Bicycle-safe Antwerp

A redevelopment of city centre streets through Dutch guidelines

Bachelor End Project

Student
Erik Scholten
4014510

Coördinators
Yufei Yuan
Maria Salomons

TU Delft

Preface

The reason for this research was to check if the cycling network of the Netherlands with its safety standars could be implemented in the rest of the world. To check this, the neighbouring country Belgium was taken as an example, more specifically testing of Antwerp. If this is possible, maybe in the coming decenia a better standard for cycling safety can be realised in Europe.

My thanks goes to my coordinators Yufei Yuan and Maria for their guidance with the process; to my fellow students Don, Chris, Thijs, Timo, Bart and Simone for making the Tuesday afternoons more pleasant; to Rob van Nes for the suggestion of Antwerp; and to my family and friends for general guidance, comments and their patience when hearing again and again my complaints about bicycle safety problems that I encounter while cycling with them.

Summary

In this report, the streets in the city centre of Antwerp are tested with the Dutch cycling safety standards to create a bicycle safe cycling network. A general advice is given to increase the bicycle safety in the city centre of Antwerp. In addition, an underdeveloped part of Antwerp's cycling network is redeveloped with respect to Dutch safety standards as an example for other redevelopments.

The large level of bicycle use in the Netherlands has led to a high quality cycling network. With the European Union getting more control over country policies with the goal to unify qualities and standards across all countries, it is interesting to look if the globally respected Dutch cycling network, with its corresponding safety standards, can be implemented in neighbouring countries as a start of unifying the safety quality of the European cycling network. To test how this can be done, the close neighbouring city of Antwerp is taken as an example. This report is trying to give an answer to the question how the streets in the city centre of Antwerp can be redeveloped with respect to Dutch safety guidelines to create a more bicycle-safety environment.

Within recent years, Antwerp has expanded their cycling. The problem is that mostly all of the constructions have been realised in the outer ring of the city while the city centre itself has mostly been left out. In the city centre itself a small amount of streets have bike paths and bike lanes. In majority, the layout of the streets and the corresponding bicycle safety does not match with the cycling usage of the streets. It can be said that the city is designed for the car, with a lack of safe cycling services

As a start of the research the current cycling network is analysed. Firstly, it is examined what Antwerp has already done in the past years for bicycle safety and what the plans are in the future for the city centre. Secondly, the current bike paths and lanes in the city centre are found and inspected for what the current quality is. Thirdly, data of cycling usage in Antwerp is analysed to look where the busiest streets are and if any of these busy streets have cycling safety characteristics, like bike lanes. Lastly, the current cycling network is checked if it matches with the amount of cycling. With the combination of the previous steps, a route is found which is suitable for redevelopment.

The route that is found, namely the Lange Dijkstraat, is tested with the Dutch safety standards. This route will be an example as how Antwerp's municipality can create a cycling network that is safely fit for a high cycling demand. In this example, two alternatives are given. The first is a short term plan. This is a quick way to create a more bicycle safe street. Mostly this will be bike markings on the road. The physical layout is the same. The second alternative gives more safe (although more expensive) solution and is a total redevelopment of the street. Here a physical change is made to the street with respect to car parking, bike lanes, line markings, intersections and the curb. The road is widened, trees and parking is mixed together, curbs are smaller and bike suggestion lanes are implemented. All the safety requirements are matched with Dutch safety regulations.

Lastly, tips are given (mostly based on the suggested redesign) to resolve general problems that occur in the city centre of Antwerp. Topics that are handles are for example the limited space in streets, streets with trams and cycling guidance (e.g. line markings, traffic lights).

In conclusion, Antwerp can still do much to increase the safety of their cycling network in the city centre to meet with the Dutch cycling safety guidelines
For a quick increase in bicycle-safety in the streets of the city centre of Antwerp, bike lane line markings and lane colouring should be implemented. This reserves a part of the road for cyclists and

better safety is created. Also for car drivers this is a visual reminder that the road is shared with cyclists. This still isn't a solution for the small amount of space the cyclist get in the city centre. Ultimately, a total redevelopment of certain streets is required to match with the Dutch guidelines. If Antwerp is expanding their cycling network and with it the safety quality, the municipality should try to separate cars and bicycles on the road. Preferably physically, otherwise visually. With the limited width of the streets, parallel parking on the street should get to a minimum so more space is left for transport. With more space left for cyclists, a safer environment can be realised.

Table of contents

1. Introduction

Cycling is a big part of the culture in The Netherlands. Moreover, with trends like healthier living, climate problem and the up and coming of the e-bike, the bicycle will become more of a component in our life than it is now. In addition, with more of urbanization happening it is expected that the bicycle will become a prominent part in city centres. For this focus shift of transportation types (cars, public transport, bicycles) the cities have to adept with this change and create a transport network that is capable of dealing with the new usage of the bicycle.

As cycling is in the roots of Dutchmen, it is expected that the cycling network is at an advanced level compared to other countries. Although it is not perfect, we are a nation that could be an example for the rest of the world. Therefore, focussing on other parts in the world could bring more major advancements. To expand our cycling network and culture it is feasible to focus on our neighbours. The city of Antwerp (Belgium) is a close neighbour where advancements in their cycling network would be preferable. Therefore Antwerp is taken as a example to look if the Dutch cycling safety guidelines could be implemented in other countries.

1.1. Problem definition

Antwerp has gone through many changes that are in the benefit of cyclists. It remains as the best large city in Belgium for cycling [3]. A bike sharing system has been introduced, more bike racks are implemented in the city and a new wide infrastructure around the city centre (see Figure 1) has been built around the city centre. The last one has created a more cycling-friendly way of connecting the suburbs with the city centre.

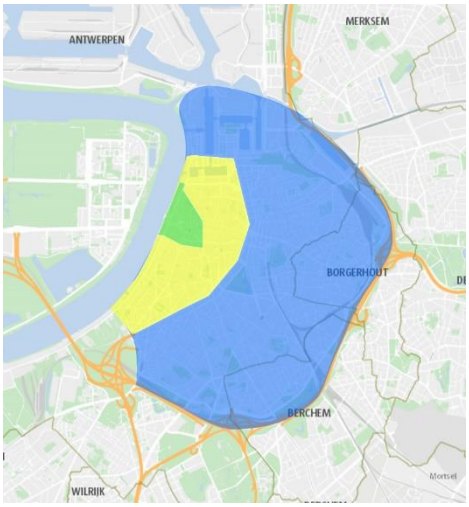

Figure 1: Depicted in the figure is the general city centre (blue), the touristic city centre (yellow) and the old city centre (green).

The car takes up a big part in the streets, and in many streets, parallel parking is the prominent way of parking. Because of the old history of Antwerp and the historical architecture that goes with it, the width of the streets in the city centre has not changed. Little space has left for the bicycle. In addition, Antwerp has a large public transport network where the tram is a big part of that system. Many streets are shared between cars, public transport, cyclists and pedestrians.

The sharing of the streets and the limited space in these streets is a problem in the centre city of Antwerp, and with the change of transport in the city in the future, a different perspective has to be taken to adapt with this change.

1.2. Client and stakeholders

Below a short explanation is given of the client and the stakeholders. Their function is explained and the way they are connected to the problem.

1.2.1. Client

Municipality of Antwerp The municipality of Antwerp is the client the thesis will be based on. It is the sole owner of the streets of Antwerp and is responsible for the caretaking of Antwerp itself. The municipality is the organisation that has the best care for the citizens and is the one that can act on it. The streets of the city centre fall out of the jurisdiction of the county Antwerp.

1.2.2. Stakeholders

Fietsersbond Belgium The Fietsersbond (cycling union) is a prominent part of the cycling community in Belgium. This is a union that is in close contact with the cyclists and know about the problems Belgium is facing in regard of cycling.

Cyclists The experience of cycling in Antwerp should be a pleasant one, and interaction between the municipality of Antwerp and the cyclist group is of a high priority.

Car drivers Cars is the group that has the most spatial influence on cyclists. On many locations the cars and cyclists are on the same road, not separated with colours, lines or spatial differences (height, offset, etc).

Store owners With the redesigning of the streets it is wise to consult with the stores that are on street level. Sidewalks are a key feature for reaching their facilities, so sidewalks should not suffer from the redesign.

1.3. Reference projects

As mentioned in The Copenhagenize Bicycle Friendly Cities Index [4], Antwerp is on number seven of the list. This means that Antwerp has realized bicycle friendly projects in the past years, but this doesn't mean that every part of Antwerp is bicycle safe (this is mentioned later in the paper). Higher on the list at position two and three are respectively the Dutch cities Utrecht and Amsterdam. As the Index is a respected source used by different main cycling and urban planning websites, these two cities will be used as reference projects to see what has been done for bicycle safety in the past years. No extended analysis will be done about the two cities, but the cities are used in global background research for examples of what can be done to get a more bicycle friendly city centre environment.

1.4. Research questions

1.4.1. Main question

How can the streets in the city centre of Antwerp be redesigned through Dutch safety guidelines, so a more bicycle-safety environment can be created?

1.4.2. Sub-questions

1. *How is the transport network of Antwerp designed for cycling?*
   This is to get a current view of the situation in Antwerp.
2. *Which streets are being used the most?*
   This is to check if the amount of cycling per street matches with the design.
3. *Who is the main user of the transport network?*
   For an idea how the streets are divided and which space is reserved for what kind of transport.
4. *How does Antwerp differ from the Netherlands with cycling safety?*
   With this question a difference is made between Antwerp and the Dutch guidelines.

1.5. Reading guide

Chapter 1 is an introduction of the paper with problem explanation and basics for the research. Chapter 2 is an analysis of the current situation of Antwerp, cycling usage and a decicison for the route to check for cycling safety. Chapter 3 tests the Dutch cycling safety standards with the current situation of Antwerp. Chapter 4 is a redevelopment of the Lange Dijkstraat as an example how to redesign a street. This is done for short-term and long-term planning. Chapter 5 gives the conclusion and recommendations. Lastly, attachments, bibliography and a figures list can be found.

2. Network analysis

2.1. Planned developments

2.1.1. Noorderlijn

The Noorderlijn is the inner-city ring which gets a total make-over [5]. The ring is being tunneled for cars and trams, and above grounds the whole layout is redesigned to create a more safe and green environment.

2.1.2. Cycling network

The cycling network with fast connections in and out of Antwerp is begin expanded over the next couple of years [6]. Apparently, the route which is taken for redesigning in Chapter 4 was already in planning. This was later found out in the process.

2.2. Car usage

Streets

Antwerp can be compared to one big parking lot. In almost every street there is parallel parking. And most of the time parallel parking on each side of the street. The problem with parallel parking is:

- It takes almost the space of a car lane [7].
- The time it takes to park a car is long compared to other ways of parking, especially with unexperienced drivers. This holds up to traffic. Now cyclists have to swift around the parking car and cycle in the middle of the road, hereby creating an unsafe situation for the cyclist.

Figure 2: Zone 30 km/h in blue. Although a large part has a limit of 30, some streets do have a limit of 50 km/h. Not all have a bike lane or path.

Speed zones & limits

Most of the streets in the city centre of Antwerp are a Zone 30 km/h. See Figure 2 for visualisation. The streets which aren't blue marked is a speed limit of 50. In some of these Zone 50 streets, no separated bike lane is existing.

Garages and underground parking

There are around 25 garages in the city-centre of Antwerp, but mostly in the touristic city centre [8].

Accidents

Accidents mostly happen on the inner ring near at the height of train station Antwerpen-Centraal (Figure 3). This is the inner-point of the city centre, understandably the busiest. The southern part of the route in Chapter 4 is where some accidents happen. Not clear what kind of road users where in the accident. But it is clear that the situation is not safe enough [9].

Figure 3: Heatmap of accidents in Antwerp.

2.3. Cycling networks

Upper local Functional Cycle route network

Figure 4: The Bovenlokaal Functioneel Fietsroutenetwerk depicted in blue.

Bike paths network

Figure 5: The bike paths in Antwerp depicted in green. These bike paths are separated from the road.

Combination BFF and bike paths network

Figure 6: Combination of the UFC and the bike path networks.

The Bovenlokaal Functioneel Fietsroutenetwerk (BFF), translated from Bovenlokaal Functioneel Fietsroutenetwerk, is a cycling network which connects locations like residential areas, shopping centres, schools and public transport stations [10]. This network is created so a fast connection between these busy places is possible. The routes of this network are mostly located next to busy roads. See Figure 4 for a map of this network in Antwerp.

In Figure 5 are the available bike paths of Antwerp visualised on a map [11]. The bike paths are separated from the road. These bike paths bring safety as they are separated from the road, so contact with cars is at a minimum. The amount of bike paths within the inner ring is scarce. Data about the present bike lanes wasn't available.

Next the BFF and bike paths are combined in one map to see the similarities and differences. This way As seen in Figure 6, a large percentage of the BFF has dedicated bike paths. The routes that are left (blue) are cycling routes which do not have a such bike paths. Most of the BFF in the North-West of Antwerp has not been finished yet. For the redeveloping of a route as an example, one of these routes should be redesigned as these suffice the least of the BFF.

Fieldtrip

For this research, a field trip to Antwerp has been made. In this fieldtrip it was tried to get a global understanding of Antwerp's cycling safety standards, and to check a minimum of two blue routes in Figure 6. As this was a one day field trip with limited time, not all of the roads mentioned in 'Combination BFF and bike paths network', only the road next to the river Schelde and the route from Antwerpen-Centraal to the North could be checked. This is taken into consideration for choosing the route to redevelop.

2.4. Cycling usage data

2.4.1. Strava

Strava is a company which has an sporting app with the same name . The Strava app can be used for cycling to track the route you just have cycled. This data is collected anonymously by the company, and with this data a heat map is made which is publicly available. Using this map (Figure 7) it is clear to see where the busiest activities are. When compared the red lines of Strava with the maps mentioned in 2.3, it checks out that these are busy streets and are a good option for redeveloping.

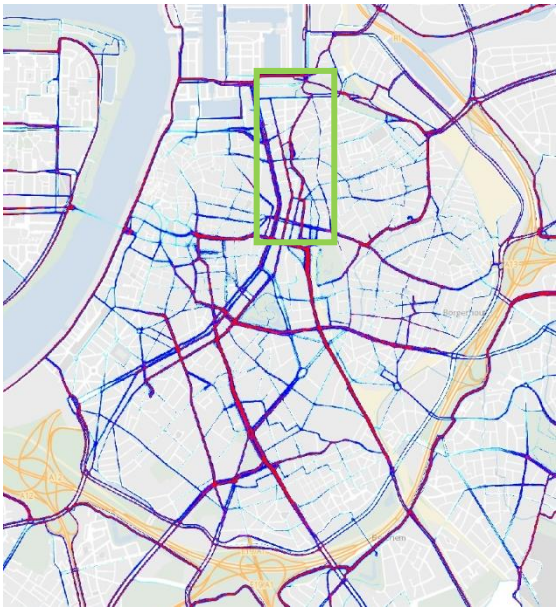

Figure 7: Map of cycling data of Strava. Blue lines display the usage of a street. Red means a busier street than average. The green rectangle is the route which is taken to check with the Dutch guidelines [1].

2.4.2. European Cycling Challenge 2015

In 2015, Antwerp joined the European Cycling Challenge [12]. This is a competition where European cities can join and compete with each other for the most amount of kilometres ridden on the bicycle. Citizens of Antwerp joined with a GPS app and with this a good overview of the busy streets was made. This data checks out with Strava, therefore Strava is a reliable source.

2.5. Route to check with Dutch safety guidelines

With the combination of the fieldtrip and the previously mentioned three cycling ‘networks’, the route which is taken to check with Dutch safety guidelines is the one mentioned in Figure 7. This is the route from train station Antwerpen-Centraal to the North of the city centre. This is a route which is in the BFF, has no bike lanes of paths and is travelled through with a high amount. Found in the planning for construction in Antwerp , this route is planned for redesigning [6].

3. Cycling safety standards

3.1. Dutch versus Antwerp road design

3.1.1. Bike lanes/paths

Road hardening

Dutch	Antwerp
On every side of a road there must be road hardening of asphalt quality.	Most of the have a flat hardening, but in many streets in the old city centre they use a kind of cobblestones which are hellish for a cyclist.

Width

Dutch	Antwerp
A bike lane should be minimum 1.50 meter wide [13]. A bike path should be minimum 2.00 meters wide.	There is no constant factor in Antwerp as goes for bike lanes. The bike bike paths that are available don't have a constant width.

Line markings

Dutch	Antwerp
When applicable, a combination of different line markings is used on the road [14]. Also a two-direction bike paths should have dotted centre line markings.	In many streets there are no lines, just a slab of asphalt. This gives an unclear idea how the street is used or should be used. Bike paths don't have line markings

Colouring

Dutch	Antwerp
Bike lanes and bike paths are coloured, mostly with red.	This is the same, although bike lanes aren't always coloured.

Traffic lights

Dutch	Antwerp
On many intersections a lower traffic light is placed so cyclists on the front of the waiting line can also see the green light [15].	No such traffic light found in the field trip.

3.1.2. Intersections

Roundabouts

Dutch	Antwerp
In many cities and villages the roundabout is an important part in a transport network. The main reason why the roundabout is being used as much, is because of the higher capacity and a reduction of 46% of high casualties [16].	The amount of roundabouts can almost be counted on one hand. It is clear that the concept of roundabouts isn't implemented in the city. The roundabouts they have are most of the time around a historic pillar where the roads have been a plaza in the past. All the other crossings are intersections.

Recommendation

If possible, a crossing should be transformed into a roundabout only if cyclists are separated from the cars and get priority. With this change, the amount of traffic flow increases and the time standing still in front of a traffic light is eliminated. Also with this installment the cyclists have less contact with cars than on a normal intersection.

Traffic lights for cyclists

In some cases where the cyclists are waiting at an intersection with traffic lights, the traffic lights are designed for the car drivers and not for cyclists. With an addition of a smaller traffic light attached lower on the pole, the traffic lights are better visible for cyclists . At some intersections, these cyclists' traffic lights are present, but there is not a constant factor if this sort of light is at an intersection or not.

Waiting space for cyclists

When bicycles and cars are mixed on the road waiting at an intersection, a bicycle waiting box (OFOS in Dutch) should be implemented [14]. In Antwerp no such waiting box can be found. Cyclists have to wait between the cars which can give an unsafe experience.

Speed bumps

A speed bump is a device which is used to slow down the speed limit. This is used a lot in the Netherlands. In Antwerp almost no speedbump can be found. 'Bump islands', a heightened intersection with on each street a bump can reduce speed. This will only be necessary on streets with no traffic lights.

4. Redevelopment of street design

4.1. Determining route for redevelopment

For defining the route to check with the Dutch regulation, the following map is used (see Figure 8). To determine which route to redevelop, three different routes are used to find which is the most preferable location. The route to consider is from start location the Ellermanstraat in the North near bus station Antwerpen Ellermantstraat (green dot) to final destination train station Antwerpen-Centraal (red dot). And of course the same way back. Following is an explanation of the three routes that are used.

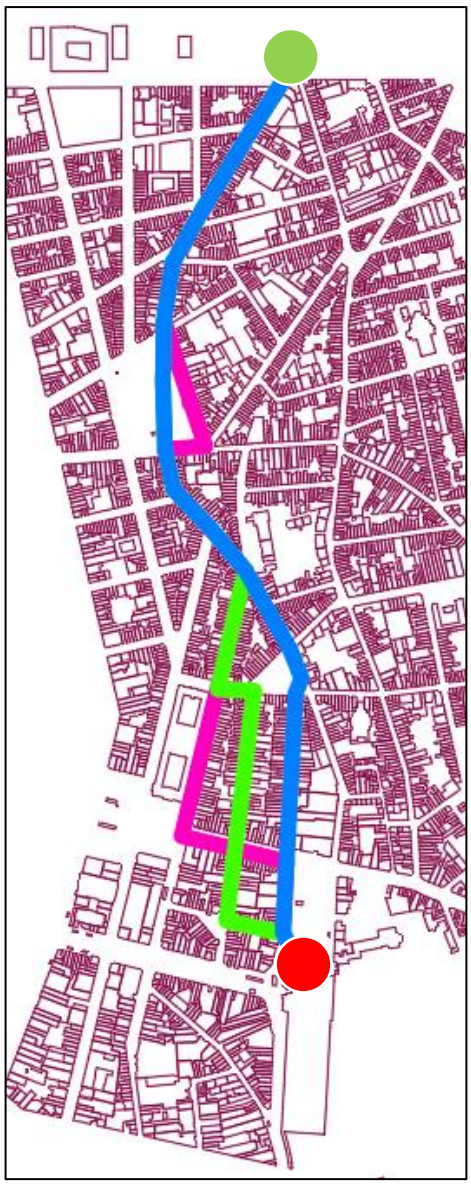

Figure 8: Three possible routes to train station Antwerp-Central. Blue is the route with the least amount of turns. Green is the route which is used the most. And purple is the route which the province of Antwerp wants to realise.

Blue route

The blue route is the route that takes the least amount of turns. Therefore, at every crossing, except at plazas, the intersection can be crossed with a straight line. This would be the most direct route van start to finish. The problem with this route is that from the Rotterdamstraat to the train station there is interference with the tram network. Also the street Van Wesenbekestraat is a busy street with shops and tram rails. There is limited space to redevelop. With many factors and parties happening in the street, a safe route for cyclists is difficult to realise.

Green route

The green route displays the route that is used the most. This route is determined with the data of Strava and the GPS data of the European Cycling Challenge of 2015. A large part of the green route is the same as the blue route. The cyclists do change their route from the blue route when the tram rails are on the road. Is some parts of the Rotterdamstraat the layout of the road has two sidewalks, parallel car parking and two tram lanes. With this amount of different transport situated in the street, little space is left for cyclists. Sometimes a bit more than 50 centimetres between the tram rail and the sidewalk left to cycle, so it is understandable that cyclists avoid this route. The part of the route that is shown green on the map (Figure 8) crosses mostly the Van Arteveldestraat. This street is used only by cars, cyclists and pedestrians. No bus lines and tram lines cross this route. Therefore it is understandable that this street is preferable for cyclists, as the interaction with different kind of transport types is limited. The whole Van Arteveldestraat is used for parallel parking. Now the street only space is left for two cars, no space left for bike lanes.

Purple route

The purple route is getting fastest to one of the main streets Antwerp with a width of 23,5 meters, namely the Gemeentestraat. This route is part of the Bovenlokaal Functioneel Fietsroutenetwerk

[10]. It is clear from the cycling usage data (Strava) that this route is not used the most. This is probably for the fact that this is a street which is used by three bus lines [17]. Here the cyclist has to ride between the busses and the cars, and with no bike lane this is not a safe situation.

Figure 9: The Lange Dijkstraat, which will be the street for redevelopment.

Location for redevelopment: Lange Dijkstraat

Although the three routes are different in their own way, one factor that is constant is the northern part, mainly the Lange Dijkstraat. This street is relatively quiet for cars, it is wide, no busses or trams, a small amount of shops and it lies in a residential area. For the limited time that is available for this research, this street is chosen for redevelopment as an example. This is an important part of the cycling network, while the current situation is not designed to be part of a cycling network. Next is an analysis of the current street layout.

4.2. Current situation of the Lange Dijkstraat

As mentioned in the chapter above, the Lange Dijkstraat is part of all the three different routes. So whichever the total route is going to be that will be redeveloped by the municipality, it is certain that this part will go under construction. In this chapter, the current layout of the Lange Dijkstraat will be analysed.

4.2.1. Average cross section

The Lange Dijkstraat has a length of 442 metres. As of the many intersections in the street, the street is divided in different parts. It happens to be that not every part of the street has the same width. Therefore to get a global idea of the street an average is taken. Figure 10 displays an average cross section of the Lange Dijkstraat.

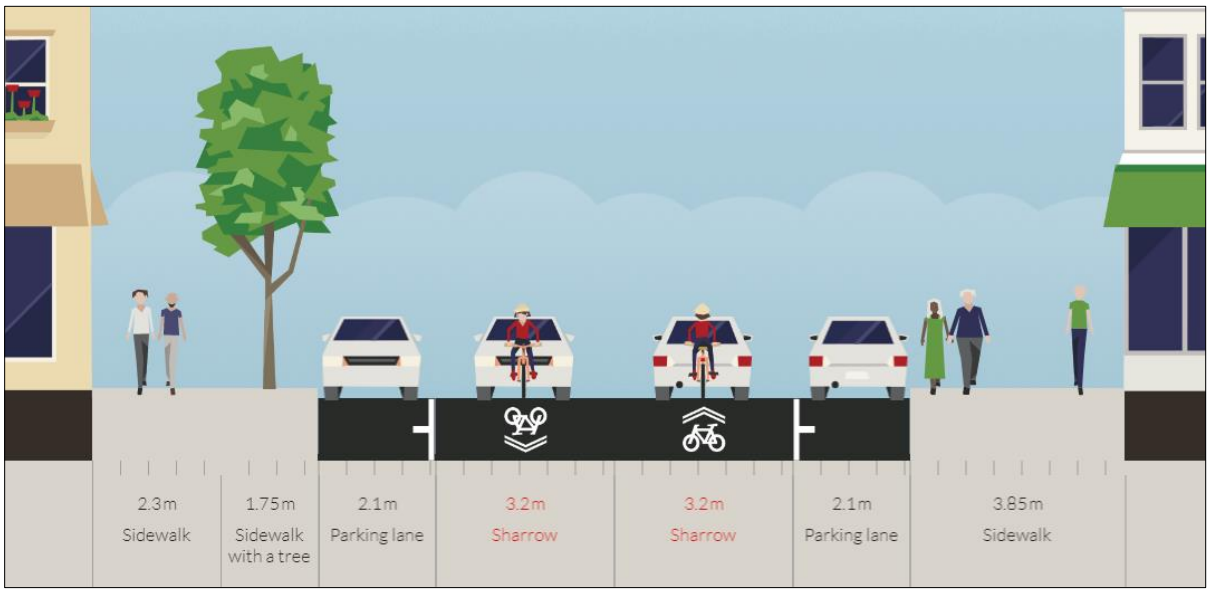

Figure 10: Cross section for the average width of the Lange Dijkstraat. Road markings on this figure are absent in reality (see Figure 11.

The average width of the whole street is approximately 18.5 meters. The street is divided in three main uses: walking, parking and driving/cycling. Now parking takes up 22% of the total width.

Sidewalks

The sidewalk has a large width between 3.15 and 4 meters, this depends on which part of the street you are looking at. Most of the sidewalk has a width near 3.9 meters. The street lies in a residential area, which means that the amount of pedestrians is at a lower level when compared to a shopping street. With this lower level of usage, the width of the sidewalks don't need to be the width it currently has. On one side of the street trees are present. As the trees are separated of each other with an average of 10 meters, the space between the trees is somewhat useless. Pedestrians don't zigzag between the trees and the free sidewalk.

Speed zone

As it is a residential zone, the Lange Dijkstraat has a speed limit of 30 km/h, much like the rest of Antwerp This means that different safety guidelines apply than for a street with a speed limit of 50 km/h, which is the speed limit for a big part of the Bovenlokaal Functioneel Fietsroutenetwerk. As most of this cycling network consists of bike paths, it is possible to have bike lanes instead.

Figure 11: Photo of the current situation of the Lange Dijkstraat.

4.2.2. Lack of road markings

As seen in Figure 11, the Lange Dijkstraat has a street design that only consists of a flat piece of asphalt. No line markings are present, which give an unorganized environment.

4.2.3. Parking

In the current situation, parking is a free for all. If a space is possible, it is filled. No regulations of line markings are present.

4.3. Short-term redeveloped situation

Figure 15 displays the Lange Dijkstraat with short-term redeveloping applied.

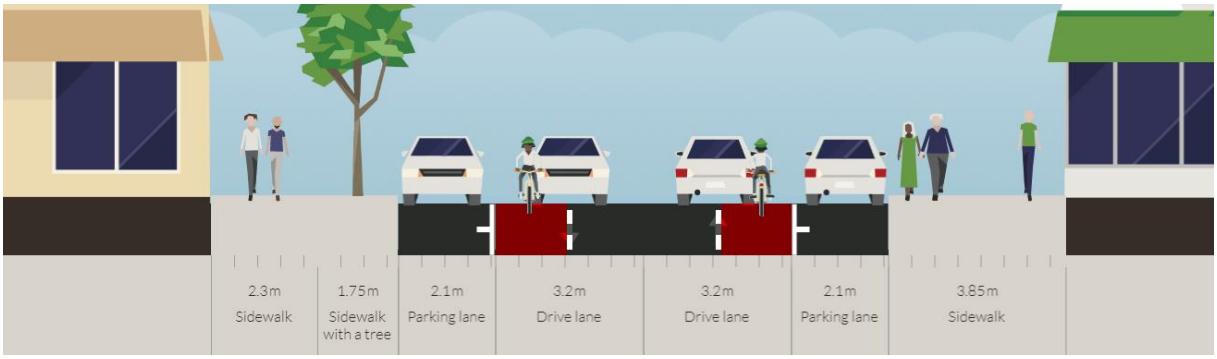

Figure 12: Quick redeveloped situation for the Lange Dijkstraat. Road markings are the main difference.

4.3.1. Bike suggestion lanes

Reasoning for bike suggestion lanes

Bike suggestion lanes don't have a legally status of a bike lane. This means that it actually is part of the road and cars can just drive over it. But they do have some functionality, mostly to emphasize the presence of bicycles on the road.

Bike lanes are physically on the road, but legally they are only reserved for cyclists. A one direction bike lane has a minimum width of 1.5 meters [13]. As parking is highly demanded for the residential area, parallel parking is not possible with bike lanes.

Bike paths are also not a possibility because for this wider measurements are necessary and still no availability for car parking.

So if car parking is a must for the street, the only possibility that is left are bike suggestion lanes. This way, sidewalks are possible on both side of the street, parallel parking is possible on both side of the street and still there is an emphasis for the presence of bicycles on the road. The best possible way is to eliminate parallel parking on one side of the road. This creates more space to realise a bike path. But without a research for a solution for the eliminated parking space, the amount of parking spaces should be limited as little as possible.

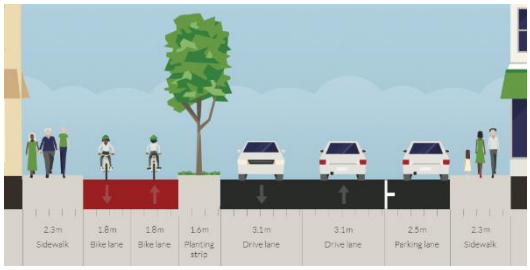

Figure 13: Solution if one side of parallel parking is eliminated.

Width

For a safe usage of a bike suggestion lane, there should be a minimum width. According to the ASVV 2012 this is 1.7 meters minimum [14].

Markings

A dotted line should be the marking of the bike lane with a width of 10 cm. The reason why this is dotted is for the space left for the cars. The width that is left is not sufficient for two trucks from the opposite sides to pass.

On the streets that are connected to the Lange Dijkstraat, shark teeth should be used. This way a safe passage of cyclists is guaranteed. See Figure 14 for an example.

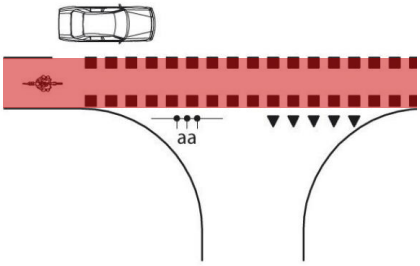

Figure 14: Shark teeth and line markings on an attached street. (CROW)

Colouring

Colouring of the bike lane is a must. This is a visual reminder for the cars that the road is shared with cyclists, and this gives the cyclists a feeling a place is reserved for them. To colour is not specified per se, but as seen for the rest of Antwerp, red is suggested.

4.3.2. Parallel parking

Measurements

According to the NEN 2443:2000 nl [7] the minimum width of a parking place is 2.5 meters; the minimum length is 6.00 meters.

Markings

With dotted line markings, the parking spaces are marked. This creates an ordered situation and no random empty spaces of different sizes.

4.3.3. Sidewalk

The sidewalk will be just the same as it is now. This will still be the wide sidewalks which take up space which could be used for cyclists.

4.4. Long-term redeveloped situation

The long-term solution will take more effort to realise. A total redevelopment is necessary for this, not only line markings but also physical widening of the road. See Figure 15 for a cross section. See Attachment 6.1 for 3D graphics and a 2D map of this plan with implemented bike suggestion lane.

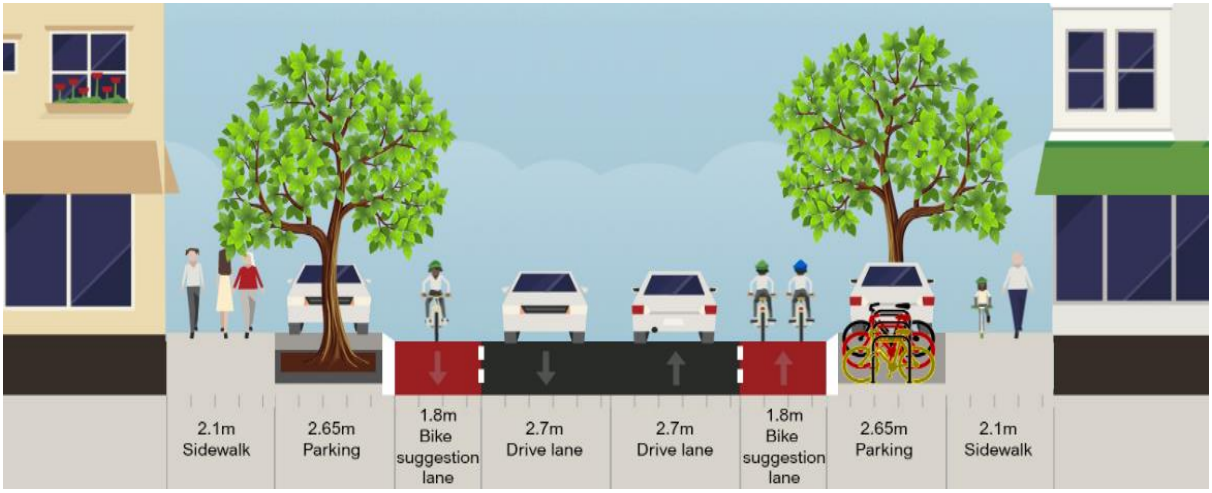

Figure 15: Long term redeveloped Lange Dijkstraat. Here the road is wider and parking is on the sidewalk.

4.4.1. Sidewalk

The sidewalk can be more efficiently redesigned. For the amount of usage the sidewalks are too wide. With limiting the width of the sidewalk, more space can be created for cyclists.

Width

According to the ASVV 2012 [18] the width of a sidewalk should have a minimum of 1.8 meters. In addition, for every 100 meters there should be a turning point with a width of *2.1 meters*. For the sidewalk, the latter width will be taken. This is sufficient even for handicapped pedestrians. An extra

Obstacles

The sidewalk can be limited to a minimum of 0.9 meters at obstacles like road signs. A minimum of 1.2 meters can only happen with a narrowing of 10 meters length tops.

4.4.2. Parking

Parallel car parking

Parking of the cars will now be on the sidewalk. To get on the parking places, the driver has to cross a sloped curb [19]. On the sidewalk, different coloured stones (than the colour of the real sidewalk) will depict the parking places, see Attachment 6.1. As mentioned before, the width is 2.5 meters, a sloped curb and the length is 6 meters. At the end of the parallel parking line, a heightened block is placed to have a physical blockage, which will prevent illegal parking. The trees that are planted in the before situation can be planted between the cars. This way the street still has a green environment. This will be done on both sides, which created an even greener environment.

No parking near corners

In the Dutch regulations [20] it is forbidden to park your car within a distance of 5 meters of an intersection, most of the times at the corners. With the parking places visually dedicated on the sidewalk, there is no possibility for unsafe parking near an intersection. This way for cyclists it is easier to see if a car comes from another street, as parking spaces can be placed at a safe distance so no blocking of the view is happening.

Bicycle parking
As the sidewalk has widened, the width of the parking spaces (2.5 meters) will provide for a sufficient space to implement bicycle parking or maybe other objects (see Attachment 6.1 or Figure 15).

4.4.3. Bike suggestion lane

Usage
Priority for cyclists, but sometimes can be used by a car or a truck as a bicycle suggestion lane isn't legally a bike lane. It is even possible to unload a truck on a bike suggestion lane. The bike suggestion lanes are implemented on both sides of the street.

Width
A width of 1.8 meters is suggested (1,70 meters minimum [14] + 0.10 meter intermittent line markings). With the 2D map in the attachments was checked if the designed road could be implemented while still achieving a sidewalk with a minimum width of 1.8 meters. In the Lange Dijkstraat this is possible.

Colouring and line markings
To make it clear that the bike lane is most definitely used for cyclists, colouring of the bike lane should be implemented. This also gives the cyclists a feeling that they a place for their own on the road. The kind of colour is up to the municipality. The bike lane has the same line markings as in the short-term solution.

Surface type
Important for cycling safety is that the surface type should be flat. In many locations in the city centre (most of the time the old city centre) the road surface is made of setts, sometimes known as Belgian blocks. Driving on this surface type with a bicycle gives a shocking unpleasant experience and over the years become slippery for two-wheelers [21]. Therefore, it is suggested to apply asphalt as surface type. This gives a smooth riding feeling, better handling with rain and easier to apply markings. This is suggested for every street.

4.4.4. Road (car)

Width
As seen in the ASVV 2012 [14], the width of the road designed for the car should have a minimum of 4.80 meters, with an optimum of 5.50 meters. The width designed for the long-term design is 5.40 meters. With this width, cars are still easily passing each other. Wide trucks on the other hand probably have to drive on the bike suggestion lane behind the bicycle until the road is clear for passing.

Surface quality
The road should have the same quality as the bike suggestion lanes, namely asphalt. As a bike suggestion lane is not legally a bike lane reserved for cyclists and parallel parking is happening in the street, sometimes a cyclist has to drive on the car road if the bike lane is blocked by a vehicle. For this, the car road should be of equal quality as the bike lane.

Line markings
In the design, no centre line markings are used. With a speed limit of 30 km/h it is not necessary to have a separation centre line. Also the lack of separation lines suggests that the street is begin shared with other cars and no lane is severed for the driver, therefore lowering the speed.

4.4.5. Bumps

Bumps at pedestrian crossing

It is recommended to have bumps at the place of a pedestrian crossing [22]. This will lower the speed, therefore delivering a safer situation. Cars and cyclists do have to stop for pedestrians. Also, add signing of a pedestrian crossing and extra lightning for a better view of the situation.

Crossroad plateau

At an intersection it is recommended to have a crossroad plateau [23]. This will lower the speed and gives an opportunity for pedestrians to cross with no height differences. Shark teeth should be drawn at the attached streets.

4.4.6. Reference project

As a reference project, the Albatrosstraat in Utrecht can be used as an example [24]. Here the bike suggestion lanes have a width of 1.80 meters, and the road has a width of 5 meters. Trucks and busses use the bike lane for passage. The traffic safety has been given a 7.2 through a survey. In the long-term plan of the Lange Dijkstraat the car road has a total width of 5.4 meters which gives just that little extra space for cars.

Figure 16: Albatrosstraat in Utrecht which can be as an example situation for the Lange Dijkstraat.

4.4.7. Problems with the new design

Problems with parallel car parking

With the bike suggestion lanes, parallel parking is still happening on both sides of the street. It is possible that drivers just after parking their cars slam open their doors without looking at the bike lane, hereby hitting cyclists. With the width of 2.65 meters in total, and with an average width of 2 meters of a personal car, there is a dooring buffer that limits the chance of an accident, although this isn't wide.

Higher exit height out of the car when parked

The problem with parallel parking on a heightened sidewalk is that there is a possibility that the height when exiting out of the car is larger than normal. The driver has to exit on the bike lane. This of the height difference of the curb.

4.5. General recommendations streets city centre

4.5.1. Streets with trams

The tram is in some streets mixed with cars, cyclists and pedestrians. Problem with some of those streets is that the space reserved for every kind of road user does not match with the safety requirements, especially for cyclists. A small space is reserved between the curb and the tram rail, often a max of 1 meter (see Figure 17). A cycling space with a minimum of 1.5 meters should be implemented with a surface type of asphalt.

Figure 17: Street with a tram. Notice the small space for cyclists.

4.5.2. Sidewalk

On many locations the sidewalk's width does not match with the usage as seen in Figure 17. In this case the sidewalk is way bigger than is necessary for pedestrians. A smaller sidewalk creates space for a bike lane.

5. Results

In this chapter the recommendations and conclusion are included.

5.1. Recommendations

Many different things can be concluded. The main ones are mentioned below.

5.1.1. Limited space

The lack of space in the streets in the city centre is the main problem.

Parallel car parking

The biggest problem is the amount of space that is reserved for car parking in a street. In the possible route to redevelop, an average of 22% of the available space is dedicated for parallel parking. This means that a fifth of the streets is being used for stationary cars. If the amount of parked cars can be reduced, space is available for bike lanes. There are different solutions to limit the amount of publicly parked cars. More multi-storey car parks can be built or an increase in the price for public parking.

Another way is to mix the trees planted in the streets with parallel car parking. Now in many streets, car parking gets its own row and the trees get their own row. The two can be combined so cars can be parked between two trees. This created space for road usage.

Sidewalks

The width of sidewalks is not constant with the usage of the sidewalk. For example, in the touristic centre some sidewalks are small with a maximum of two people and in the residential areas the sidewalk is way bigger than is required for the amount of pedestrians. The amount of space reserved for a sidewalk should be consistent with the demand. This way the space can be given to other ways of transport.

5.1.2. Lack of bike lanes and paths

Bike lanes

The problem is that there is a small amount of bike lanes in the city centre. Although a large amount of the streets belong in the ‘30 speed zone’ where the speed difference between cars and bicycles is limited, the amount of traffic is making it unsafe for cyclists. With the lack of bike lanes, the car driver is not getting a visual reminder that the road is being shared with cyclists. Also the cyclists don’t have ‘safe’ space to cycle. A solution is making a coloured cycling lane with optional line markings.

Bike paths

Although almost the whole city is in the ’30 speed zone’, there are still streets left with a 50 km/h limit [25]. Although many of these streets have bike paths, this 50 km/h network is not fully equipped with bike paths yet (e.g. the Van Maerlantstraat). Where bicycles cycle with an average speed of 17 km/h, passing cars with 50 km/h create a large speed difference and as a result an unsafe situation. It has a high priority for the realisation of a bike path in these streets. If space is not available, a dedicated bike lane with closed line markings is necessary.

With many of the bike paths available in Antwerp there is only a visual difference between the bike paths and the sidewalk. A level difference is suggested. This way the chance of pedestrians on a bike path is decreased. A sloped curb creates a soft edge. If this isn’t possible, line markings should be applied.

5.1.3. Visual guidance

Line markings

In many streets with a speed limit of 30 km/h there is a lack of line marking. Whether line markings are necessary depends on the amount of traffic. This lack of line markings give the driver (car and bike) an unclear idea of the traffic rules in a street. Line markings in the middle of the street represent for a two-way street. At crossings, line markings make it clear where the cyclists are expected to cross.

Coloured bike lanes

Colouring of a lane gives a direct visual clue which type of driver is expected to use the lane. This reminds the car user that they are not the only ones using the street. Favourably this is combined with line markings.

5.1.4. Road quality

Asphalt banding

The road experience on low quality roads between cars and cyclists differ a lot. This happens most of the time in the touristic city centre where some roads exist completely of cobblestones. For cars this is not a problem, but a cyclist does notice this. A recommendation is to flatten the side banding of the road to asphalt. This way the comport level is higher for cyclists. In addition, colouring can directly be applied.

Space between tram rail and curb

The room that sometimes is left between the tram rail and the curb differs in each street. This can range between 1+ metres to 50 centimetres, where the last can be of a problem. Here the chance a bike can get between the rails is high. Moreover, it is even possible to find storm drains in these 50 centimetres. In these problematic streets the space between the tram rails and the curb must be widened.

5.2. Conclusion

A shift of car usage to bicycle usage is ideal in a city. This can be done by making the car less interesting to use, or by promoting cycling. Cycling safety is a great way to promote cycling. If a cyclists doesn't feel safe, other ways of transport will be used.

Ideally in every street bike paths are realised, but this isn't possible everywhere. Separation of transport types should be the goal, either physically, otherwise visually. In some cases, streets have to be partly reconstructed with new road surfaces and a shift in the amount of lanes per type of transport. However, in many cases applying road markings should be sufficient. To get more space, Antwerp has to do something about the amount of parallel parking. When parking in the street is brought to a minimum, more space is left to redesign the street and make a bicycle network which is more separated from the cars through bike lanes and paths.

Applying the Dutch safety design requirements will increase the safety of cyclists in the city centre of Antwerp, but it is a long way before this can be realised.

6. Attachments

6.1. Visualisations of total redeveloped Lange Dijkstraat

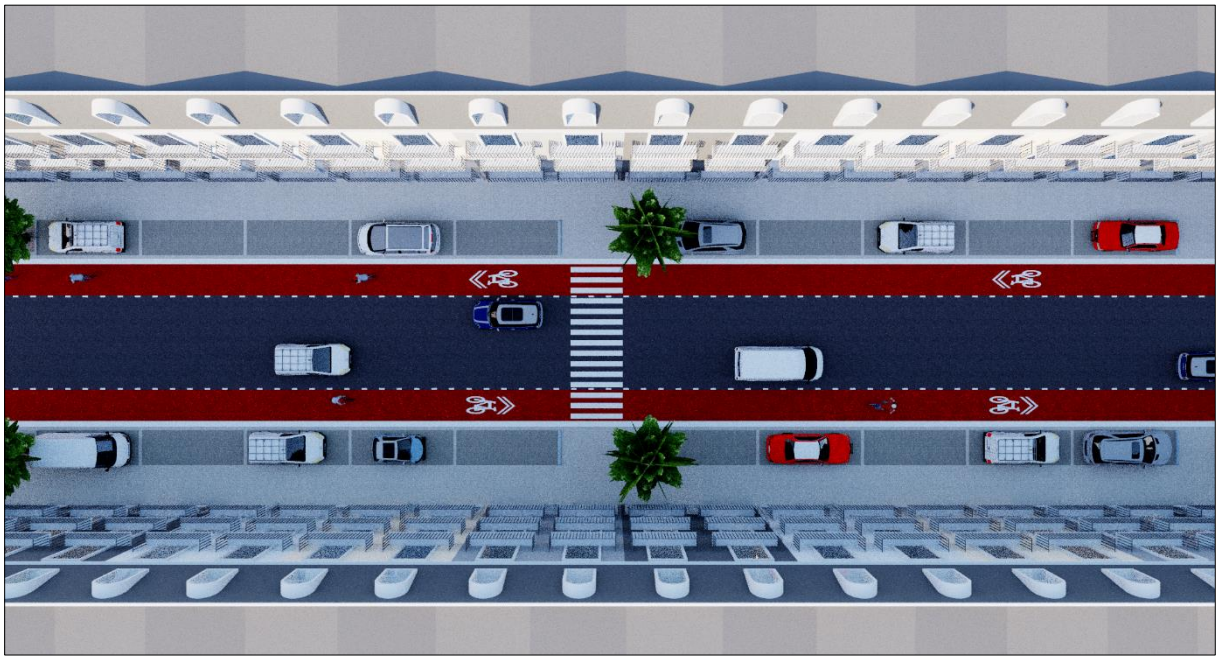

Figure 18: Topview

Figure 19: Interaction between cyclists and cars.

Figure 20: Semi cross section of the Lange Dijkstraat.

Figure 21: Cyclists visually separated from cars.

Figure 22: Pedestrian crossing.

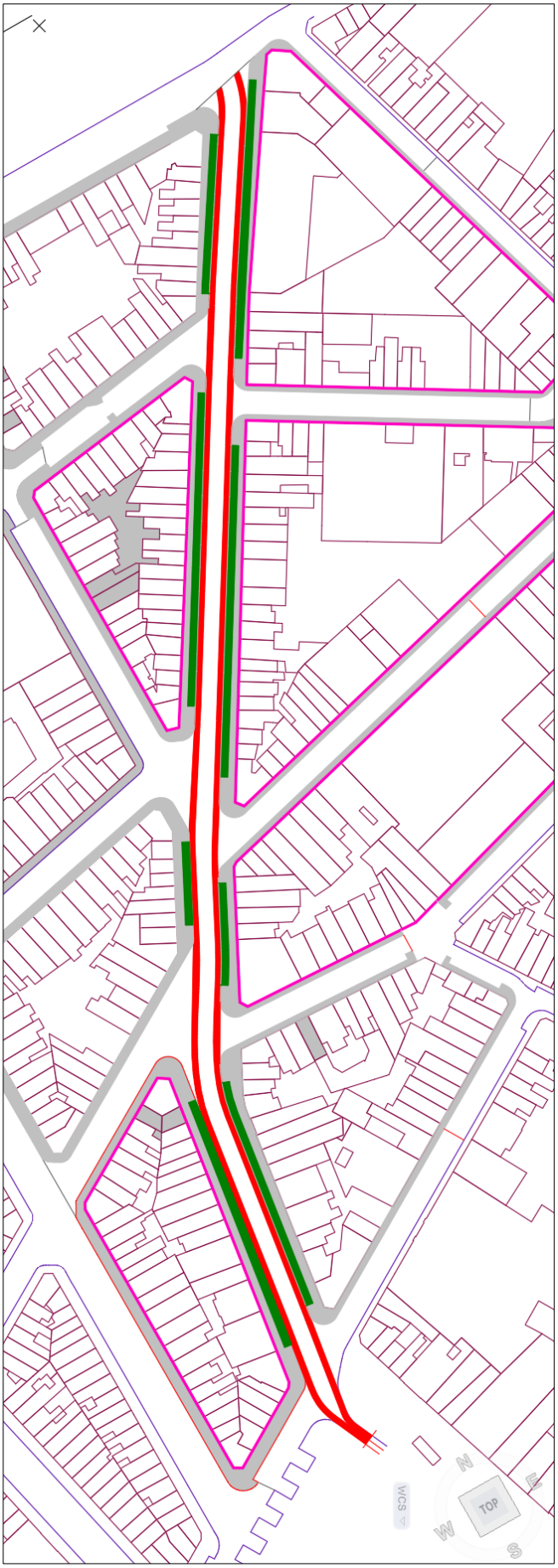

Figure 23: Schematic top view of long-term redesign of Lange Dijkstraat.

Grey = sidewalk
Green = parallel parking on sidewalk
Red = bike suggestion lane

(AutoCAD file from [2]

7. Bibliography

1. Strava, *Global Heatmap*. 2015.
2. Agentschap voor Geografische Informatie Vlaanderen, *Kadaster Vlaanderen*. 2017.
3. Copenhagineze Design Company. *Antwerp, Belgium*. 2017 [cited 2017; Available from: http://copenhagenize.eu/index/07_antwerp.html.
4. Copenhagineze Design Company. *The Copenhagenize Bicycle Friendly Cities Index 2017*. 2017; Available from: http://copenhagenize.eu/index/index.html.
5. Gemeente Antwerpen. *Noorderlijn*. 2017; Available from: www.noorderlijn.be.
6. Stad Antwerpen, *Snelle fietsverbindingen van en naar Antwerpen*, in *Fietskaart*. 2014.
7. Selectoo. *Parkeerplaats afmetingen in breedte en lengte*. 2017; Available from: http://selectoo.nl/parkeerplaats-afmetingen-breedte-lengte.html.
8. Centrumparkeren.nl. *Parkeergarages Antwerpen*. Available from: http://www.centrumparkeren.nl/antwerpen/parkeergarages.
9. Knack. *Nergens meer fietsdoden in Europa dan in Vlaanderen*. 2015; Available from: http://www.knack.be/nieuws/belgie/nergens-meer-fietsdoden-in-europa-dan-in-vlaanderen/article-normal-575941.html.
10. Provincie Antwerpen. *BFF: Bovenlokaal Functioneel Fietsroutenetwerk*. [cited 2017; Available from: https://www.provincieantwerpen.be/aanbod/drem/dienst-mobiliteit/fietsbeleid/bff-bovenlokaal-functioneel-fietsroutenetwerk.html.
11. ESRI, *Bike paths of Antwerp*.
12. European Cycling Challenge. *General website*. 2017; Available from: http://www.cyclingchallenge.eu.
13. Fietsersbond. *Fietspaden*. 2017; Available from: https://www.fietsersbond.nl/ons-werk/infrastructuur/fietspaden/.
14. CROW, *ASVV 2012*, in *16. Verkeersregulerende voorzieningen*. 2012.
15. CROW, *ASVV 2012*, in *17. Technische onderwerpen*. 2012.
16. SWOV, *Rotondes*, in *SWOV-factsheet*. 2012.
17. De Lijn, *Netplannen Antwerpen*. 2017: De Lijn.
18. CROW, *ASVV 2012*, in *Langzaam Verkeer*. 2012.
19. Ir. Bas Janssen, *Verkeersveiligheid van trottoirbanden*, in *Vervolgonderzoek*. 2017, Rijkswaterstaat Water Verkeer en Leefomgeving,.
20. Ministerie Infrastructuur en Milieu, *RVV 1990*, in *10*, Ministerie Infrastructuur en Milieu, Editor. 1990.
21. CROW, *ASVV 2012*, in *17.3.2. Wegdekeigenschappen per verhardingssoort*. 2012.
22. Veilig Verkeer Nederland. *Oversteekplaatsen voor voetgangers*. [cited 2017; Available from: https://vvn.nl/dossier/oversteekplaatsen-voor-voetgangers.
23. CROW, *11. Erftoegangswegen*, in *11.3.2. Kruispuntplateau*. 2012.
24. Fietsberaad. *B1-profiel Utrecht Albatrosstraat*. [cited 2017; Available from: http://www.fietsberaad.nl/?section=Voorbeeldenbank&lang=nl&ontwerpvoorbeeldPage=Fietsstroken%20en%20fietspaden&mode=detail&repository=B1+profiel+Utrecht+Albatrosstraat.
25. ANWB. *Verkeersregels in België*. 2017; Available from: https://www.anwb.nl/vakantie/belgie/informatie/verkeersregels.

Sources used for general knowledge, but not used in paper

1. Antwerpen.be. *Stadsplan*. 2017 12 september; Available from: https://www.antwerpen.be/nl/stadsplan/stadslagen.
2. Multiple articles from www.fietsberaad.nl.

3. Antwerpen.be. *Mobiliteitsprojecten*. [cited 2017; Available from: https://www.antwerpen.be/nl/overzicht/mobiliteitsprojecten/masterplan-2020/masterplan-2020.
4. Fietsberaad CROW. *Hoe ziet de ideale fietsstraat eruit?* 2016; Available from: http://www.fietsberaad.nl/?section=Nieuws&lang=nl&mode=newsArticle&newsYear=2016&repository=Hoe+ziet+de+ideale+fietsstraat+eruit.
5. Fietsersbond, *Fietsen naar 2040.* 2017
6. Gemeente Antwerpen, *Gemeentelijke stedenbouwkundige verorderning - bouwcode herziening*. 2014.
7. LADOT. *Thinking Outside the Box: Separated Bicycle Lanes*. 2011; Available from: http://bike.lacity.org/thinking-outside-the-box-separated-bicycle-lanes/.
8. Lange, M.d., H. Talens, and R. Hulshof, *Drukte op fietspaden: een inventarisatie van knelpunten, maatregelen en ideeën*, Fietsberaad CROW, Editor. 2017.
9. Tour de Force, *Agenda Fiets 2017-2020*. 2016.
10. Mondiaal Nieuws. *Antwerpen daalt licht in Copenhagenize Bike Index, maar krijgt stevige waarschuwing*. 2015; Available from: http://www.mo.be/zeronaut/antwerpen-daalt-licht-copenhagenize-bike-index-maar-krijgt-stevige-waarschuwing.
11. Some articles on the European Cyclists Federation website.
12. dr. Jolieke de Groot-Mesken, Luuk Vissers, and Kirsten Duivenvoorden, *Gebruikers van het fietspad in de stad*, in *Aantallen, kenmerken, gedrag en conflicten*. 2015, SWOV.

8. Figures list