43	135
8.30	8.39	545	599	27	113
8.40	8.49	502	459	43	76
8.50	8.59	308	302	59	86
Cyclists+Pedestrians					
Start	**End**	**N343 South**	**N343 North**	**Gunnerstraat**	**De Aanleg**
7.10	7.19	11	22	0	38
7.20	7.29	11	11	5	22
7.30	7.39	16	27	16	27
7.40	7.49	22	0	11	11
7.50	7.59	16	38	22	5
8.00	8.09	0	22	5	11
8.10	8.19	49	16	22	11
8.20	8.29	49	5	38	16
8.30	8.39	11	11	11	11
8.40	8.49	11	0	11	11
8.50	8.59	11	5	0	11

Table D-2: Motorized vehicle route choices in percentages

Route choices per time interval											
	0-600	600-1200	1200-1800	1800-2400	2400-3000	3000-3600	3600-4200	4200-4800	4800-5400	5400-6000	6000-6600
	N343 South										
AB (Straig	0,93671	0,80952	0,79381	0,85714	0,81081	0,875	0,78	0,78182	0,78218	0,76344	0,684211
AC (Left)	0,01266	0,08333	0,08247	0,06723	0,0991	0,03409	0,08	0,06364	0,09901	0,10753	0,087719
AD (Right)	0,05063	0,10714	0,12371	0,07563	0,09009	0,09091	0,14	0,15455	0,11881	0,12903	0,22807
	N343 North										
AB (Straig	0,93636	0,93478	0,97403	0,97238	0,94118	0,98361	0,93333	0,91736	0,9009	0,87059	0,857143
AC (Left)	0,03636	0,04348	0,01948	0,0221	0,04202	0,01639	0,0381	0,04959	0,05405	0,10588	0,053571
AD (Right)	0,02727	0,02174	0,00649	0,00552	0,01681	0	0,02857	0,03306	0,04505	0,02353	0,089286
	Gunnerstraat										
AB (Straig	0,11111	0,11111	0,2	0,07143	0,2	0,5	0,42857	0,25	0,4	0,25	0,545455
AC (Left)	0,05556	0	0	0,07143	0,06667	0	0,14286	0,25	0	0,125	0,090909
AD (Right)	0,83333	0,88889	0,8	0,85714	0,73333	0,5	0,42857	0,5	0,6	0,625	0,363636
	De Aanleg										
AB (Straig	0,16667	0,13333	0,02632	0,05263	0,15	0,1	0,07407	0,16	0,04762	0,21429	0,0625
AC (Left)	0,75	0,8	0,81579	0,78947	0,8	0,7	0,85185	0,6	0,71429	0,78571	0,8125
AD (Right)	0,08333	0,06667	0,15789	0,15789	0,05	0,2	0,07407	0,24	0,2381	0	0,125

Table D-3: Cyclists and pedestrians route choices in percentages

Route choices per time interval											
	0-600	600-1200	1200-1800	1800-2400	2400-3000	3000-3600	3600-4200	4200-4800	4800-5400	5400-6000	6000-6600
	N343 South										
AB (Straig	0	0,5	0,66667	0	0	1	0	0,33333	0	0,5	0
AC (Left)	0	0,5	0,66667	0,25	0	1	0	0,22222	0	0,5	0
AD (Right)	0	0,5	0	0,25	0,33333	1	0,44444	0,33333	0,5	0,5	1
	N343 North										
AB (Straig	0	0	0	1	0,14286	0	0	1	0	1	1
AC (Left)	0	0	0	1	0,14286	0	0	1	0	1	1
AD (Right)	0	0	0	1	0	0	0	0	0	1	0
	Gunnerstraat										
AB (Straig	1	0	0	0	0	0	0	0	0,5	0	1
AC (Left)	1	0	0	0	0	0	1	1	0	0	1
AD (Right)	1	0	0,66667	0,5	0,5	1	0	0	0,5	0,5	1
	De Aanleg										
AB (Straig	0,14286	0,5	0,2	1	0	0,5	0	0,33333	0,5	0,5	0,5
AC (Left)	0,14286	0,5	0,2	0,5	0	0,5	0	0	0,5	0,5	0,5
AD (Right)	0	0	0	0	0	0	0	0	0	0	0

Table D-4: Mode split in percentages for the amount of trucks

		Mode split			
Start	End	N343 South	N343 North	Gunnerstraat	De Aanleg
7.10	7.19	0,23	0,07	0,39	0,04
7.20	7.29	0,18	0,09	0,44	0,07
7.30	7.39	0,04	0,03	0,2	0
7.40	7.49	0,08	0,06	0,07	0,11
7.50	7.59	0,03	0,06	0,2	0
8.00	8.09	0,05	0,06	0,25	0
8.10	8.19	0,05	0,04	0	0
8.20	8.29	0,05	0,07	0,13	0,04
8.30	8.39	0,06	0,06	0,4	0,1
8.40	8.49	0,09	0,14	0,13	0,07
8.50	8.59	0,07	0,07	0,18	0,06

10.5 Appendix E: Input variables verification

Here an overview of all input data is given for the dataset of 26-11-2024.

Table E-1: Vehicle inputs in vehicles per hour

Input variables 20-11-2024					
Motorized vehicles					
Start	End	N343 Sou	N343 Nort	Gunnerstr	De Aanleg
7.10	7.19	367	616	81	113
7.20	7.29	470	626	76	108
7.30	7.39	524	740	49	178
7.40	7.49	589	632	43	189
7.50	7.59	599	621	54	97
8.00	8.09	486	632	54	130
8.10	8.19	394	616	65	103
8.20	8.29	448	562	59	167
8.30	8.39	389	497	76	178
8.40	8.49	367	437	38	113
8.50	8.59	351	329	43	108
Cyclists+Pedestrians					
Start	End	N343 Sou	N343 Nort	Gunnerstr	De Aanleg
7.10	7.19	11	16	0	16
7.20	7.29	16	38	0	16
7.30	7.39	16	0	5	0
7.40	7.49	16	5	5	5
7.50	7.59	11	27	16	16
8.00	8.09	0	16	5	22
8.10	8.19	27	0	27	0
8.20	8.29	65	5	5	27
8.30	8.39	11	16	16	16
8.40	8.49	16	5	11	11
8.50	8.59	0	5	5	22

Table E-2: Motorized vehicle route choices in percentages

Route choices per time interval											
	0-600	600-1200	1200-180	1800-240	2400-300	3000-360	3600-420	4200-480	4800-540	5400-600	6000-6600
	N343 South										
AB (Straig	0,85294	0,87356	0,84536	0,77982	0,66667	0,73333	0,82192	0,61446	0,91667	0,64706	0,6
AC (Left)	0,07353	0,10345	0,09278	0,10092	0,14414	0,11111	0,0411	0,10843	0,04167	0,11765	0,27692
AD (Right)	0,07353	0,02299	0,06186	0,11927	0,18919	0,15556	0,13699	0,27711	0,04167	0,23529	0,12308
	N343 North										
AB (Straig	0,94737	1	0,94161	0,94017	0,95652	0,95726	0,94737	0,90385	0,90217	0,96296	0,88525
AC (Left)	0,03509	0	0,0438	0,03419	0,01739	0,02564	0,05263	0,05769	0,05435	0,02469	0,09836
AD (Right)	0,01754	0	0,0146	0,02564	0,02609	0,01709	0	0,03846	0,04348	0,01235	0,01639
	Gunnerstraat										
AB (Straig	0,06667	0,07143	0	0,375	0	0,1	0,5	0,18182	0	0,14286	0
AC (Left)	0,13333	0	0,11111	0,125	0	0,1	0,08333	0	0,21429	0,28571	0,25
AD (Right)	0,8	0,92857	0,88889	0,5	1	0,8	0,41667	0,81818	0,78571	0,57143	0,75
	De Aanleg										
AB (Straig	0,2381	0,25	0,0303	0,17143	0,16667	0,04167	0,05263	0,09677	0,0303	0,09524	0,25
AC (Left)	0,66667	0,7	0,78788	0,65714	0,77778	0,95833	0,78947	0,80645	0,81818	0,61905	0,65
AD (Right)	0,09524	0,05	0,18182	0,17143	0,05556	0	0,15789	0,09677	0,15152	0,28571	0,1

Table E-3: Cyclists and pedestrians route choices in percentages

Route choices per time interval											
	0-600	600-1200	1200-180	1800-240	2400-300	3000-360	3600-420	4200-480	4800-540	5400-600	6000-6600
	N343 South										
AB (Straig	0	0,33333	0	0,33333	0	1	0,6	0	0	0	1
AC (Left)	0,5	0	0	0	0	1	0,2	0,16667	0,5	0,66667	1
AD (Right)	0,5	0,66667	1	0,66667	1	1	0,2	0,83333	0,5	0,33333	1
	N343 North										
AB (Straig	0	0	1	1	0,2	0	1	0	0	0	0
AC (Left)	0	0,28571	1	0	0	0	1	0	0	0	0
AD (Right)	1	0,71429	1	0	0,8	1	1	1	1	1	1
	Gunnerstraat										
AB (Straig	1	0	0	0	0	0	0	0	0,5	0	1
AC (Left)	1	0	0	0	0	0	1	1	0	0	1
AD (Right)	1	0	0,66667	0,5	0,5	1	0	0	0,5	0,5	1
	De Aanleg										
AB (Straig	0,66667	0,66667	1	0	0,33333	1	1	0	0,33333	0,5	1
AC (Left)	0	0	1	0	0	0	1	0	0	0	0
AD (Right)	0,33333	0,33333	1	1	0,66667	0	1	1	0,66667	0,5	0

Table E-4: Mode split in percentages for the amount of trucks

		Mode split			
Start	End	N343 Sout	N343 Nort	Gunnerstr	De Aanleg
7.10	7.19	29	10	40	10
7.20	7.29	25	4	79	0
7.30	7.39	14	7	33	0
7.40	7.49	15	5	38	0
7.50	7.59	15	5	20	0
8.00	8.09	14	8	10	0
8.10	8.19	14	8	33	11
8.20	8.29	17	3	36	0
8.30	8.39	18	4	21	6
8.40	8.49	16	6	57	0
8.50	8.59	25	5	63	5

10.6 Appendix F: Verification and validation initial model

In this chapter the verification and validation are given for the initial model.

Table F-1: Verification of the model

	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343-south straight	724	757	-4,346677236	-33
N343 South Left	65	70	-7,407407407	-5
N343 South Right	108	108	0	0
De Aanleg Straight	23	23	-1,709401709	0
De Aanleg Left	165	176	-5,982905983	-11
De Aanleg Right	37	30	24,57912458	7
N343 North Straight	1124	1099	2,284102284	25
N343 North Left	55	47	17,52136752	8
N343 North Right	41	26	57,08812261	15
Gunnerstraat Straight	17	24	-30,04115226	-7
Gunnerstraat Left	7	7	-2,777777778	0
Gunnerstraat Right	75	66	14,15525114	9
C N343 South Straight	5	15	-67,32026144	-10
C N343 South Left	6	6	-4,761904762	0
C N343 South Right	17	13	34,92063492	4
C De Aanleg Straight	13	21	-37,19806763	-8
C De Aanleg Left	9	8	11,11111111	1
C De Aanleg Right	0	0	#DIV/0!	0
C N343 North Straight	3	23	-87,17948718	-20
C N343 North Left	4	3	48,14814815	1
C N343 North Right	18	0	#DIV/0!	18
C Gunnerstraat Straight	3	6	-52,38095238	-3
C Gunnerstraat Left	14	10	41,41414141	4
C Gunnerstraat Right	10	7	38,88888889	3

Table F-2: Verification of the validation data

Input data Validation	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343-south straight	612	662	-7,608695652	-50
N343 South Left	90	96	-6,542056075	-6
N343 South Right	103	109	-5,417814509	-6
De Aanleg Straight	22	32	-30,15873016	-10
De Aanleg Left	191	201	-4,833084205	-10
De Aanleg Right	26	33	-21,92192192	-7
N343 North Straight	1005	1031	-2,559627691	-26
N343 North Left	43	40	8,585858586	3
N343 North Right	23	20	16,16161616	3
Gunnerstraat Straight	14	14	3,703703704	1
Gunnerstraat Left	7	13	-44,44444444	-6
Gunnerstraat Right	90	86	4,166666667	4
C N343 South Straight	17	23	-24,44444444	-6
C N343 South Left	3	5	-33,33333333	-2
C N343 South Right	7	6	11,11111111	1
C De Aanleg Straight	8	12	-31,62393162	-4
C De Aanleg Left	14	14	3,703703704	1
C De Aanleg Right	0	0	#DIV/0!	0
C N343 North Straight	18	20	-9,090909091	-2
C N343 North Left	1	2	-44,44444444	-1
C N343 North Right	3	2	66,66666667	1
C Gunnerstraat Straight	4	4	11,11111111	0
C Gunnerstraat Left	10	5	85,18518519	5
C Gunnerstraat Right	8	7	11,11111111	1

Table F-3: Extreme conditions test

Extreme conditions test	Travel time average	Travel time MAX	Delay average	Delay MAX
N343-south straight	2723,49%	3226,80%	7088,76%	5498,27%
N343 South Left	2112,37%	1819,86%	3850,00%	2449,93%
N343 South Right	2346,37%	2384,84%	7233,90%	4077,03%
De Aanleg Straight	596,55%	290,45%	614,86%	283,75%
De Aanleg Left	586,16%	295,45%	613,92%	281,82%
De Aanleg Right	583,87%	290,79%	594,03%	276,18%
N343 North Straight	2206,45%	2524,28%	12347,69%	7321,64%
N343 North Left	1447,38%	1084,64%	3806,65%	1652,72%
N343 North Right	2116,53%	2242,37%	21108,47%	10386,63%
Gunnerstraat Straight	327,42%	339,04%	337,66%	338,99%
Gunnerstraat Left	782,88%	922,95%	1390,04%	1249,37%
Gunnerstraat Right	917,38%	1979,68%	4668,97%	5027,13%
C N343 South Straight	-100,00%	-100,00%	0,00%	0,00%
C N343 South Left	-100,00%	-100,00%	-100,00%	-100,00%
C N343 South Right	-100,00%	-100,00%	-100,00%	-100,00%
C De Aanleg Straight	166,67%	163,87%	314,99%	178,48%
C De Aanleg Left	138,62%	67,89%	47,78%	-55,84%
C De Aanleg Right	0,00%	0,00%	0,00%	0,00%
C N343 North Straight	-100,00%	-100,00%	0,00%	0,00%
C N343 North Left	-100,00%	-100,00%	-100,00%	-100,00%
C N343 North Right	-100,00%	-100,00%	-100,00%	-100,00%
C Gunnerstraat Straight	189,23%	187,78%	443,21%	266,51%
C Gunnerstraat Left	-100,00%	-100,00%	-100,00%	-100,00%
C Gunnerstraat Right	168,64%	166,96%	0,00%	0,00%

10.7 Appendix G: Verification and validation roundabout model

In this chapter the verification and validation are given for the roundabout model.

Table G-1: Verification of the model

Input data 2024-11-26	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343-south straight	721	757	-4,743030783	-36
N343 South Left	65	70	-7,407407407	-5
N343 South Right	108	108	0	0
De Aanleg Straight	17	23	-27,35042735	-6
De Aanleg Left	169	176	-3,703703704	-7
De Aanleg Right	38	30	27,94612795	8
N343 North Straight	955	1099	-13,09491309	-144
N343 North Left	39	47	-16,66666667	-8
N343 North Right	35	26	34,09961686	9
Gunnerstraat Straight	17	24	-30,04115226	-7
Gunnerstraat Left	7	7	-2,777777778	0
Gunnerstraat Right	75	66	14,15525114	9
C N343 South Straight	5	15	-67,32026144	-10
C N343 South Left	6	6	-4,761904762	0
C N343 South Right	17	13	34,92063492	4
C De Aanleg Straight	13	21	-37,19806763	-8
C De Aanleg Left	9	8	11,11111111	1
C De Aanleg Right	0	0	#DIV/0!	0
C N343 North Straight	3	23	-87,17948718	-20
C N343 North Left	4	3	48,14814815	1
C N343 North Right	18	0	#DIV/0!	18
C Gunnerstraat Straight	2	6	-68,25396825	-4
C Gunnerstraat Left	14	10	41,41414141	4
C Gunnerstraat Right	11	7	52,77777778	4

Table G-2: Verification of the validation data

Input data Validation	Total (simulated)	Total Counted	Difference (%)	Difference in value
N343-south straight	612	662	-7,608695652	-50
N343 South Left	88	96	-8,618899273	-8
N343 South Right	104	109	-4,499540863	-5
De Aanleg Straight	21	32	-33,33333333	-11
De Aanleg Left	189	201	-5,829596413	-12
De Aanleg Right	29	33	-12,91291291	-4
N343 North Straight	951	1031	-7,795229785	-80
N343 North Left	49	40	23,73737374	9
N343 North Right	20	20	1,01010101	0
Gunnerstraat Straight	14	14	3,703703704	1
Gunnerstraat Left	7	13	-44,44444444	-6
Gunnerstraat Right	90	86	4,166666667	4
C N343 South Straight	3	23	-86,66666667	-20
C N343 South Left	6	5	33,33333333	2
C N343 South Right	18	6	185,7142857	12
C De Aanleg Straight	14	12	19,65811966	2
C De Aanleg Left	0	14	-100	-14
C De Aanleg Right	8	0	#DIV/0!	8
C N343 North Straight	1	20	-94,94949495	-19
C N343 North Left	4	2	122,2222222	2
C N343 North Right	17	2	844,4444444	15
C Gunnerstraat Straight	10	4	177,7777778	6
C Gunnerstraat Left	9	5	66,66666667	4
C Gunnerstraat Right	3	7	-58,33333333	-4

Table G-3: Comparison travel times and delays

Validation	Travel time average	Travel time MAX	Delay average	Delay MAX
N343-south straight	9,61%	25,81%	38,32%	57,32%
N343 South Left	7,42%	13,93%	28,25%	23,01%
N343 South Right	9,81%	37,70%	40,76%	69,60%
De Aanleg Straight	33,99%	186,43%	225,99%	606,14%
De Aanleg Left	8,22%	33,28%	41,05%	77,71%
De Aanleg Right	11,33%	114,22%	51,99%	249,26%
N343 North Straight	-9,42%	-3,14%	-12,07%	-2,53%
N343 North Left	-12,90%	-5,03%	-16,92%	-5,47%
N343 North Right	5,60%	2,11%	6,60%	1,42%
Gunnerstraat Straight	-14,51%	-44,25%	-34,85%	-69,35%
Gunnerstraat Left	-3,46%	30,63%	-2,23%	24,80%
Gunnerstraat Right	5,24%	-26,64%	8,00%	-34,03%
C N343 South Straight	27,60%	35,81%	1019,28%	987,95%
C N343 South Left	-6,20%	-9,35%	3600,00%	5366,67%
C N343 South Right	1,26%	0,07%	-57,14%	-66,31%
C De Aanleg Straight	4,78%	19,31%	-55,67%	-68,10%
C De Aanleg Left	-100,00%	-100,00%	-100,00%	-100,00%
C De Aanleg Right	0,00%	0,00%	0,00%	0,00%
C N343 North Straight	-7,20%	-17,92%	391,67%	247,06%
C N343 North Left	-7,74%	-10,16%	-55,84%	-78,06%
C N343 North Right	-0,91%	4,19%	5,56%	16,00%
C Gunnerstraat Straight	-1,60%	-1,60%	0,00%	0,00%
C Gunnerstraat Left	-1,98%	5,85%	234,12%	412,20%
C Gunnerstraat Right	9,78%	6,46%	-20,00%	-27,27%

Table G-4: Extreme conditions test

Extreme conditions test	Travel time average	Travel time MAX	Delay average	Delay MAX
N343-south straight	757,12%	670,06%	1349,31%	739,38%
N343 South Left	811,12%	612,26%	1695,19%	605,47%
N343 South Right	891,72%	672,73%	1714,38%	662,38%
De Aanleg Straight	3194,87%	4586,43%	17815,61%	14217,38%
De Aanleg Left	2616,18%	3254,17%	9526,18%	6677,98%
De Aanleg Right	2985,86%	3718,52%	11032,20%	7709,85%
N343 North Straight	172,12%	191,35%	46,96%	102,33%
N343 North Left	179,00%	187,09%	64,30%	94,75%
N343 North Right	225,15%	187,92%	100,29%	105,98%
Gunnerstraat Straight	1369,75%	1446,54%	2832,96%	1806,20%
Gunnerstraat Left	1555,18%	1644,85%	4128,37%	2588,79%
Gunnerstraat Right	1566,75%	2000,94%	2909,58%	2562,11%
C N343 South Straight	194,13%	185,53%	4559,04%	4559,04%
C N343 South Left	284,21%	474,46%	123400,00%	195246,67%
C N343 South Right	124,82%	180,08%	2868,57%	2425,67%
C De Aanleg Straight	173,96%	767,30%	5682,47%	9565,80%
C De Aanleg Left	90,60%	154,97%	464,71%	216,91%
C De Aanleg Right	0,00%	0,00%	0,00%	0,00%
C N343 North Straight	570,32%	1346,72%	161508,33%	341952,94%
C N343 North Left	213,57%	327,00%	6819,48%	5514,19%
C N343 North Right	141,17%	177,93%	8700,00%	18892,00%
C Gunnerstraat Straight	110,82%	110,82%	0,00%	0,00%
C Gunnerstraat Left	151,04%	149,83%	4783,53%	4401,63%
C Gunnerstraat Right	112,45%	183,40%	960,00%	2595,45%

10.8 Appendix H: Comparison distances

In this chapter a comparison between the distances is given.

Table H-1: Comparison distances

Name	Distance Initial	Distance Roundabout
N343-south straight	470,95	496,11(5%)
N343 South Left	488,27	566,29(16%)
N343 South Right	465,41	457,33(-2%)
De Aanleg Straight	442,05	480,83(9%)
De Aanleg Left	425,5	465,76(9%)
De Aanleg Right	417,46	409,42(-2%)
N343 North Straight	402,87	414,37(3%)
N343 North Left	422,79	448,49(6%)
N343 North Right	408,48	427,54(5%)
Gunnerstraat Straight	184,19	203,88(11%)
Gunnerstraat Left	185,11	241,39(30%)
Gunnerstraat Right	155,24	168,26(8%)
C N343 South Straight	161,43	191,05(18%)
C N343 South Left	211,6	282,48(33%)
C N343 South Right	153,7	148,5(-3%)
C De Aanleg Straight	205,38	231,03(12%)
C De Aanleg Left	195,65	216,81(11%)
C De Aanleg Right	154,98	138,38(-11%)
C N343 North Straight	161,28	172,07(7%)
C N343 North Left	213,49	233,09(9%)
C N343 North Right	170,13	185,35(9%)
C Gunnerstraat Straight	199,65	219,52(10%)
C Gunnerstraat Left	206,56	260,54(26%)
C Gunnerstraat Right	146,63	158,36(8%)