THE FUNNEL OF AMSTERDAM

Accessibility & Viability of “De Entree” in Amsterdam

Eline Molier

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A thesis for the Bachelor of Science of Civil Engineering, sector Transport & Planning

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Preface

This Bachelor thesis is submitted as final Bachelor work for the bachelor's degree in civil engineering. The reason for choosing the area in front of the Central Station in Amsterdam is my origin from Amsterdam and through this my experience in the public transport and crowded areas of Amsterdam.

The thesis provides a solution for managing the growing crowds in the area, in the form of a redesign of the intersections in the area. This is in interest for the city planners of the area itself or a start for other crowded areas.

I want to thank Rolf Koster and Yufei Yuan for their guidance in the project and their feedback on the interim reports. I also want to thank the people in my workgroup: Lise Andringa, Lars Heijenrath, Mees Poppe and Lara Witte, for the feedback and thinking along on the different parts of the thesis. Finally, I want to thank my parents and friends around me for thinking along my questions during working on the thesis.

Delft, June 2018

Eline Molier

Summary

One of the most crowded areas in the city of Amsterdam is the area in front of the Central Station, because it is one of the entrances to the city. To prepare the area for the growth in travellers for the coming years, sufficient changes are needed. The different traffic flows cross each other, which provides hindrance for the road users. To reduce this, the following main question has been formulated: "How can the traffic flows of trams, cyclists and pedestrians be regulated to reduce traffic conflicts?"

To reduce the conflicts of the different traffic flows and thereby answer the question, a new design has been made. To get to this design, an investigation has been done of the current conflict points. Then, criteria have been made to test the improvement of the new design. With this information, different options are worked out to come to a new design. Finally, the different options are tested in combination and apart from each other, to get to a new, sufficient design.

According to the test, a combination of options could be used for a new design. The design will create more space for the traffic flows, reduce the waiting time of the traffic flows and reduce the conflict points between public transport itself and between public transport and motorized vehicles. In this design, some adjustments are made to the existing space, coming from tests and guidelines, the trams are combined and no longer cross each other at the intersections and a pedestrian bridge is made over the intersection of Prins Hendrikkade and Damrak, with the note that this could be tested with a temporary bridge before installing a special designed bridge. Recommendations after this study are to make traffic counts for a more integral study, investigate the consequence of the increased space for cyclists and pedestrians, study the routes of the trams outside the area, study the spacious planning in the underground of the area and make a detailed research on the requirements of the World Heritage List.

1 Introduction

The introduction of the thesis contains the reason and goal, including the background and the problem of the area of the project. Furthermore, the main question and key questions of the thesis, and the method on how to do the research to get answers on the questions are treated. Furthermore, the introduction contains the structure description. In Appendix B and C, the context of the project and the resources and constraints are worked out.

1.1 Background and problem

This paragraph contains the background and problem of the project, in the form of an overview of the area and the problem definition.

1.1.1 The area of the project

The area of the project is located in the front of the Central Station in Amsterdam. In Figure 2, the streets around the area are visible after the renewals of the municipality: in the middle is Stationsplein, with next to it Prins Hendrikkade. From there, a few streets lead to different parts of the city of Amsterdam: Martelaarsgracht, Damrak, Oosterdokskade and De Ruijterkade.

Cars can drive through all the streets at the moment. At Stationsplein, trams make a loop as end of their route, as can be seen in Figure 2. Also, visible in Figure 2, is the bus station at the west of Prins Hendrikkade. At Damrak straight ahead from the station, Prins Hendrikkade, and near the Station, bicycle tracks are located, which are marked pink and red in Figure 2. The bicycle parking facilities are located at the left and right side of the Station, and at the water, which is visualized in Figure 2 with a grey square in the upper left of the figure. Through the area, footpaths are created to let pedestrians cross from the Station to the city centre and vice versa.

At the intersection of Damrak and Prins Hendrikkade, see Figure 1, is a combination of those traffic flows: cars, trams, buses, cyclists and pedestrians use the intersection. Another intersection with a combination of the traffic flows is the intersection of Martelaarsgracht and Prins Hendrikkade. This combination of different road users makes it crowded intersections. In addition, the road users are often unfamiliar in the area and therefore uncertain where to go to.

Figure 1 Surrounding streets of the Central Station of Amsterdam (Ruimtelijkeplannen, 2018)

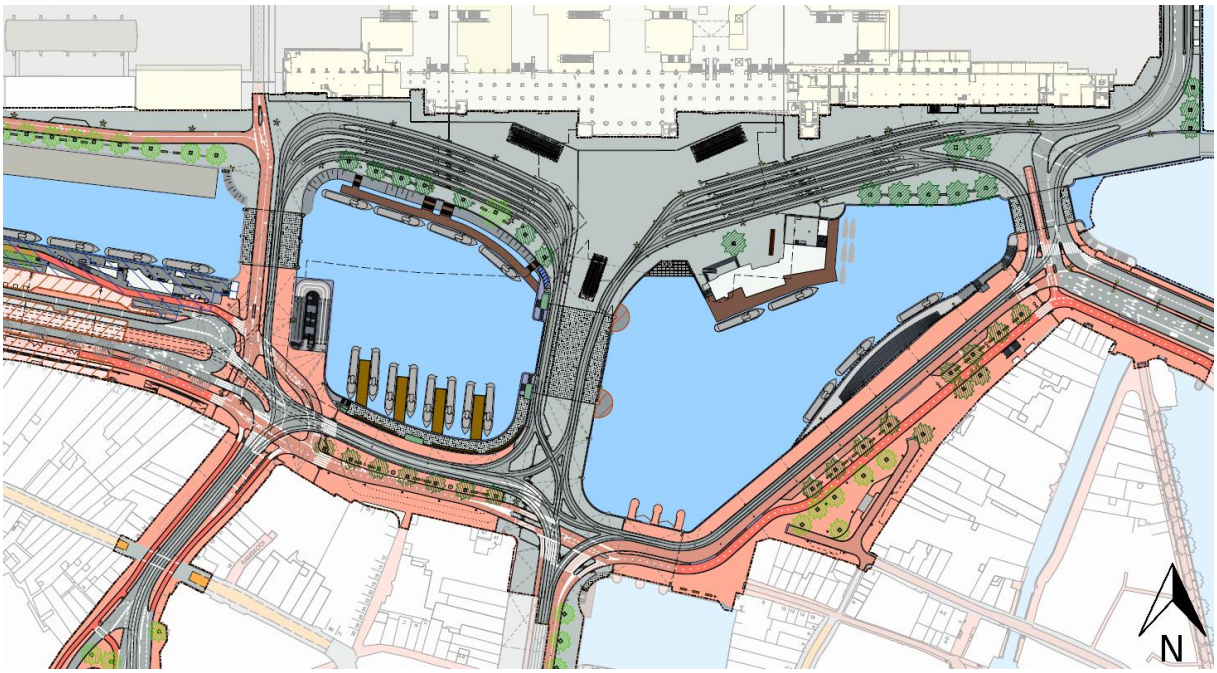

Figure 2 Preliminary design of ground level after the re-defining of the area (Sprietsma & van Amerongen, 2015)

1.1.2 Problem definition

Every year, more tourists visit Amsterdam, and a lot of them enter the city through the Central Station, which makes it a crowded area. (Middendorp & Redactie NRC, 2015; Politico, 2017) In the city are ongoing discussions on what to do with the big crowds, the newspaper of Amsterdam, “Het Parool”, writes about it almost every week. (Couzy, 2018) After realizing the metro network “Noord-Zuidlijn”, the municipality of Amsterdam is now starting with a renewal of the area of “De Entree". There will be more water, more greenery and more space for pedestrians and cyclists. A bicycle parking facility will be installed beneath the water, bottlenecks in traffic are being addressed, some parts of the area become car-free and the

tramway and -stops are renewed. (Gemeente Amsterdam, 2018b) Next to these renewals, the municipal transport company GVB will change a lot in the transport network at the moment that the metro network Noord-Zuidlijn starts its service, on 22 July 2018. (GVB Amsterdam, 2016) However, the renewals and changes in the transport network do not include changes in all the routes of the transport. Also, after the upcoming renewals a lot of traffic flows will cross each other and ensure conflicts. This provides traffic hindrance for the road users, in terms of waste of time and danger due to the conflict points of distinct traffic flows. A conflict occurs when two or more traffic flows cross or meet at the same location, this location is called the conflict point. The crossing traffic flows cannot have green or yellow lights at the same moment. These problems can only be solved by re-defining the area from the start, instead of refining the existing area. To get to a new infrastructure design for the area, the crossing traffic flows need to be addressed. Especially the flows of trams, cyclists and pedestrians provide a lot of conflict points after the current renewals, because a part of the area will already be car-free, while the flows of trams, cyclists and pedestrians remain almost unchanged.

1.2 Main question and key questions

The main goal of the project is re-defining and area development of “De Entree". The focus is on reducing the crossing traffic flows of trams, cyclists and pedestrians in the area, by making a redesign for the traffic flows. To find a solution to the research problem, the following sub-aims need to be considered:

- keep the frequency of the public transport the same;
- give more space to cyclists and pedestrians;
- provide a better continuity of the different traffic flows than it will be after the changes that take effect on 22 July.

To find an answer on the research question; “How can the traffic flows of trams, cyclists and pedestrians be regulated to reduce traffic conflicts?”, the following information is needed:

- what is the frequency of the public transport at the moment?
- what is the frequency of the public transport after 22 July?
- how much space do the cyclists and pedestrians use and how much is needed?

And the following sub-goal can be defined:

- what are the possible changes to provide a better continuity of the different traffic flows?

1.3 Method

To accomplish re-defining and area development, it is needed to make an overview of the crossing traffic flows in the time it takes and when they take place, by quantifying the types and number of public transport in vehicles, cyclists and pedestrians in the area during peak hours. This overview will be a text with an output of a conflict matrix for each intersection. The overview needs to be made before and after the change on 22 July, to be able to see what differences come with the changes. The quantification of the public transport will be done by going through the timetable of GVB and counting the number of vehicles in the peak hours. The presence of cyclists and pedestrians will be estimated by describing the routes of the traffic flows and the conflict points that originate due to these traffic flows. Also, the overview needs to give an insight on what space is needed for the different traffic flows, by quantifying how much space is needed for the amount of people in the area in peak hours. This overview will answer the questions: “What is the frequency of the public transport at the moment?”, “What is the frequency of the public transport after 22 July?” and “How much space do the cyclists and pedestrians use and how much is needed?”

Also, criteria need to be made to test options for a new design which should reduce the conflicts due to the crossing traffic flows. These criteria need to be made before the options for the design are made, and they are based on the change in conflict points that result from the changes after 22 July, guidelines and the practical problems of the traffic flows.

After mapping the crossing traffic flows, the options for the design to reduce the conflicts can be made. These options will be made in a static analysis, wherein the demand of the traffic flows is projected on a map made in Microsoft Office Visio. The options will address the problems that come forward in the overview of the crossing traffic flows, and answer the question: “What are the possible changes to provide a better continuity in terms of less loss in time, of the traffic flows of trams, cyclists and pedestrians?”
These options need to be tested on the criteria, apart from each other and combined. Per criterium, the options will be tested on the degree of compliance with the criterium. After this, the degree of compliance per criterium will be compared to conclude which of the options will be the best design to answer the main question: “How can the traffic flows of trams, cyclists and pedestrians be regulated to reduce traffic conflicts?”

1.4 Structure description

The structure of this thesis is as follows: Chapter 2 describes the traffic flows of the trams, cyclists and pedestrians, and the conflict points that result from the crossing of these flows. Besides that, the chapter contains the criteria of the options for the design. Chapter 3 contains the options for the design itself, and chapter 4 contains the test of the options for the design. Chapter 5 describes the conclusion of the thesis.

2 Crossing traffic flows

As already stated, the focus is on traffic flows of trams, cyclists and pedestrians. In this paragraph, the traffic flows of the cars, public transport, cyclists and pedestrians will be worked out separately to get a complete overview of all the traffic flows. Hereby, the situation after the renewals is maintained. After that, a conclusion will be made about the crossing traffic flows. Furthermore, the criteria for the options for the design will be given in the last paragraph.

Cars

After the re-defining of the area, as shown in Figure 2, cars can turn right at the Prins Hendrikkade to Martelaarsgracht. Before this turn, there is a parking garage at Prins Hendrikkade. Prins Hendrikkade between Damrak and Martelaarsgracht will be car free. Ongoing car traffic passes the area at the back of the Central Station. From Damrak, cars can only turn right to the east of Prins Hendrikkade. (Gemeente Amsterdam, 2018b, 2018a)

Supply traffic is able to drive from Martelaarsgracht to the west of Prins Hendrikkade, between 7 am and 12 am. (Gemeente Amsterdam, 2018a)

Public transport

As can be seen in Figure 3, Figure 4 and Appendix D, the trams, buses and metros go to the Central Station through different streets:

- At the moment, cluster T1 with tram lines 1, 2, 5, 13 and 17 enters and leaves through Martelaarsgracht. After 22 July, cluster T1 will consist of tram lines 2, 11, 12, 13 and 17;
- At the moment, cluster T2 with tram lines 4, 9, 16 and 24 enters and leaves through Damrak. After 22 July, cluster T2 will consist of tram lines 4, 14 and 24;
- Cluster T3 with tram line 26 enters and leaves through De Ruijterkade via Stationsplein;
- At the moment, cluster B1 with bus lines 18, 21 and 22 enters and leaves through the west of Prins Hendrikkade. After 22 July, the cluster will no longer pass the area in front of the Central Station;
- At the moment, cluster B2 with bus lines 22 enters and leaves through the east of Prins Hendrikkade. Bus lines 32, 33, 34, 35, 48, 301, 304, 306, 307, 308, 312, 314, 315, 316, 319, 391, 392 and 394 enter and leave at the back of Central Station, and therefore they do not pass the area in front of the Central Station. After 22 July, the cluster will no longer pass the area in front of the Central Station;
- At the moment, cluster B3 with bus lines 48 and 248 enters and leaves at the back of the Central Station, and therefore the cluster does not pass the area in front of the Central Station;
- Cluster M1 with metro lines 51, 53, and 54 enters and leaves in the underground at the subway station in front of the Central Station in the direction of Nieuwmarkt;
- Cluster M2 is the new metro line 52, and will enter and leave in the underground at the subway station in front of the Central Station in the direction of Rokin when it starts its service.

Figure 3 Clusters before 22 July (GVB Amsterdam & Carto Studio BV, 2017)

Figure 4 Clusters after 22 July (GVB Amsterdam & Carto Studio BV, 2018)

In two different loops, visible in Figure 2, the trams have stops at Central Station. After the stop, they continue their different routes through the city of Amsterdam.

At the moment, the buses have a stop at the west of Prins Hendrikkade. After the stop, they continue their routes through the different sides of Prins Hendrikkade. After 22 July, the bus lines will stop at the back of the Central Station, and the bus station will only be used for tourist buses.

The metros have a stop in the underground in front of the Central Station, with a connection to Stationsplein via escalators.

The frequency of the public transport differs during the week and during the day. The peak hours for every cluster can be seen in Table 1, with the clusters as stated before. (GVB Amsterdam, 2018a)

Table 1 Frequency of the public transport

Cluster	Before/after 22 July	Week/weekends	Time of the day	Maximum number of vehicles/hour
T1	Before	During the week	8 am – 10 am 2 pm – 7 pm	100 96
		On weekends	12 am – 8 pm	104
	After	During the week	8 am – 9 am 12 am – 8 pm	72 88
		On weekends	12 am – 8 pm	80
T2	Before	During the week	1 pm – 6 pm	64
		On weekends	12 am – 6 pm	64
	After	During the week	8 am – 7 pm	40
		On weekends	11 am – 7 pm	44
T3	Before and after	During the week	8 am – 9 am 4 pm – 7 pm	30 30
		On weekends	12 am – 6 pm	20
B1	Before	During the week	7 am – 10 am 3 pm – 8 pm	44 46
		On weekends	11 am – 8 pm	38
B2	Before	During the week	7 am – 10 am 4 pm – 7 pm	14 16
		On weekends	11 am – 6 pm	12
M1	Before and after	During the week	7 am – 10 am 3 pm – 7 pm	48 48
		On weekends	10 am – 10 pm	36
M2	After	During the week	Ca. 7 am – 10 am Ca. 3 pm – 7 pm	12 12
		On weekends	Ca. 10 am – 10 pm	12

From Table 1 can be seen that the intersection of Martelaarsgracht and Prins Hendrikkade has to process a maximum of 104 trams/hour and 46 buses/hour before 22 July and 88 trams/hour after 22 July. Hereby, cluster B2 is not included because the bus line is already included in cluster B1, as stated in Appendix D.

Furthermore, it can be seen that the intersection of Damrak and Prins Hendrikkade has to process a maximum of 94 trams/hour and 16 buses/hour before 22 July and 64 trams/hour after 22 July. Thereby, the 104/hour trams before 22 July, and 88 trams/hour after 22 July that go to the intersection of Martelaarsgracht and Prins Hendrikkade, pass this intersection in one way at the corner. This gives a total of 146 trams/hour and 16 buses/hour before 22 July and 108 trams/hour after 22 July.

Next to the trams, buses and metros, there are touring cars in the area. At the moment, they drive at Prins Hendrikkade. According to P. Zuidam, loading and unloading of these cars will only be possible at two points at Prins Hendrikkade after 22 July: at the west, where they make a turn to go back to the west or turn right to Martelaarsgracht, as visible in Figure 2, and at the east where they come from Damrak and follow Prins Hendrikkade. An alternative for the touring cars will be the pilot to stop at the bus station at the back of Central Station. (P. Zuidam, communication advisor of Max Bögl Nederland B.V., 2018; Gemeente Amsterdam, 2018a; Tours & Tickets, 2018)

Cyclists

As can be seen in Figure 2, the bicycle tracks in the area are marked red. Cyclists can enter the area from different sides: from Damrak, both sides of Prins Hendrikkade and the west of De Ruijterkade. With help of the red markings, the bicycle flows are regulated to drive only there, where the red markings are. Every day, thousands of cyclists go from one side of the city to the other on these bicycle tracks, which makes it one of the most crowded bicycle tracks in the city. (Couzy, 2018)

Pedestrians

Pedestrians enter the area from all sides, not only from the station and the larger streets such as Damrak, Prins Hendrikkade, Martelaarsgracht, Oosterdokskade and De Ruijterkade, but also from all the bystreets between the larger streets. This makes the sidewalks in the area one of the most crowded in the city. The pedestrian flows are regulated with the help of pedestrian lights and walking areas. The bicycle track is an obstacle between the sidewalk and the station, and sometimes even life-threatening for tourists. (Couzy, 2018)

2.1 Conclusion of the crossing traffic flows

The different traffic flows, investigated in the previous paragraphs, cross each other and then create conflict points. The number of conflict points in the area give an insight of the hindrance that road users will experience, because that part of the road needs to be shared with other traffic flows.
As mentioned in the description of the area of the project, there are two intersections with traffic flows of the trams, cyclists and pedestrians: the intersection of Martelaarsgracht and Prins Hendrikkade, and the intersection of Prins Hendrikkade and Damrak.

In Figure 5 can be seen that the trams of cluster T1 come from the Martelaarsgracht, cross the intersection, and go north to the station. After leaving the station, the trams come from the east of Prins Hendrikkade, and go left to Martelaarsgracht.

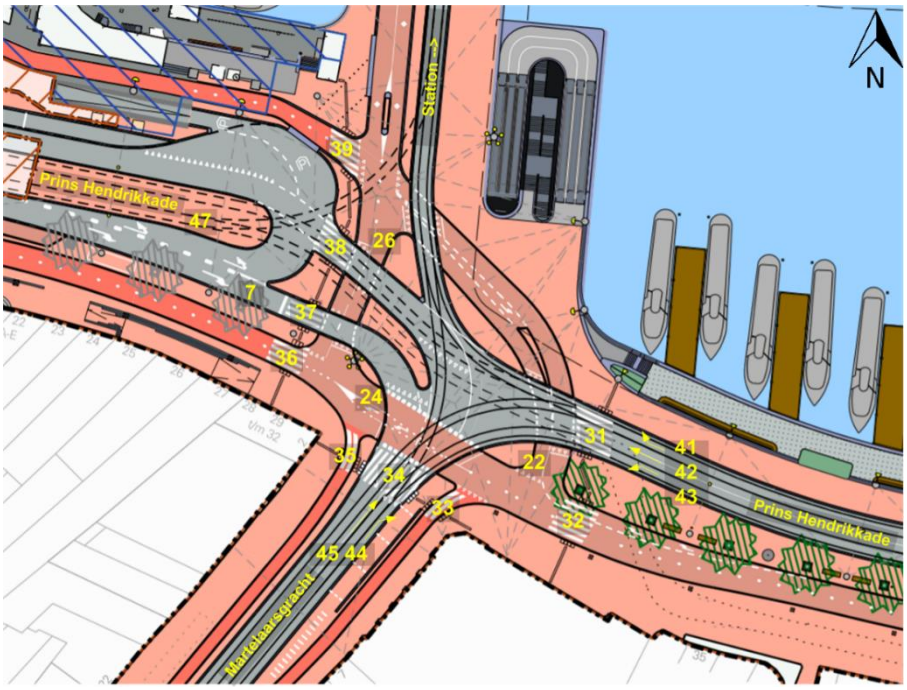

Figure 5 The intersection of Martelaarsgracht and Prins Hendrikkade with numbers of traffic flows (CROW, 2018; Sprietsma & van Amerongen, 2015)

In Figure 6 can be seen that the trams of cluster T1 that go to Martelaarsgracht, pass the intersection at the corner, from the north to the west. Trams from cluster T2 that come from Damrak, go to the station via the east. After leaving the station, they go straight on from the north of the intersection to Damrak. Cluster T3 passes the intersection at the corner from the north to the east.

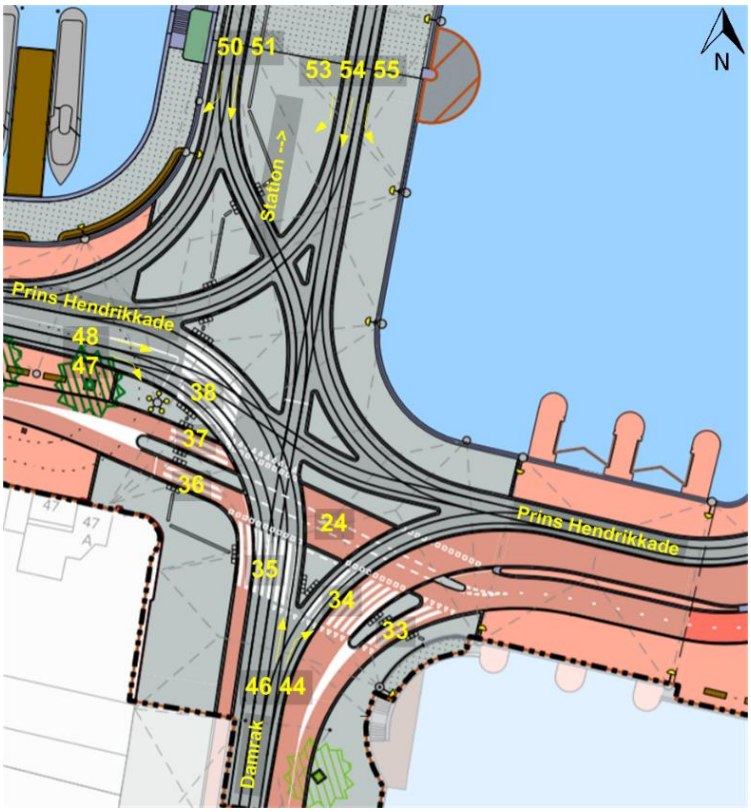

Figure 6 The intersection of Prins Hendrikkade and Damrak with numbers of traffic flows (CROW, 2018; Sprietsma & van Amerongen, 2015)

Conflict points of the crossing traffic flows

In Figure 5 and Figure 6 can be seen where the trams; drawn with tram tracks, will cross the cycle tracks; the red marked tracks. The crossings for the pedestrians are marked as pedestrian crossings. All the pedestrian crossings cross tram tracks and cycle tracks.

For the different traffic directions numbers are given, following the manual traffic light regulations 2014. With this numbers, a conflict matrix can be made to get an overview of the conflict points of the traffic flows. (CROW, 2018) This is including trams, buses, cars, cyclists and pedestrians.

Table 2 contains the conflict matrix of the intersection of Martelaarsgracht and Prins Hendrikkade, Table 3 contains the conflict matrix of the intersection of Prins Hendrikkade and Damrak. The numbers in the tables are the same numbers in Figure 5 and Figure 6. The X represents a conflict point, a / represents a conflict point next to the intersection. A number represents the maximum number of conflicts on that conflict point in an hour, without the number of cars, cyclists and pedestrians.

Table 2 Conflict matrix of the intersection of Martelaarsgracht and Prins Hendrikkade

	07	22	24	26	31	32	33	34	35	36	37	38	39	41	42	43	44	45	47
07	-	-	X	X	-	-	-	X	-	-	X	-	-	-	-	52	-	-	-
22	-	-	-	-	-	/	-	-	-	-	-	-	/	0	8	52	0	52	8
24	X	-	-	-	-	/	-	-	-	/	-	-	-	-	-	52	0	52	-
26	X	-	-	-	-	-	-	-	-	/	-	-	/	-	8	-	-	-	8
31	-	-	-	-	-	-	-	-	-	-	-	-	-	0	8	52	0	-	8
32	-	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52	0	52	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	8
39	-	/	-	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	0	-
42	-	8	-	8	8	-	-	-	-	-	-	8	-	-	-	-	-	58	-
43	52	52	52	-	52	-	-	52	-	-	-	-	-	-	-	-	-	104	58
44	-	0	0	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-	0
45	-	52	52	-	-	-	-	52	-	-	-	-	-	0	58	104	-	-	58
47	-	8	-	8	8	-	-	-	-	-	-	8	-	-	-	58	0	58	-

Table 3 Conflict matrix of the intersection of Prins Hendrikkade and Damrak

	24	33	34	35	36	37	38	44	46	47	48	50	51	53	54	55
24	-	-	-	-	/	/	-	32	0	0	-	-	0	-	32	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	32	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	0	0	-	-	0	-	32	-
36	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	0	0	8	-	-	-	-	-
44	32	-	32	-	-	-	-	-	-	-	40	-	-	-	-	47
46	0	-	-	0	-	-	0	-	-	-	0	52	0	0	0	-
47	0	-	-	0	-	-	0	-	-	-	-	-	0	-	0	-
48	-	-	-	-	-	-	8	40	0	-	-	-	0	-	40	23
50	-	-	-	-	-	-	-	-	52	-	-	-	-	52	-	-
51	0	-	-	0	-	-	-	-	0	0	0	-	-	0	0	-
53	-	-	-	-	-	-	-	-	0	-	-	52	0	-	-	-
54	32	-	-	32	-	-	-	-	0	0	40	-	0	-	-	-
55	-	-	-	-	-	-	-	47	-	-	23	-	-	-	-	-

2.2 Criteria for the options of the design

In this paragraph, the criteria for the options of the design are worked out, to be able to use them while testing the options for the design.

The design should reduce the number of conflict points in such an amount that the area changes in a positive way that is worth the costs and road work. The changes that will happen at 22 July, give a reduction of conflict points of 15% and 23% of trams at the intersection. GVB calls this a historic plan due to the large amount of changes. (GVB Amsterdam, 2016) Another reduction of conflict points of 10 to 15% would be worth the costs and road work.

In the design should be more space for traffic flows, to be able to process larger quantities of the traffic flows. Hereby, the changes will have to meet the standards following the new guidelines and Level of Service. For pedestrians, this means that the recommended widths of the London guidelines should be met. (Transport for London, 2010) For bicycle paths, this means that the recommended width of 2.50 m per direction should be met. (CROW-Fietsberaad & Hendriks, 2017) For trams is assumed that GVB has researched the required space, so the frequency of the trams must be maintained.

The waiting time for trams, cyclists and pedestrians should be reduced or even eliminated in the design: the time that it takes for a tram to pass by – and the delay due to it – and lengths of rows that arise of the different flows and stagnation that comes from it.

3 Options to reduce the conflict points

This chapter contains the different options for the design to reduce the conflict points due to the different crossing traffic flows, based on chapter 2.

Adjustments of the space for cyclists and pedestrians

In the public space, more and more the space is assigned to cyclists and pedestrians, over other modalities. The cycle paths and pedestrian sidewalks become wider and the use by cyclists and pedestrians is promoted. (Nationaal Voetgangerscongres: Lopen Loont, 2017) To get more space for cyclists and pedestrians, some adjustments can be made to the current area.

Cyclists

In the re-defining of the area is thought of adjustments of the space by creating more space for cyclists and pedestrians, which is done by blocking motorized traffic and a greater distance between cyclists and pedestrians. Furthermore, the paving is being tiled again. (Gemeente Amsterdam, 2018b)
However, in Figure 2 can be seen that the spaces for the different traffic flows are still in the common style, and there are no ingenious adjustments that Fietsberaad suggests, such as ‘bananas’, a ‘bag of fries’, reducing block marking between bicycle paths and pedestrian crossing roads, boxes with crosses and pre-sorting arrows. These suggestions are already tested in Amsterdam, and they can give the traffic flows some extra space, which increases the capacity. Besides, the measures are relatively inexpensive and quick to implement. (CROW-Fietsberaad & Hendriks, 2017)

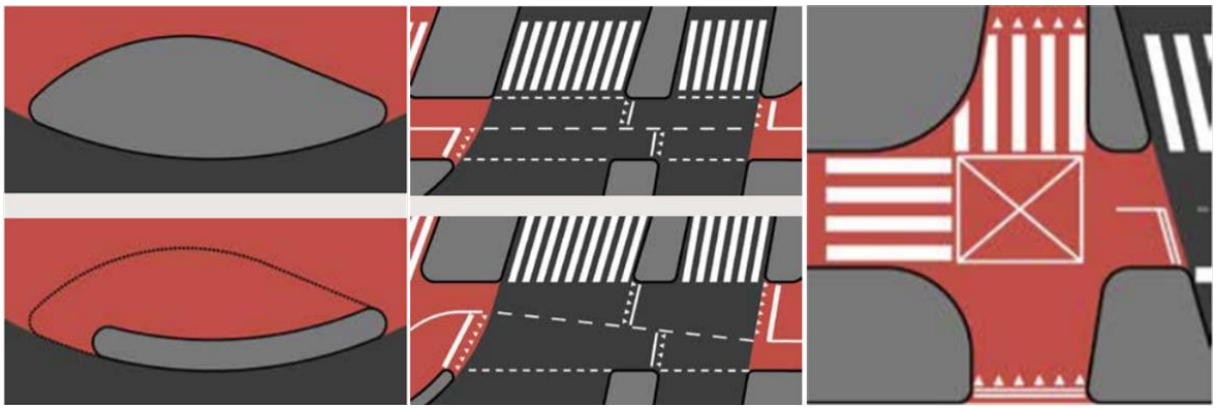

Figure 7 Suggestions of Fietsberaad: the 'banana', the 'bag of fries' and boxes with crosses (CROW-Fietsberaad & Hendriks, 2017)

The 'banana' is a curved elevation, which is reduced in size in comparison with the current traffic islands, as shown in the upper left corner of Figure 7. Hereby, there is more space for cyclists.
The middle of Figure 7 shows the 'bag of fries', which funnels cyclists on two-way paths. The bicycle path at the start of the crossing is being widened considerably. After this start, the strip narrows and the cyclists head to the desired direction on the other side.
Space can be gained by putting the block mark along a bicycle crossing not on the crossing itself, but next to it. Or it can be deleted completely, since it is not legally required between a pedestrian and bicycle crossing.
Another option is to use pre-sorting arrows, to keep cyclists that go to different directions apart. In the video of SHIFT, an agency for behavioural change, can be seen that pre-sorting arrows help road users choosing their position while waiting. (SHIFT Gedragsverandering, 2017)
When flows of cyclists cross each other and one of the flows has to wait, it blocks the other flow. To give space to the continuing flow, boxes with crosses can be used, as can be seen in the right of Figure 7.
An objective of Amsterdam is to have bicycle paths with a minimum width of 2.50 metres per direction. From the ground level design of the re-defining of the area, is measured that the widths of the bicycle paths differ a lot in the area: some of them are already 2.50 metres, some of them are not. (Gemeente Amsterdam, 2016) The widths are put apart in Figure 8, hereby, the total width of the bicycle path is given instead of the width per direction. This means that all widths with a I smaller than 2.5 metres and with a II smaller than 5.0 metres are too small.

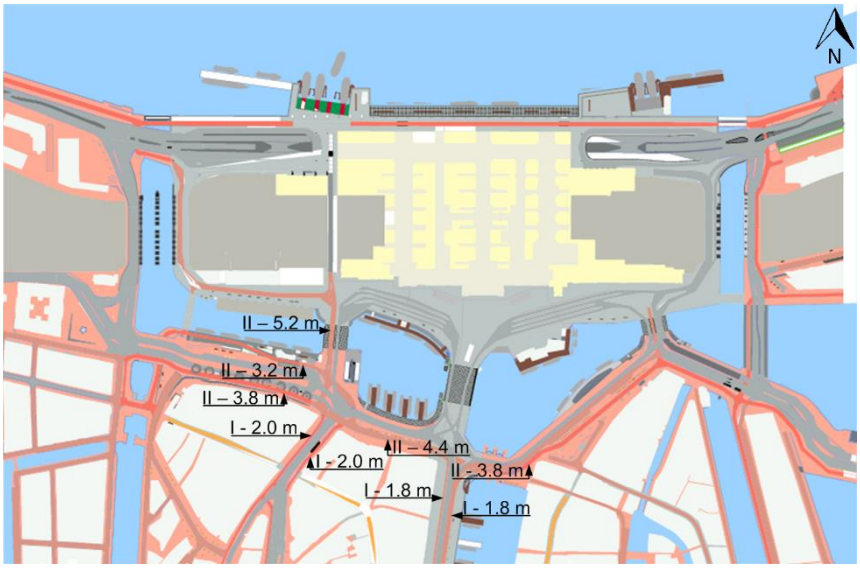

Figure 8 Ground level design De Entree surfaces contract drawing (Gemeente Amsterdam, 2016)

Also, there may be a pilot project in Amsterdam where cyclists can use the space on the road during the rush hour, or to give cyclists room on the roadway by making cars use the tram tracks. However, during rush hour all the traffic flows are present in large quantities, so all the space is used. This makes it unnecessary to redistribute the space.
Finally, in the TU master's thesis of Bas Janssen is looked at the behaviour of cyclists in different types of curbs: the traditional raised tire, the slanted curb and the ground-level edge. Depending on the distance and feeling of safety that is needed between bicycle and pedestrian, one of the curbs is preferred: cyclists keep the most distance from the traditional raised tire, and the least space to the slanted curb. (CROW-Fietsberaad & Hendriks, 2017)

In Figure 2 is visible that there are no 'bananas', 'bag of fries' and boxes with crosses on the intersections. At these intersections, 'bananas' are not always a good choice, because it can reduce space for pedestrians. But on the corners where there are no pedestrians, 'bananas' are possible. The 'bag of fries' and boxes with crosses can be introduced on all the crossings for cyclists. Furthermore, the block marks between the pedestrian and bicycle crossing can be eliminated. At the intersections, there are already a few pre-sorting arrows. This could be extended with pre-sorting arrows at all places where sorting of cyclists is possible. Also, the width of the bicycle paths need to be widened to meet the wish to have a width of 2.50 m. To secure safety for cyclists and pedestrians, the curbs between the bicycle and pedestrian paths need to be clear. This can be realized by using the traditional raised tire, because cyclists will keep the most distance from this curb and thereby the most distance from pedestrians. Slanted curbs are not safe enough in this area, because cyclists can easily cross this curb, for example to overtake other cyclists, while it is too crowded on the pedestrian crosswalk to cycle there. The locations of these changes are visualized in Figure 9 and Figure 10.

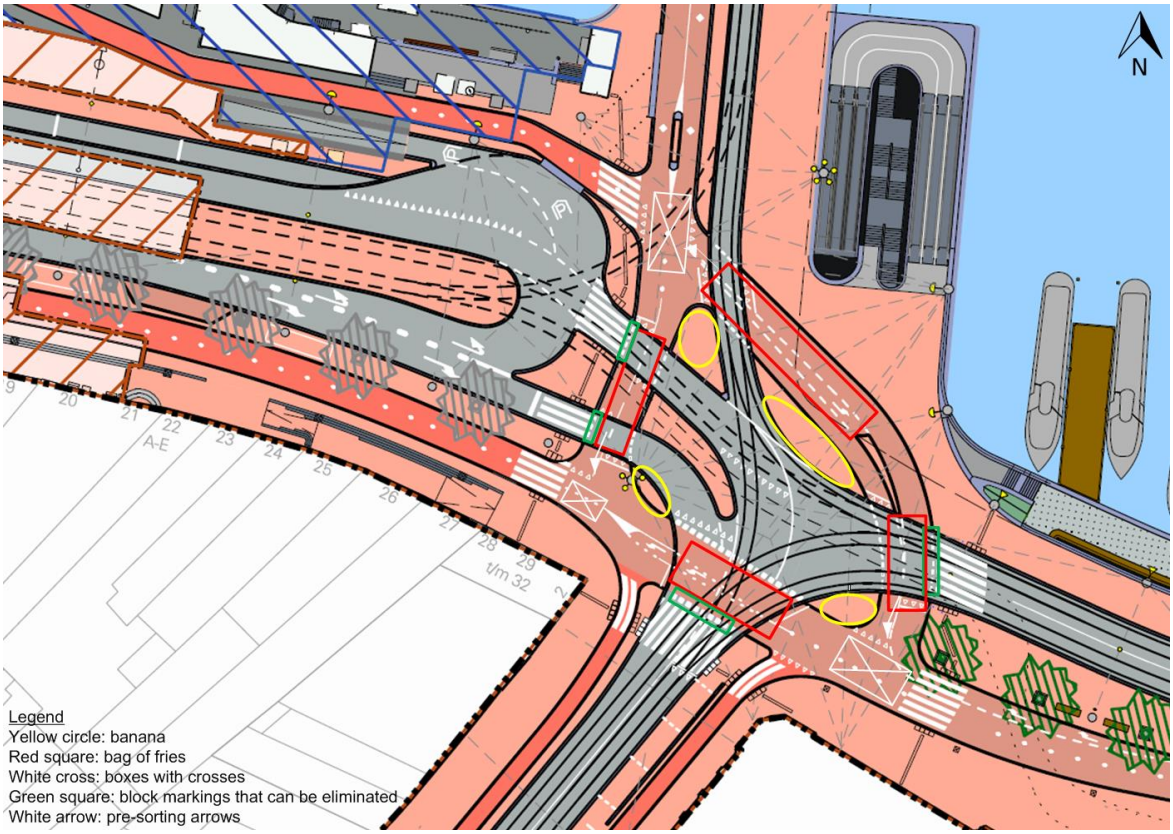

Figure 9 Adjustments for cyclists on the intersection of Martelaarsgracht and Prins Hendrikkade (Sprietsma & van Amerongen, 2015)

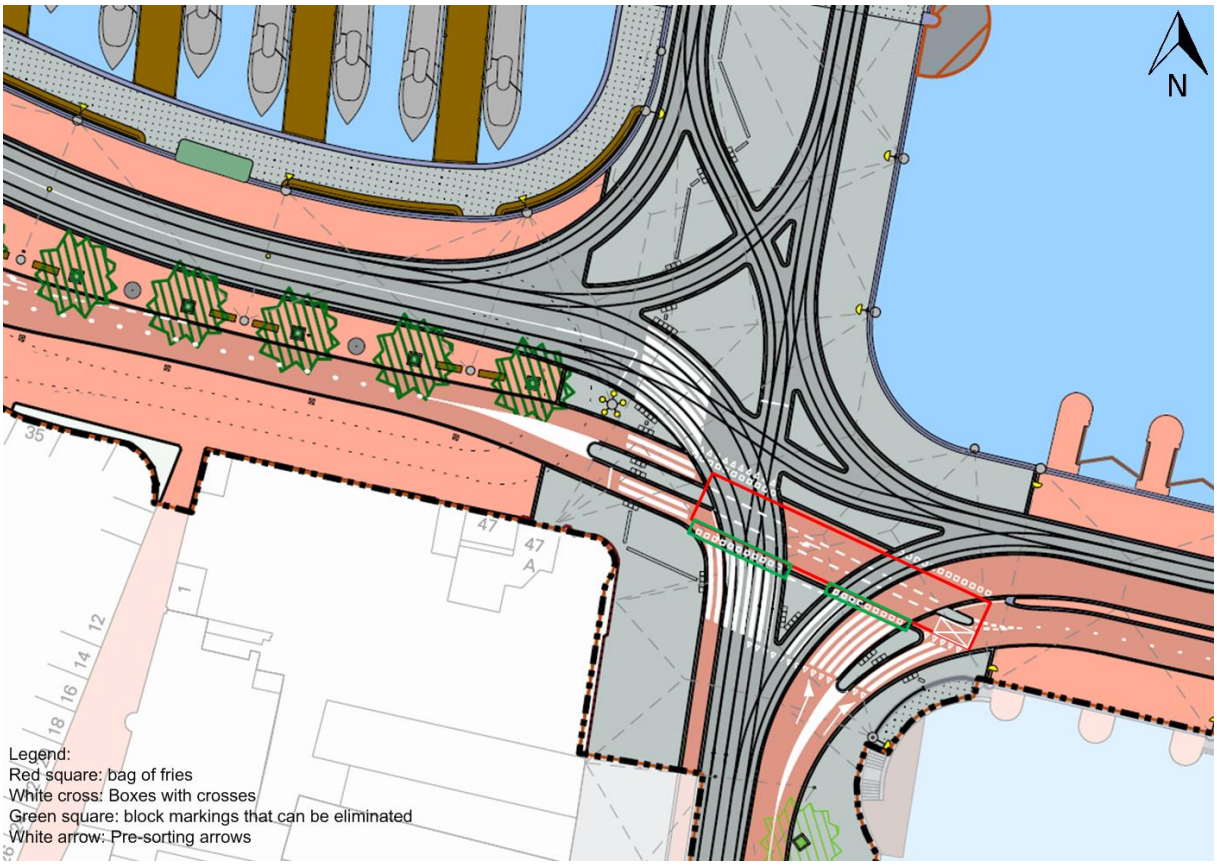

Figure 10 Adjustments for cyclists on the intersection of Prins Hendrikkade and Damrak (Sprietsma & van Amerongen, 2015)

Pedestrians

The walking space is under pressure due to other space claims, such as parked bicycles and advertising banners. The human tendency is to avoid body contact and, if possible, protect his personal space. This gives a minimum distance that one keeps: the 'passing distance' or 'shy away distance'. This distance is dependent on the situation, on more crowded streets the passing distance decreases. For London, a comfort level guidance is made to create a layout of the street for pedestrians. In this guide, recommended widths are determined. For high flows, with more than 1200 people per hour, the recommended width is 5.3 m including a large piece of street furniture, or 3.3 m without the street furniture. To get sufficient walking space and a feeling of comfort, the flow needs to have enough space, and should thereby be improved to safeguard from obstacles. (Bruijne, 2016; Nationaal Voetgangerscongres: Lopen Loont, 2017; Transport for London, 2010) Since the area is the entrance to Amsterdam, there are boards with information and such on the crosswalks, so expanding the width of the crosswalks towards 5.3 m would be recommended.

Combination of trams

In the paragraph about trams, as one of the crossing traffic flows, appears that on peak hours the number of trams on the intersections in the area is very high. If combinations of tram lines or tracks can be made, the number of trams at the intersections could be reduced. As can be seen in Figure 11, cluster T1 goes to Nieuwezijds Voorburgwal after leaving the area of the Central Station, and cluster T2 goes to Rokin. Tram 14 crosses the clusters by passing through Dam. From the different sides of Dam, it is possible to go to different directions, following the tram tracks in Figure 11. Another option is to go to different directions

further in the city, for example at Weteringschans. This means that trams passing through Martelaarsgracht to Nieuwezijds Voorburgwal and Damrak to Rokin, could change directions at Dam or Weteringschans. This would change the clusters and the loops in front of the Central Station.

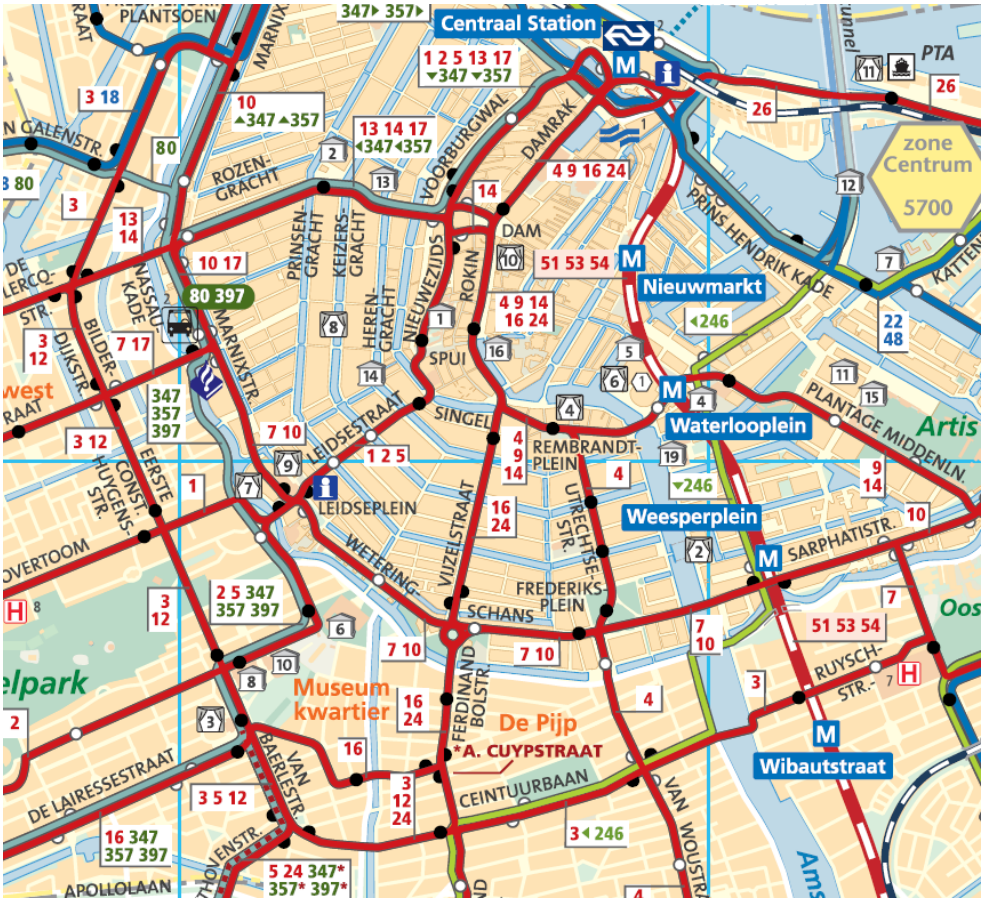

Figure 11 Public transport in the city centre of Amsterdam at the current situation (GVB Amsterdam & Carto Studio BV, 2017)

As concluded in chapter 2, the intersection of Martelaarsgracht and Prins Hendrikkade has to process a maximum of 104 trams/hour at the moment, and the intersection of Prins Hendrikkade has to process a maximum of 146 trams/hour at the moment, including the trams that pass the intersection at the corner, because this tram track has a conflict with a pedestrian flow.

From the comparison of the current situation with the situation after 22 July, it is clear that the amount of public transport reduces, with 16 trams/hour less on the intersection of Martelaarsgracht and Prins Hendrikkade, and 46 trams/hour less on the intersection of Prins Hendrikkade and Damrak. This change is achieved by changing the tram network of the city, including adding tram lines and removing tram lines.

A change to further reduce the number of trams in front of Central Station, could be to redesign the loops and the way of driving to the Central Station, by changing the streets into one-way traffic streets. At Nieuwezijds Voorburgwal and Damrak, the trams almost drive at a free track, which means that they drive without interference of other traffic flows, except some pedestrian crossings. So, the clusters T1 and T2 would both be entering the area in front of Central Station via Nieuwezijds Voorburgwal, and leaving the area via Damrak, because the current route at Stationsplein is in this direction. Hereby, multiple options are possible. At first, visible in Figure 12, clusters T1 and T2 use a joint loop from Nieuwezijds Voorburgwal to Stationsplein to Damrak. Then, cluster T3 uses its own loop in the same way as in the current situation.

In the second option, visible in Figure 13, cluster T1 and T2 make the same loop as in the first option, and cluster T3 changes to a bi-directional tram, so the tram only needs to enter Stationsplein, and then turn.

In the two options, less tram tracks are needed, which means that there is more space for other traffic flows, in particular option 2 needs less tram tracks. Furthermore, the one-way traffic at Nieuwezijds Voorburgwal and Damrak ensures that there is more space for the larger amount of trams passing through the streets. Moreover, the accessibility of other destinations will barely be influenced. The trams stop at the same stops, and the connections do not change outside the area in front of Central Station. The only thing that is not possible anymore, is to take the tram in the other direction at Nieuwezijds Voorburgwal and Damrak. At Nieuwezijds Voorburgwal, that is uncomfortable at the stop of Nieuwezijds Kolk, the white circle which is visible in Figure 11. However, the other stops at Nieuwezijds Voorburgwal and Damrak are close to Dam, and therefore not very uncomfortable to miss.

Figure 12 Option 1 for a new loop, with a joint loop for cluster T1 and T2, and an own loop for cluster T3

Figure 13 Option 2 for a new loop, with a joint loop for cluster T1 and T2, and cluster T3 bi-directional

Split level

To escape from the conflict points, the flows could move through different levels, so they will not cross each other. This means that some of the flows should move to another level than ground level, potentially with a bridge or tunnel. To move trams, the tracks should move with it, including necessities such as the electronic systems and space that is needed for the overhead line. To move cyclists and/or pedestrians, the roads and sidewalks should move with them, considering the requirements of the area, such as buildings, streets and the overhead line of the tram. With all the water in the area and the metros and bicycle parking facility underneath the water, it has been assumed that there is no space underground for a tunnel, because if there is space left, it could be used for more bicycle parking facilities. Furthermore, the tunnel needs social safety and enough view, requirements that are difficult to fulfil in little space.

Figure 15 shows in a yellow line the option for split level. Hereby, a pedestrian bridge crosses over the intersection of Prins Hendrikkade and Damrak. By this design, pedestrians have their own space to walk between the Station and the city centre, while trams have space on the intersection, which reduces crowded crossings at the intersection. Although it seems that pedestrians can cross the intersection as well as take the bridge, without having to take the stairs, the bridge will still be used because of the possibility to look out over Stationsplein. So, except of the functionality of the bridge, it is also an aesthetic work and thereby a landmark. For example, at National tulip day in Amsterdam, a temporary bridge is made over Dam, so people can look at the tulips and people at Dam, see Figure 14. Although it is not needed to take the bridge, it is attractive because of the possibility of looking further around you.

Due to the spatial profile of the tram, the bridge has a height of 10 metres. (Gemeente Amsterdam, 2015). The span of the bridge is approximately 80 metres, inclusive stairs. Because of the expected high costs due to the high surface, it is possible to install a temporary bridge first, like the bridge at National tulip day, to test the attractiveness of the bridge.

Figure 14 National tulip day in Amsterdam (Nationale tulpendag, 2018)

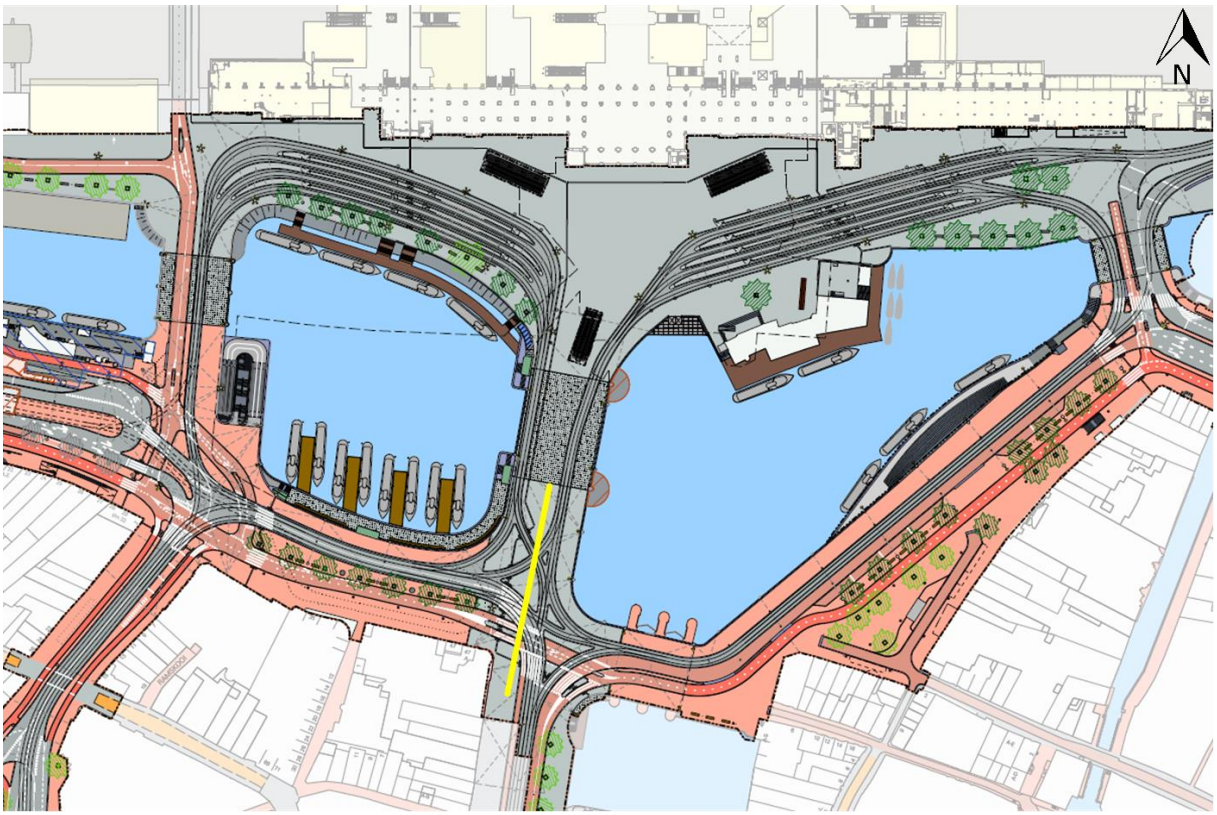

Figure 15 Option for split level, with a bridge for pedestrians over the intersection

3.1 Discussion of the combined options

Adjustments of the space for cyclists and pedestrians are possible next to the other options, because this option does not interfere with the changes made in the other options. The adjustments are still possible if the intersections change due to the other options.

The option of split level would be a good combination with option 2 of the combination of trams, because the north of the pedestrian bridge would be at a location where there is no tram track. In option 1 of the combination of trams, there are tram tracks close to or even at the same location of the pedestrian bridge, which makes the rest of the space too small for a pedestrian crosswalk. So, with the pedestrian bridge and option 2 of the combination of trams, the pedestrian flow is separated from the trams and cyclists.

Because option 2 of the combination of trams seems to fit best with the option of split level, including the adjustments of the space, this option is worked out more detailed, as visible in Figure 16 and Figure 17.

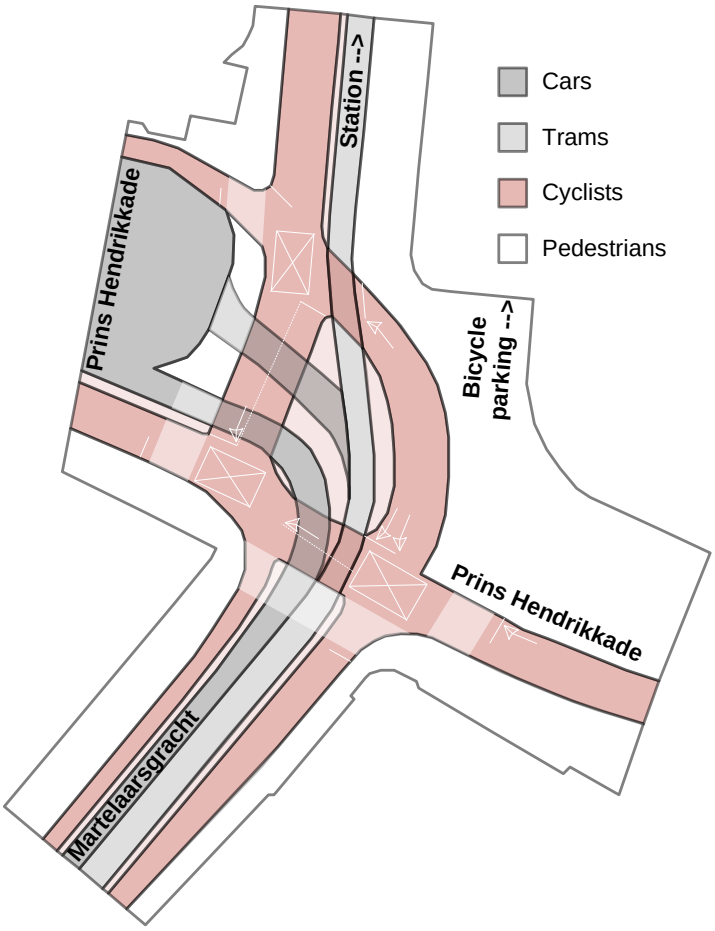

Figure 16 New design of the intersection of Martelaarsgracht and Prins Hendrikkade

At the intersection of Martelaarsgracht and Prins Hendrikkade, there is space for pedestrians, cyclists, trams and cars, as shown in Figure 16. Cars turn right from Prins Hendrikkade to Martelaarsgracht, while buses turn around at Prins Hendrikkade. For loading and unloading, supply traffic can turn left from Martelaarsgracht to Prins Hendrikkade, between 7 am and 12 am. Trams go from Martelaarsgracht to the Central Station. Cyclists and pedestrians can go to all sides of the intersection, with help of crossings. From the curve at the cycle path, cyclists can go to the new bicycle parking facility under water.

The ‘bananas’, ‘bag of fries’, boxes with crosses and pre-sorting arrows are added to the intersection, at the places which were chosen earlier in the thesis. The block marks between the pedestrian and bicycle crossings are eliminated. The bicycle paths are widened where possible, to fulfil the wish to have bicycle paths with a width of 2.50 m. Where the tram tracks disappeared is more space for pedestrian crosswalks to expand towards the recommended 5.3 m.

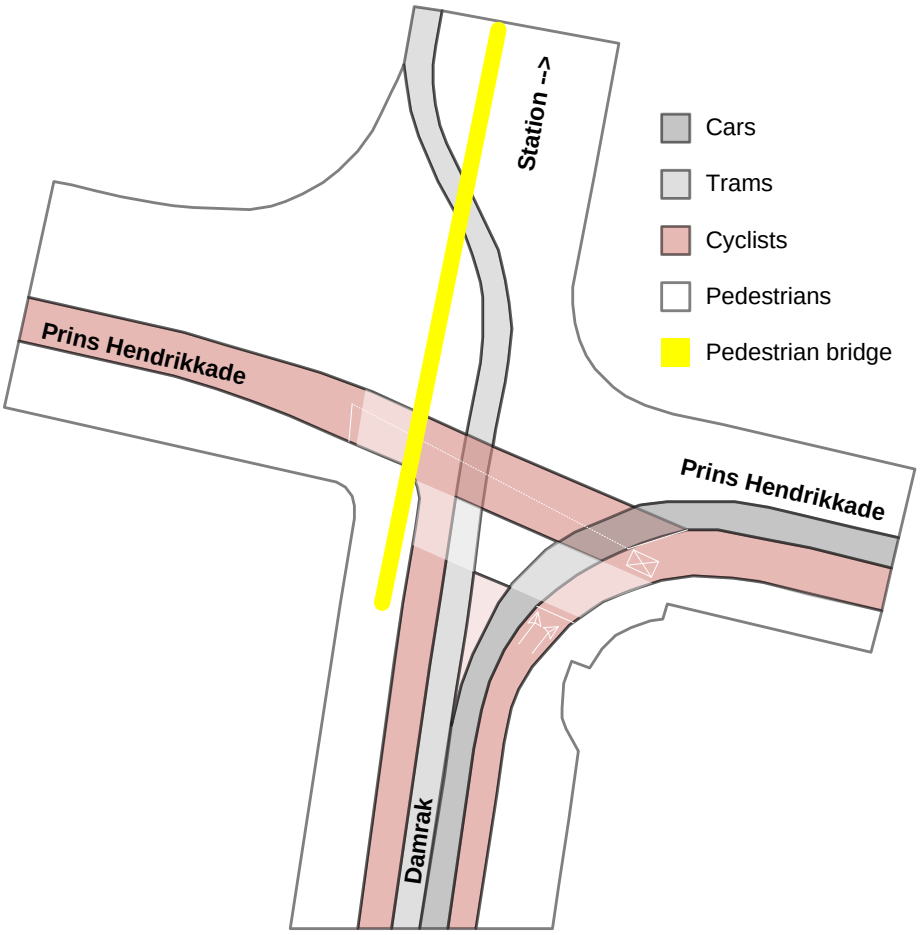

Figure 17 New design of the intersection of Prins Hendrikkade and Damrak

At the intersection of Prins Hendrikkade and Damrak there is space for pedestrians, cyclists, trams and cars, as shown in Figure 17. Cars turn right from Damrak to Prins Hendrikkade. Trams come from the Central Station and go to Damrak. Cyclists can cycle between Prins Hendrikkade and Damrak, with help of crossings. Pedestrians can go to all sides of the intersection, with help of crossings and the pedestrian bridge.

The 'bag of fries', box with cross and pre-sorting arrows are added to the intersection, while the block marks between the pedestrian and bicycle crossing are eliminated. Like the other intersection, the width of the bicycle paths and pedestrian crosswalks are widened where possible, to fulfil the recommendations of respectively 2.50 m and 5.3 m.

4 Testing the options by criteria

In this chapter, the different options for the design are tested by criteria in a design assessment. First, the test is done for the options combined, then the test is done for the separate options, to go into further detail per option.

4.1 Test of the options combined

Reduce the number of conflict points

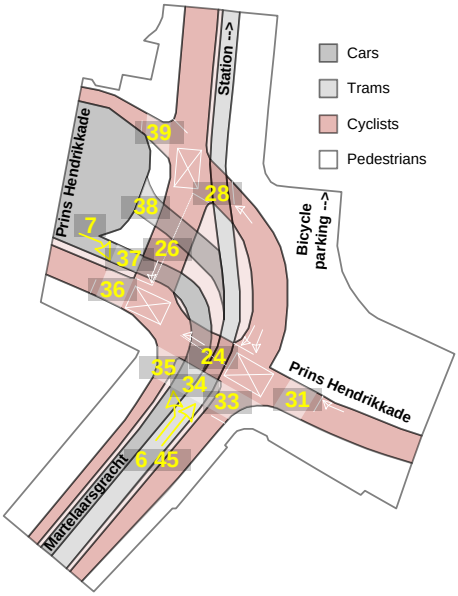

Figure 18 New design of the intersection of Martelaarsgracht and Prins Hendrikkade including the numbers of flows

In Figure 18, the new design of the intersection of Martelaarsgracht and Prins Hendrikkade is visible, including the numbers of the traffic flows on the intersection in the same order as the numbers of flows in Figure 6. With these numbers, a conflict matrix is made, as visible in Table 4. The conflict matrix is filled in the same way as the conflict matrices before.

Table 4 Conflict matrix of the new design of the intersection of Martelaarsgracht and Prins Hendrikkade

	06	07	24	26	28	31	33	34	35	36	37	38	39	45
06	-	-	X	X	-	-	-	X	-	-	-	X	-	-
07	-	-	X	X	-	-	-	X	-	-	X	-	-	-
24	X	X	-	-	-	/	-	-	-	/	-	-	-	128
26	X	X	-	-	-	-	-	-	/	/	-	-	-	-
28	-	-	-	-	-	/	-	-	-	-	-	-	/	128
31	-	-	/	-	/	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	X	X	-	-	-	-	-	-	-	-	-	-	-	128
35	-	-	-	/	-	-	-	-	-	-	-	-	-	-
36	-	-	/	/	-	-	-	-	-	-	-	-	-	-
37	-	X	-	-	-	-	-	-	-	-	-	-	-	-
38	X	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	/	-	-	-	-	-	-	-	-	-
45	-	-	128	-	128	-	-	128	-	-	-	-	-	-

In comparison with Table 2, there is a reduction of 19 to 14 traffic lights in Table 4. The 128 conflicts in an hour give the idea that there are more conflicts than in the original design, while this number should be compared with several numbers in Table 2: the trams with traffic light 45 have the sum of 104 and 58 conflicts in an hour, which gives a higher total number of conflicts than the 128 conflicts for traffic light 45 in the new design, so there is a reduction of conflicts of 26%. However, the 58 conflicts occur due to buses, and they are relocated in the new design, which means that the number of conflicts due to trams are increased in the new design with 23%. The difference in change in conflicts means that the relocation of the buses is needed to get a reduction of conflicts at the intersection.

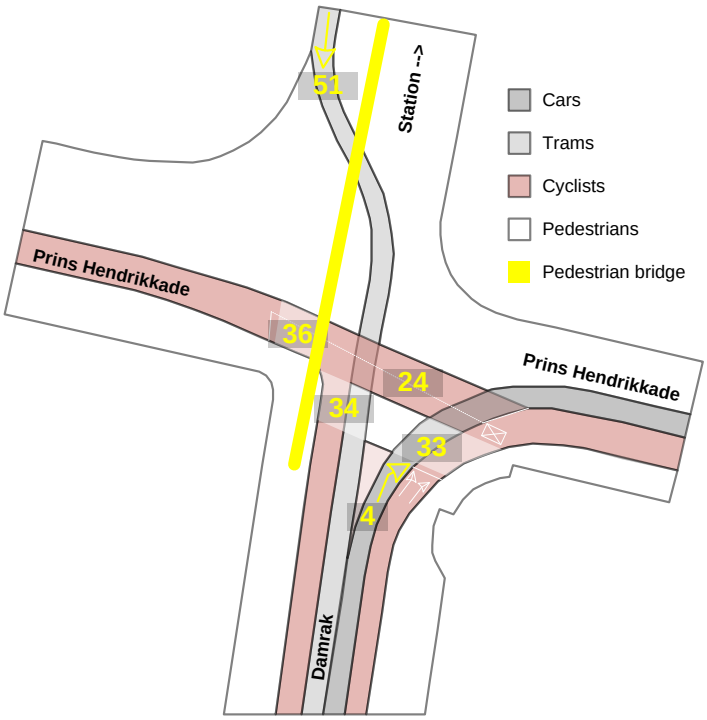

Figure 19 New design of the intersection of Prins Hendrikkade and Damrak including numbers of flows

In Figure 19, the new design of the intersection of Prins Hendrikkade and Damrak is visible, including the numbers of the traffic flows on the intersection. With these numbers, a conflict matrix is made, as visible in Table 5.

Table 5 Conflict matrix of the new design of the intersection of Prins Hendrikkade and Damrak

	04	24	33	34	36	51
04	-	X	X	-	-	-
24	X	-	-	-	X	128
33	X	-	-	-	-	-
34	-	-	-	-	-	128
36	-	X	-	-	-	-
51	-	128	-	128	-	-

The 6 traffic lights in the new design, are much less than the 16 traffic lights in the original design. In particular the number of tram lights are reduced, what gives a reduction for traffic lights for other traffic flows. Traffic light 51 is a result of the traffic flows that use the traffic lights 44, 50, 54 and 55 in Table 3. The combination of these traffic lights gives a total of 131 conflicts in an hour, thus the 128 conflicts in an

hour are a decrease of 2%. Also, in this intersection the number of conflicts due to buses are reduced due to the relocation of the buses, just the touring cars cross the intersection in the new design. Furthermore, the pedestrian bridge reduces the conflict points for the pedestrian crossing with traffic light 36.

However, for both intersections, the type of conflict points has changed: in the original design conflict points occur between public transport and other traffic, and between public transport itself. In the new design, conflict points occur between public transport and slow traffic, but no longer between public transport itself and public transport and motorized vehicles. This means that the type of traffic flows that experience hindrance has been changed.

More space for traffic flows

In the new design, the recommended width of 2.50 m per direction for cyclists is satisfied where possible. Almost all the bicycle paths smaller than 2.50 m are widened. The bicycle paths smaller than 2.50 m per direction go from the intersection of Martelaarsgracht and Prins Hendrikkade to Martelaarsgracht and to the west of Prins Hendrikkade, because there is no space for widening. Furthermore, the adjustments are applied at all the locations where they are recommended by Fietsberaad, so this gives extra space according to the tests done by Fietsberaad.

The reduction of tram tracks gives some extra space for the cycle paths, but most released space is extra space for pedestrians. In particular on the north of the intersection of Prins Hendrikkade and Damrak, there is only one tram track left of the five, so the space of the four eliminated tram tracks is now for pedestrians. Between the two intersections is just a cycle path, the rest of the space is free for pedestrians. Also, the pedestrian bridge ensures extra space for pedestrians. Due to the extra space for pedestrians, the crosswalks are almost everywhere 5.3 m, as recommended in the guidelines. The only crosswalk smaller than 5.3 m, is the crosswalk of Martelaarsgracht towards the area. With a width of 4.4 m, it meets the requirements of the guidelines as long as there is no street furniture.

Reduce the waiting time

In the new design, there is no conflict point between trams itself and between trams and motorized vehicles at the intersections, and there are no buses anymore. Due to the priority of public transport, managed with traffic lights, trams will be able to cross the intersection without interference of other traffic flows. This means that the waiting time in the original design disappears completely.

Since there are more trams at the intersections in the new design compared with the original design and the trams have priority, the waiting time for cyclists and pedestrians will increase, since the number of traffic lights for these flows are only slightly decreased in comparison with the increased number of trams. At the intersection of Prins Hendrikkade and Damrak, pedestrians can use the pedestrian bridge to escape from the other traffic flows and reduce the waiting time of the different traffic flows.

4.2 Tests of the different options

Adjustments of the space for cyclists and pedestrians

The adjustments of the space for cyclists and pedestrians will not change the number of conflict points, since the crossings of the different traffic flows do not change.

The benefit of the adjustments of the space for cyclists and pedestrians is the increase of space for those traffic flows. Images before and after a renovation of an intersection assume the effective change of the interventions. It facilitates the growth of urban bicycle traffic in the coming years, but the boundaries are in sight and the changes are not enough for the future. (CROW-Fietsberaad & Hendriks, 2017)

While using the adjustments of the space for cyclists and pedestrians, the flow will be improved, as stated before. All these changes to use the space more efficient, ensures the increase of capacity and therefore reduce the waiting time.

Combination of trams

The number of conflict points for option 1 and 2 of the combination of trams are the same for the intersection of Martelaarsgracht and Prins Hendrikkade, see Figure 20. The conflict matrix and conclusion are the same as the conflict matrix and conclusion of the test of the options combined, see Figure 18 and Table 4.

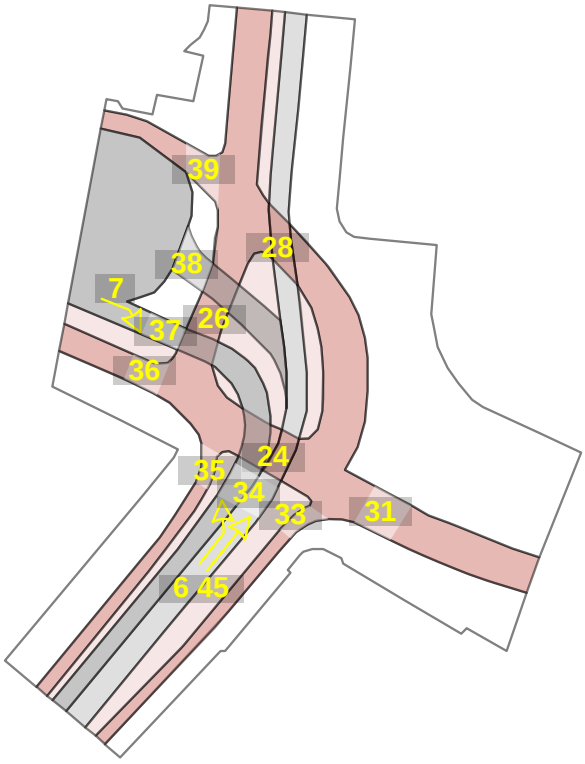

Figure 20 Option of the intersection of Martelaarsgracht and Prins Hendrikkade including the numbers of flows for the combination of trams

The reduction of tram tracks means that there is more space for other traffic flows, in this option the space is used by pedestrians.

Because there is no conflict anymore between trams itself and between trams and motorized vehicles, there is no waiting time for the trams. However, the waiting time for cyclists and pedestrians will increase, since the number of trams increased.

Figure 21 shows the intersection of Prins Hendrikkade and Damrak for option 1. With the numbers of flows, a conflict matrix is made, as shown in Table 6. With the 131 conflicts in an hour in the original design, this gives a decrease of 2%.

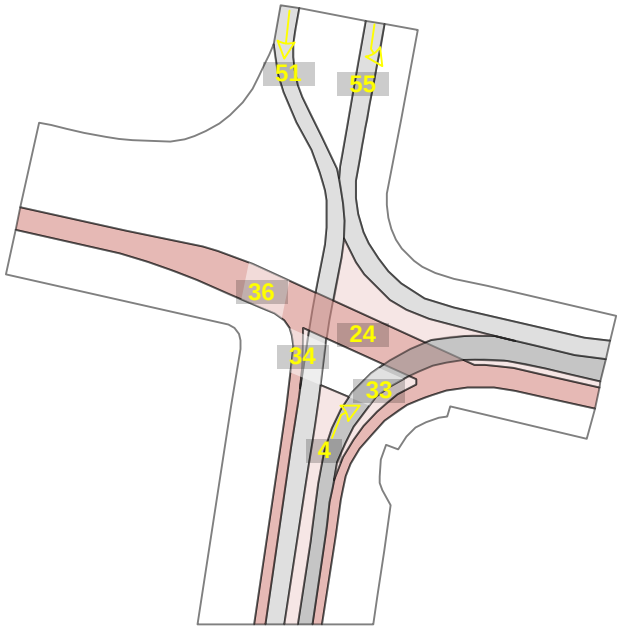

Figure 21 Option 1 of the combination of trams of the intersection of Prins Hendrikkade and Damrak including the numbers of flows

Table 6 Conflict matrix of option 1 of the combination of trams

	04	24	33	34	36	51	55
04	-	X	X	-	-	-	-
24	X	-	-	-	/	128	-
33	X	-	-	-	-	-	-
34	-	-	-	-	-	128	-
36	-	/	-	-	-	-	-
51	-	128	-	128	-	-	-
55	-	-	-	-	-	-	-

The change in space and the waiting time are the same as the intersection of Martelaarsgracht and Prins Hendrikkade, as worked out before.

Figure 22 shows the intersection of Prins Hendrikkade and Damrak for option 2. With the numbers of flows, a conflict matrix is made, as shown in Table 7. This gives the same reduction as option 1.

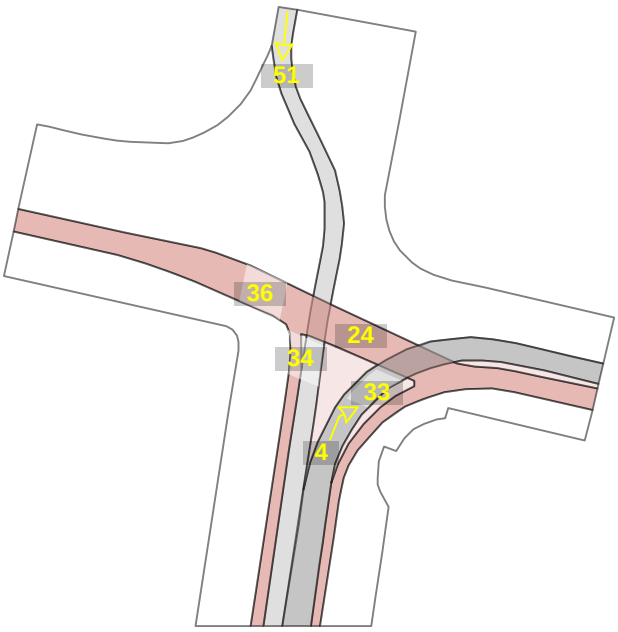

Figure 22 Option 2 of the combination of trams of the intersection of Prins Hendrikkade and Damrak including the numbers of flows

Table 7 Conflict matrix of option 2 of the combination of trams

	04	24	33	34	36	51
04	-	X	X	-	-	-
24	X	-	-	-	/	128
33	X	-	-	-	-	-
34	-	-	-	-	-	128
36	-	/	-	-	-	-
51	-	128	-	128	-	-

The change in space and the waiting time are the same as the intersection of Martelaarsgracht and Prins Hendrikkade, as worked out before.

Split level

Split level will decrease the number of conflict points with the bicycle track, constantly named with traffic light 24, and the tram tracks, because pedestrians can walk via the pedestrian bridge, instead of using the pedestrian crossings at the intersection.

The increased space is in the surface of the pedestrian bridge. So, with this option, only pedestrians will have some extra space.

By using the pedestrian bridge, pedestrians escape from the traffic lights for crossing the bicycle track and tram tracks. This reduces the waiting time of the pedestrians using the bridge to zero, because they do not have conflict points and can move on without hindrance. Besides, pedestrians that do not use the bridge, will experience a reduction in waiting time, because there are less pedestrians using this route.

5 Discussion and conclusion

The test of the combined options by criteria shows that the number of conflicts increases on the intersection of Martelaarsgracht and Prins Hendrikkade with 23% and decreases on the intersection of Prins Hendrikkade and Damrak with 2%, without taking the relocation of the buses. This is far from the wanted decrease of 10% to 15%. However, the conflicts are no longer between public transport itself and between public transport and motorized vehicles, but only between public transport and slow traffic. Furthermore, the needed space for cyclists and pedestrians in the area is achieved, and the waiting time of the trams disappeared. This means that the increased number of trams at the intersections is able to move without hindrance of other public transport of motorized vehicles.

When testing the different options apart from each other, the different criteria are not simultaneously satisfied: for the adjustments of the space, the number of conflict points remain the same, but use the space and waiting time are improved. For the combination of trams, the criteria change almost in the same way as they do at the combined options, but a little less in the good way because there is less change than in the combined options. When implementing the split level, all the criteria are changed a little in the good way, but there is less change than in the combined options.

At the moment, adjusting intersections costs on average 80,000 euros for the implementation itself. This is without moving traffic lights and tramway stands. (CROW-Fietsberaad & Hendriks, 2017) However, in the design there are only some traffic lights and tramway stands removed so this will not increase the implementation costs enormous.

So, to regulate the traffic flows to reduce the traffic conflicts, the design with the combined options can be implemented. The change of 22 July is to recover the area, but this design is a step further for a change of the area. The most expensive part of the design is the pedestrian bridge, but the choice can be made to test this concept with a temporary bridge. If the concept works, a beautifully designed bridge can be placed as landmark of the area, for example made of glass or sustainable materials. Because of the advantages and disadvantages of the design, an important choice should be made on the degree of importance to have more space for cyclists and pedestrians over public transport. This is a choice for the municipality of Amsterdam, because it is an integral choice for the design of the city to be able to connect the whole network of the city.

However, care must be taken that the increased space for cyclists and pedestrians could result in an increase of cyclists and pedestrians in the area. The consequence of this should be investigated.

If the whole design is implemented, the number of trams needed according to GVB is reached and able to move without hindrance, and there is more space for cyclists and pedestrians. However, the waiting time for cyclists and pedestrians will increase.

Recommendations for a follow-up study would be, next to investigating the consequence of the increased space for cyclists and pedestrians, to make traffic counts to be able to make a more integral study. Furthermore, the study can be extended with the routes of the tram outside the area, because of the changes of the route of the trams in the area. Also, a study can be done to the planning of the underground, with the bicycle parking facility, metro and routes to the metro, it can be investigated how this spacious planning can be improved. Finally, a more detailed research can be done to the requirements due to the World Heritage List, since the canal belt is a heritage.

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Appendix

Appendix A Guidelines of the start document

The guidelines of the Start Document are made for the final work of the Bachelor. It gives an insight on the learning goals and strategy of the thesis. A schedule is made to have an overview over the weeks wherein the project is executed.

Learning goals

My two main goals are writing in English and writing on my own. By writing in English, I want to improve my English writing skills and vocabulary. Writing on my own is for me a chance to show what my personal skills are in writing a thesis and structuring it. I like to work in a structured way, and therefore I am motivated to show this in this project, with the help of the structure given by the project itself in the form of deadlines. The choice for the subject of the project comes from personal motivation: I am interested in the Master Transport & Planning because of my interest in transport networks. At the Central Station of Amsterdam, it is striking for me that the area is very crowded, and users are irritated while crossing the area. I want to help changing this, so the space of the area will be used more efficiently.

Strategy

The goals, objectives and work done will be reported in the form of the following chapters.

Preface

Summary

1 *Introduction*

1.1 Background and problem: the area of the project, the problem definition, the context of the projects and the resources and constraints.

1.2 Main question and key questions: how can the traffic flows of trams, cyclists and pedestrians be regulated to reduce traffic conflicts? Detailed area description, problem definition, crossing traffic flows, designs to reduce the conflict points and testing the designs on criteria

1.3 Method: create designs to regulate the traffic flows, and form criteria to test these designs.

1.4 Structure description

2 *Crossing traffic flows:* The chapter contains information about the crossing traffic flows in the area for the different modalities

2.1 Conclusion on the crossing traffic flows: Conclusion on the data of the crossing traffic flows; issues and effects that occur due to the crossing traffic flows, conflict matrices

2.2 Criteria of the designs

3 *Options to reduce the conflict points:* The chapter contains the different designs to reduce the conflict points due to the different crossing traffic flows, based on the conclusion in chapter 2

3.1 Discussion of the combined options

4 *Testing the designs by criteria:* In the chapter are the different designs tested by criteria

5 *Discussion and conclusion*

Bibliography

Appendix

Schedule

Month	Week / days	Appointments and deadlines	Work load
April	17, 4.1 / 23-29	23. 10:45 – 12:00 Kick-off, 2.72 27. 16:00 Detailed work plan	Choosing the subject of the BEP Working on the detailed work plan Write the problem definition Make reviews on all other students' work
May	18, 4.2 / 30-06	30. 16:00 Review on all other students' work 01. 13:00 Meeting, 4.02.1 04. 16:00 Methodology & Design approach	Prepare for the meeting Process the results of the meeting Write the detailed area description Work on the methodology & design Start thinking of criteria Start on describing the crossing traffic flows Make reviews on other students' work
	19, 4.3 / 07-13	07. Review on students' work of Lars Heijenrath and Mees Poppe 08. 13:00 Meeting, 2.38	Prepare for the meeting Process the results of the meeting Prepare for the midterm presentation Work on the text for introduction & proposal for contents Describe the crossing traffic flows Work out the criteria Start working on designs
	20, 4.4 / 14-20	15. 13:00 Midterm presentation, 2.66 17. 16:00 Draft text for Introduction & proposal for contents 18. 16:00 Review on students' work of Mees Poppe and Lara Witte	Work on the text for introduction & proposal for contents Continue working on designs Make reviews on other students' work
	21, 4.5 / 21-27	22. 13:00 Meeting, 4.02.1 25. 16:00 Preliminary results for report	Prepare for the meeting Process the results of the meeting Work on the preliminary results Test designs on criteria
June	22, 4.6 / 28-03	29. 13:00 Meeting, 4.02.1 01. 16:00 Draft Summary	Prepare for the meeting Process the results of the meeting Work on the summary Make reviews on other students' work Prepare for the presentation & elevator pitch
	23, 4.7 / 04-10	04. 16:00 Review on students' work of Lara Witte and Lise Andringa 05. 13:00 Presentation & elevator pitch: conclusions, subsequent discussion, 5.09	Prepare for the presentation & elevator pitch
	24, 4.8 / 11-17		Work on the final report
	25, 4.9 / 18-24	20. 16:00 Final report (digital version and 2 hard copies) with plagiarism scan 22. 16:00 Self-evaluation	Work on the final report Work on the self-evaluation Prepare the final presentation
July	26, 4.10 / 25-01	26. 13:00 Final presentation, 2.72	Prepare the final presentation
	27, 4.11 / 02-08	02. 16:00 (if relevant) Addition	

Appendix B Context of the project

The most important stakeholder is the municipality of Amsterdam. The municipality is responsible for the area and client of such projects. Due to this, the municipality is investor of the project and therefore has a high interest on the progress and outcome of the project.

Another important stakeholder is het GVB, the municipal transport company in Amsterdam, especially for the trams in this project. The company want to realize the frequency that they planned for to be able to provide a good public transportation in Amsterdam.

Furthermore, the road users are important, especially the cyclists and pedestrians. They are going from and to the Station or use the network around the Station to get to their destination.

Finally, business owners should be considered. The business owners in the area are quite different, there are restaurants, shops, tour boat companies and hotels. All these owners want their company to be able to run and therefore they have some interest in the project.

Appendix C Resources and constraints

A possible reference project to use, is the area of the Central Station in Rotterdam. The station and area around it are recently handled drastically, including the routes of the traffic flows. This is done to handle the growing number of travellers each day. To make a safe crossing for pedestrians at the station square, car traffic is brought to the underground by a tunnel. (COB, 2018)
Another reference project is the area of Delft Station. The zone around the station will only be for destination traffic. The different traffic flows are split by split level: on ground level there are tracks and roads for public transport such as trams, buses and taxis. For cars, there is only a road for kiss ‘n ride. Underneath ground level, bicycle parking facilities are located with access routes to it. Finally, underneath the bicycles, there is a level for trains and car parking. By using split level, the different traffic flows have been pulled apart for safety. (SpoorzoneDelft, 2018)

As resource, information from Internet will be used, such as the website of the municipality of Amsterdam and websites from contractors of the current project “De Entree".
Furthermore, there will be asked for the expertise and experience of the supervisors Rolf Koster and Yufei Yuan and managers in the project “De Entree" of Amsterdam; Bart-Jan Kouwenhoven and Peter Mooij. The last one is contract manager in the current project and will be asked for data of the amount of people in the area. If it is not possible to obtain data, the overview of the crossing traffic flows will be made on a more estimating kind of way, by describing the routes of the traffic flows and the conflict points that originate due to these traffic flows.

Appendix D Frequency of tram-, bus- and metro lines

At the moment, there are different clusters of trams, buses and metros around the Central Station:

- Cluster T1: tram lines 1, 2, 5, 13 and 17 enter and leave through Martelaarsgracht
- Cluster T2: tram lines 4, 9, 16 and 24 enter and leave through Damrak
- Cluster T3: tram line 26 enter and leaves through De Ruijterkade via Stationsplein
- Cluster B1: bus lines 18, 21 and 22 enter and leave through the west of Prins Hendrikkade

- Cluster B2: bus lines 22 enters and leaves through the east of Prins Hendrikkade. Bus lines 32, 33, 34, 35, 48, 301, 304, 306, 307, 308, 312, 314, 315, 316, 319, 391, 392 and 394 enter and leave at the back of Central Station, and therefore they do not pass the area in front of the Central Station
- Cluster B3: bus lines 48 and 248 enter and leave through the west of De Ruijterkade, and therefore will not pass the area in front of the Central Station
- Cluster M1: metro lines 51, 53 and 54 enter and leave in the underground at the subway station in front of the Central Station in the direction of Nieuwmarkt

When the Noord-Zuidlijn, metro number 52, starts its service, a lot of lines of the public transport in Amsterdam will change. For this thesis, the changes are considered next to the current situation, to be able to get an overview of the public transport after all the renovations.

The clusters of the trams, buses and metros around the Central Station will be as follows: (GVB Amsterdam, 2018b; GVB Amsterdam & Carto Studio BV, 2018)

- Cluster T1: tram lines 2, 11, 12, 13 and 17 enter and leave through Martelaarsgracht
- Cluster T2: tram lines 4, 14 and 24 enter and leave through Damrak
- Cluster T3: tram line 26 enter and leaves through De Ruijterkade via Stationsplein
- Cluster B1: bus lines 18, 21, 22, 48 and 248 enter and leave through the west of De Ruijterkade, and therefore will not pass the area in front of the Central Station
- Cluster B2: bus lines 22, 48, 305, 306, 314, 316, 391 and 394 enter and leave through the east of De Ruijterkade, and therefore will not pass the area in front of the Central Station
- Cluster M1: metro lines 51, 53 and 54 enter and leave in the underground at the subway station in front of the Central Station in the direction of Nieuwmarkt
- Cluster M2: metro line 52 enters and leaves in the underground at the subway station in front of the Central Station in the direction of Rokin

This means, that clusters T1, T2, T3, M1 and M2 will pass through the area in front of the Central Station, after 22 July, and buses will no longer pass through the area. (Gemeente Amsterdam, 2018b) Per cluster, the sum of the frequency of the lines will be listed.

Cluster T1

In Table 8, the frequency of tram lines 1, 2, 5, 13 and 17 is worked out. These trams enter and leave the area of the Central Station through Martelaarsgracht. The frequency of the tram lines come from the timetable of GVB.

In Table 9, the frequency of tram lines 2, 11, 12, 13 and 17 is worked out. These trams will enter and leave through Martelaarsgracht after 22 July. Tram line 11 will be new, and therefore the precise frequency is not available yet. However, at the telephone GVB could tell that there will be a tram every 7.5 minute between 12 am and 8 pm during the week, and every 10 minutes between 12 am and 8 pm in the weekends. The information of the frequency of the other tram lines come from the timetable of GVB, where the timetables of tram lines 2, 13 and 17 remain unchanged, and from the timetable of tram line 12 is held that the frequency remains unchanged while the route will change on 22 July.

In Table 10, the maximum number of trams/hour in the cluster are given, based on Table 8 and Table 9.

Table 8 Frequency of tram lines 1, 2, 5, 13 and 17 – before 22 July [trams/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays	Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	3	3	0	0
6 7	22	22	12	0
7 8	38	38	20	12
8 9	50	50	20	20
9 10	44	44	31	24
10 11	40	40	38	35
11 12	40	40	43	41
12 13	40	40	46	44
13 14	41	41	49	44
14 15	45	45	50	44
15 16	46	46	51	44
16 17	48	48	52	44
17 18	48	48	51	44
18 19	44	44	47	43
19 20	40	40	45	38
20 21	35	36	37	32
21 22	27	30	30	24
22 23	27	30	30	24
23 00	27	30	30	24
00 01	19	21	22	18

Table 9 Frequency of tram lines 2, 11, 12, 13 and 17 – after 22 July [trams/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays	Thursdays	Fridays	Saturdays	Sundays, Holidays
5 6	4	4	4	0	0
6 7	19	19	19	10	0
7 8	30	30	30	16	11
8 9	36	36	36	17	16
9 10	33	33	33	23	18
10 11	32	32	32	28	24
11 12	32	32	32	31	27
12 13	40	40	32	38	35
13 14	41	41	33	39	35
14 15	42	42	34	40	35
15 16	42	42	34	39	35
16 17	44	44	36	40	35
17 18	44	44	36	40	35
18 19	40	40	32	39	34
19 20	38	38	30	37	32
20 21	24	24	24	23	21
21 22	19	20	20	20	16
22 23	19	20	20	20	16
23 00	19	20	20	20	16
00 01	13	14	14	15	12

Table 10 Maximum number of trams/hour for cluster T1

Cluster T1		Time of the day	Maximum number of trams/hour
Before 22 July	During the week	8 am – 10 am 2 pm – 7 pm	100 96
	On weekends	12 am – 8 pm	104
After 22 July	During the week	8 am – 9 am 12 am – 8 pm	72 88
	On weekends	12 am – 8 pm	80

Cluster T2

In Table 11, the frequency of tram lines 4, 9, 16 and 24 is worked out. These trams enter and leave the area of the Central Station through Damrak. The frequency of the tram lines come from the timetable of GVB.

In Table 12, the frequency of tram lines 4, 14 and 24 is worked out. These trams will enter and leave through Damrak after 22 July. The information of the frequency of the tram lines come from the timetable of GVB, where the timetables of tram lines 4 and 24 remain unchanged, and from the timetable of tram line 14 is held that the frequency remains unchanged while the route will change on 22 July.

In Table 13, the maximum number of trams/hour in the cluster are given, based on Table 11 and Table 12.

Table 11 Frequency of tram lines 4, 9, 16 and 24 – before 22 July [trams/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays	Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	1	1	0	0
6 7	15	15	4	0
7 8	26	26	16	6
8 9	28	28	16	16
9 10	27	27	21	18
10 11	28	28	24	19
11 12	28	28	27	25
12 13	29	29	32	28
13 14	30	30	32	26
14 15	30	30	32	28
15 16	29	29	31	28
16 17	32	32	32	28
17 18	32	32	32	28
18 19	29	29	29	25
19 20	24	24	26	20
20 21	19	20	22	18
21 22	16	17	17	16
22 23	16	17	17	16
23 00	16	17	17	16
00 01	11	12	12	11

Table 12 Frequency of tram lines 4, 14 and 24 – after 22 July [trams/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays	Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	1	1	0	0
6 7	12	12	5	0
7 8	18	18	12	6
8 9	20	20	12	12
9 10	20	20	14	12
10 11	20	20	18	14
11 12	20	20	20	18
12 13	20	20	22	20
13 14	20	20	22	20
14 15	20	20	22	20
15 16	20	20	22	20
16 17	22	22	22	20
17 18	22	22	22	20
18 19	20	20	21	17
19 20	16	16	20	14
20 21	12	13	16	13
21 22	12	13	13	12
22 23	12	13	13	12
23 00	12	13	13	12
00 01	8	9	8	7

Table 13 Maximum number of trams/hour for cluster T2

Cluster T2		Time of the day	Maximum number of trams/hour
Before 22 July	During the week	1 pm – 6 pm	64
	On weekends	12 am – 6 pm	64
After 22 July	During the week	8 am – 7 pm	40
	On weekends	11 am – 7 pm	44

Cluster T3

In Table 14, the frequency of tram line 26 is worked out. The information of the frequency of the tram line comes from the timetable of GVB, where the timetable remains unchanged after the changes on 22 July.

In Table 15, the maximum number of trams/hour in the cluster are given, based on Table 14.

Table 14 Frequency of tram line 26 [trams/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays	Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	1	1	0	0
6 7	6	6	1	0
7 8	12	12	6	3
8 9	15	15	6	6
9 10	11	11	7	6
10 11	10	10	8	6
11 12	10	10	10	9
12 13	10	10	10	10
13 14	10	10	10	10
14 15	10	10	10	10
15 16	11	11	10	10
16 17	15	15	10	10
17 18	15	15	10	10
18 19	14	14	10	8
19 20	11	11	10	8
20 21	8	9	8	7
21 22	6	8	8	6
22 23	6	8	8	6
23 00	6	8	8	6
00 01	4	6	6	4

Table 15 Maximum number of trams/hour for cluster T3

Cluster T3	Time of the day	Maximum number of trams/hour
During the week	8 am – 9 am 4 pm – 7 pm	30 30
On weekends	12 am – 6 pm	20

Cluster B1

In Table 16, the frequency of bus lines 18, 21 and 22 is worked out. These buses enter and leave the area of the Central Station through the west of Prins Hendrikkade. The frequency of the bus lines come from the timetable of GVB.

In Table 17, the maximum number of buses/hour in the cluster are given, based on Table 16.

Table 16 Frequency of bus lines 18, 21 and 22 – before 22 July [buses/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	0	0	0
6 7	13	4	0
7 8	22	12	4
8 9	22	12	12
9 10	21	14	15
10 11	20	16	14
11 12	20	19	16
12 13	20	19	18
13 14	20	19	18
14 15	20	19	18
15 16	21	19	18
16 17	21	19	18
17 18	23	19	18
18 19	20	19	18
19 20	21	18	18
20 21	14	17	16
21 22	14	14	14
22 23	14	14	13
23 0	14	14	14
0 1	10	10	11

Table 17 Maximum number of buses/hour for cluster B1

Cluster B1	Time of the day	Maximum number of buses/hour
During the week	7 am – 10 am 3 pm – 8 pm	44 46
On weekends	11 am – 8 pm	38

Cluster B2

In Table 18, the frequency of bus line 22 is worked out. The bus enters and leaves the area of the Central Station through the east of Prins Hendrikkade. The frequency of the bus lines come from the timetable of GVB.

In Table 19, the maximum number of buses/hour in the cluster are given, based on Table 18. However, for the counting of number of buses, this is not included, because this bus comes from the west of the area in cluster B1 and is therefore already included for the counting of the number of buses.

Table 18 Frequency of bus lines 22 – before 22 July [buses/hour/direction]

	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	0	0	0
6 7	4	2	0
7 8	7	4	2
8 9	7	4	4
9 10	7	5	4
10 11	6	6	4
11 12	6	6	5
12 13	6	6	6
13 14	6	6	6
14 15	6	6	6
15 16	6	6	6
16 17	7	6	6
17 18	8	6	6
18 19	6	6	6
19 20	6	6	6
20 21	4	5	5
21 22	4	4	4
22 23	4	4	4
23 0	4	4	4
0 1	3	3	3

Table 19 Maximum number of buses/hour for cluster B2

Cluster B2	Time of the day	Maximum number of buses/hour
During the week	7 am – 10 am 4 pm – 7 pm	14 16
On weekends	11 am – 6 pm	12

Cluster M1

In Table 20, the frequency of the metro lines 51, 53 and 54 is worked out. The information of the frequency of the metro lines come from the timetable of GVB, where the timetable remains unchanged after the changes on 22 July.

In Table 21, the maximum number of metros/hour in the cluster are given, based on Table 20.

Table 20 Frequency of metro lines 51, 53 and 54 [metros/hour/direction] (GVB Amsterdam, 2018a)

	Mondays, Tuesdays, Wednesdays, Thursdays, Fridays	Saturdays	Sundays, Holidays
5 6	0	0	0
6 7	16	6	0
7 8	23	12	6
8 9	24	12	12
9 10	22	12	12
10 11	18	18	18
11 12	18	18	18
12 13	18	18	18
13 14	18	18	18
14 15	18	18	18
15 16	23	18	18
16 17	24	18	18
17 18	24	18	18
18 19	22	18	18
19 20	18	18	18
20 21	18	18	18
21 22	18	18	18
22 23	12	12	12
23 0	12	12	12
0 1	9	9	9

Table 21 Maximum number of metros/hour for cluster M1

Cluster M1	Time of the day	Maximum number of metros/hour
During the week	7 am – 10 am 3 pm – 7 pm	48 48
On weekends	10 am – 10 pm	36

Cluster M2

During rush hours, there will be 12 metro's per hour in metro line 52, which means that there will be a metro every 5 minutes in every direction. (Vaillant, 2015)

In Table 22, the maximum number of metros/hour in the cluster are given.

Table 22 Maximum number of metros/hour for cluster M2

Cluster M2	Time of the day	Maximum number of metros/hour
During the week	Ca. 7 am – 10 am Ca. 3 pm – 7 pm	12 12
On weekends	Ca. 10 am – 10 pm	12