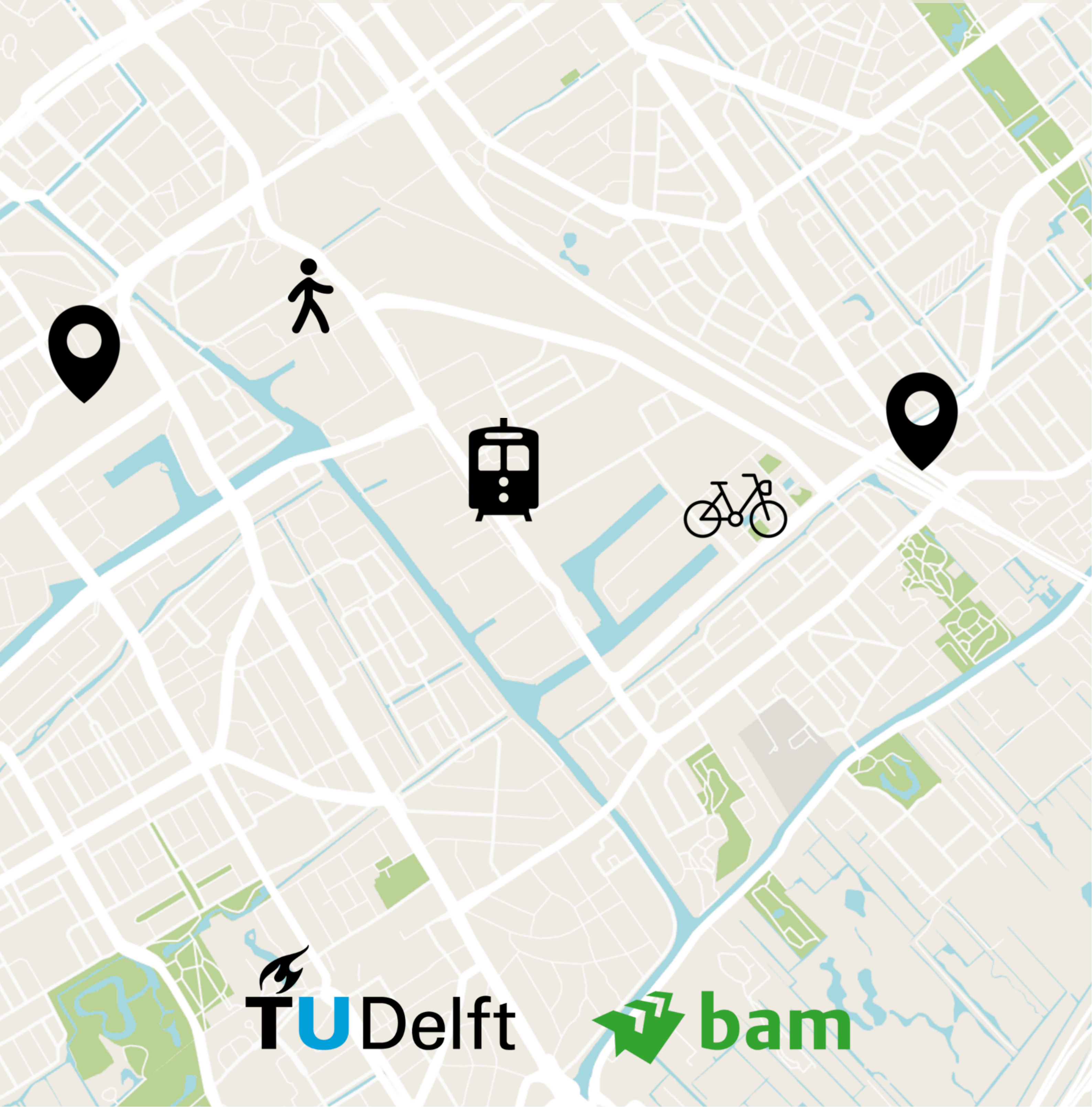
Designing an integrated bicycle-transit network

Development of a design approach and a network design for the case study Binckhorst, The Hague

S.V. Geurts



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by

S.V. Geurts

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Preface

This thesis is the result of my graduation internship at BAM Infraconsult, which is the final step to complete the Master of Science in Transport, Infrastructure and Logistics at the Delft University of Technology. Working on this project for the past ten months has been a challenging experience, which I could not have done without the help and support I got from many people along the way.

First of all, I would like to thank my graduation committee. Niels, thank you for introducing me to this topic and for your enthusiasm about my research. Your advice, both about the content and about the graduation process itself, has helped me a lot. You always made time to discuss my progress or the obstacles I ran into. Wijnand, thank you for your critical eye and feedback during the meetings we had. From the first moment, your feedback was very clear, which helped me to focus on the right things. A special thanks should go to Danique, who joined my thesis committee at exactly the right time. Your positive feedback and structured way of thinking helped me a lot when I got lost. Thank you for giving me confidence when I needed it.

Secondly, I would like to thank Sander and Marc for providing me with the opportunity to conduct this research at BAM Infraconsult. I enjoyed my time as an intern in the BAM Infraconsult office, which unfortunately ended earlier than planned due to COVID-19. Sander, thank you for introducing me to many people during my research. Your enthusiasm for research into stimulating cycling, made it extra fun for me to be able to contribute to this. Marc, thanks for carefully reading my work many times and for always making time for me when I had questions. I really appreciate it that you continued to gave me feedback until the last moment, even when this was in your free time.

Then, I would like to thank my parents for taking care of me in the last weeks of this process, during the outbreak of COVID-19. I enjoyed the time I spent with you, and all the good care and advice you gave me, which helped me a lot during the final stages of my thesis.

Lastly, my loving appreciation goes out to Olivier, who believed in me when I did not. Without you, writing this thesis would have been much more difficult. Thank you for listening to me when I needed to clear my mind and assuring me again and again that everything would be fine in the end.

Simone Geurts
Delft, June 2020

Designing an Integrated Bicycle-Transit System

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***Abstract*— The increasing urbanisation leads to more traffic movements in cities. Since car traffic in particular has a negative impact on the livability in the city, an alternative for car travel should be investigated to discourage car use. A possible alternative for car could be the integrated bicycle-transit mode. Although more and more research is being conducted on shared bicycle systems and the combination with public transport, there is still no clear approach to design such an integrated system. The aim of this research was to develop a design approach for bicycle-transit, and subsequently this approach was applied to a case study. First, a spatial multi-criteria analysis was used to find suitable locations for shared bicycle docking stations. Secondly, an assessment framework was drawn up to determine the indicators on the basis of which different network designs were assessed. Finally, traveller flows have been investigated to analyse several alternative network designs. From this research, is was concluded that the optimal network for the case study Binckhorst in The Hague consists of four shared bicycle stations and a tram line between the train stations Den Haag CS and Voorburg.**

Keywords: Shared bicycles, Public transport, Network design, Design approach, Bicycle-transit

I. Introduction

Worldwide, an increase in urbanisation can be observed. This is also the case for Dutch cities, and the prognosis for the next 25 years is that even more people will be living in cities. This will lead to more traffic movements, which negatively influences the livability of the city. Therefore the challenge is to keep cities liveable despite this increase in traffic. An alternative for car use should be investigated, as cars require a lot of space while this space in cities is scarce. On top of that, cars have other disadvantages since they cause traffic congestion and air pollution. There should be looked for alternative modes that efficiently use the public space such as walking, cycling, and public transport [1].

However, there is no single mode that is able to compete to the car. The car provides high-speed door-to-door transport, where public transport only provides high-speed travel while cycling and walking offer the door-to-door accessibility without requiring parking space. Combining train and tram with cycling results in a system with high speed and high accessibility, making it competitive with the car [2, 3]. This synergy will only appear when both modes are integrated sufficiently [4]. An effective integration of bicycle-transit services will result in increased efficiency of transit and increased cycling demand [5]. The combination of bicycle and transit has increasingly drawn attention in recent research, as a proposed solution to reduce the negative consequences of urban mobility. Policy makers are interested in encouraging cycling, as it is a healthy and cheap way of transport, which in urban areas provides faster transport than other modes as it can avoid traffic jams [6]. Still, most of the research previously conducted focused on either public transport network design [7, 8], cycling network design [9] or bicycle sharing systems [10, 11]. There is no research yet conducted that focuses on a design approach for an integrated bicycle-transit system. Therefore, this research aims at developing a structured approach to design and evaluate an integrated bicycle-transit system. This approach was applied to a case study in The Hague, the Binckhorst. Besides developing a design approach, the second goal of this study was to design an integrated bicycle transit network for this area. This research was performed to find an answer on the question:

Which approach should be used to design an integrated bicycle-transit network and how should this design look like?

As a case study for this research, the former industrial district Binckhorst in The Hague was chosen. In recent years, a start has been made on a complete redevelopment of this area. The Binckhorst is going to be transformed into a lively mixed urban area where people live and work. Since the emphasis will be on the livability of the city and the quality of the public space and thus limiting the traffic nuisance, there will be less investment in cars in the area in favour of walking, cycling, public transport and new forms of (shared) mobility.

Previous research stated that 47% of the train users in the Netherlands uses the bicycle for access while only 12% of the travellers uses the bicycle for egress [2]. Most travellers do not have a bicycle available for their egress trip. This can be solved by offering shared bicycles. According to Lee et al. (2015), people prefer electric bicycles as they are easier to use and more comfortable [12, 13]. The transit that was analysed in this study contained train and tram, because research into the case study area had shown that a (high-quality) bus connection does not provide sufficient capacity for future traveller demand in the Binckhorst [14].

II. Research methodology

The research question in this study was twofold. The first question was how an integrated network should be designed, and the second question was about how this design should look like. The methodology used for this research was also divided into two parts. The first method was used to obtain different integrated network designs by use of a spatial multi-criteria analysis. This method was used to find potential locations for the bicycle docking stations in combination with different spatial development scenarios and transit networks. The second part of the research was performed to evaluate these integrated network designs, by use of an assessment framework. A passenger flow model was constructed for analysing the traffic flows on the networks. The following subsections will explain the application of these methods.

A. Spatial multi-criteria analysis

The shared e-bikes have to be picked up and parked in docking stations where their batteries will be charged. The location of these docking stations is an important element for the success of a shared bike system, because the location has a major influence on the number of travellers using the system. [10]. Accordingly, the first step in this research was to figure out which locations are suitable for these shared e-bike docking stations, in combination with different public transport network designs. The method that was used to determine these potential locations was a spatial multi-criteria analysis (SMCA). A multi-criteria analysis (MCA) is a systematic method for the comparison of different alternatives, that is able to integrate goals, objectives, spatial data and stakeholder preferences in a systematic method [15]. The combination of criterion scores and weights that represent decision makers' preferences can be expressed in a weighted linear calculation as the suitability index S. This is the sum of the preference weights w_i and criterion values x_i (see Eq. 1):

$$S = \sum w_i x_i \tag{1}$$

The criterion scores e for I criteria over J alternatives can be expressed as the evaluation matrix E (Eq. 2) and can be combined with the preference weight vector W (Eq. 3).

$$E = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix} \tag{2}$$

and

$$W = (w_1, w_2, ..., w_I), \qquad \sum_{i=1}^{I} w_i = 1 \tag{3}$$

This results in the weighted linear combination expressed in Eq. (4).

$$\begin{bmatrix} s_1 \\ \vdots \\ s_I \end{bmatrix} = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix} * \begin{bmatrix} w_1 \\ \vdots \\ w_I \end{bmatrix} \tag{4}$$

This weighted linear combination was integrated in a geographic information system (GIS) by use of raster-based spatial analysis to enable spatial multi-criteria decision making [16].

The first step in the SMCA was to define the criteria that influence the potential of locations for a bicycle docking station. From the literature review, three main factors were found to be relevant for the docking station locations: the cycling network, the public transport network and the built environment. For the cycling network, it was assumed that only the density of the cycling network was important for this study, which was calculated by the distance from each location to the nearest cycling paths. For public transport, also the distance to stops or stations was included. The level of service was found to be influencing the location potential as well, so this was incorporated in the SMCA by use of weights for different stations or stops. The train stations that were included are Den Haag Centraal, Den Haag HS and Voorburg. Both a scenario with a potential tram line, and a scenario without this potential tram line were analysed.

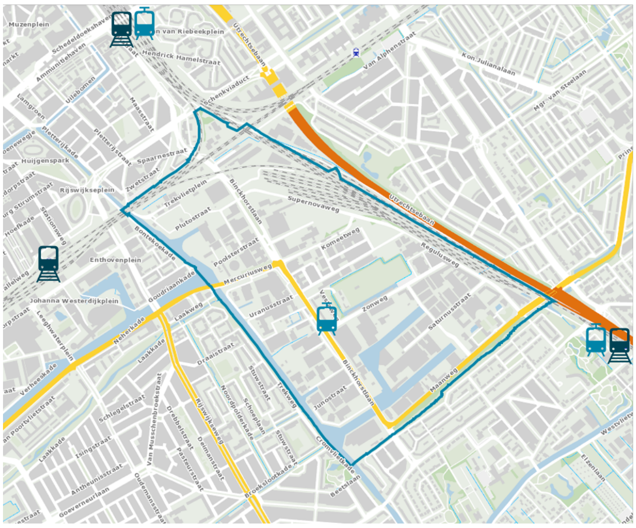

Fig. 1: Map of the case study area, including train stations (dark blue) and potential tram stop (light blue)

Seven different functions are distinguished for the buildings: residential, education, offices, shops, recreation, health care and industrial/other. The first six building types were obtained from literature, the last function was added because of some buildings did not fit any category. Table I shows the included criteria in the MCA and their corresponding units. For each of the criteria, the distance to the potential docking station location was calculated and for the buildings also the surface was included.

TABLE I: Factors MCA and measurement units

Factor	Measurement unit
Cycling network	distance [m]
Public transport stops	distance [m]
Residential buildings	distance [m] and surface [m^2]
Offices	distance [m] and surface [m^2]
Shops	distance [m] and surface [m^2]
Education	distance [m] and surface [m^2]
Health care	distance [m] and surface [m^2]
Recreation	distance [m] and surface [m^2]
Other/industrial	distance [m] and surface [m^2]

Secondly, the weights had to be determined. To include the stakeholder perspectives in the multi-criteria analysis, several stakeholders were asked to assign weights to the criteria. Different people representing the traveller, the municipality, the operator of the tram and shared bicycles and the developer of the Binckhorst were questioned. The Analytic Hierarchy Process was used to assign these weights. A weight for each criterion was determined according to a pairwise comparison of the criteria [17]. This resulted in a pairwise comparison matrix. To obtain the normalised relative criteria weights from this matrix, all elements were divided by the sum of its column. This results in the normalised relative weight matrix, in which the sum of each column is equal to 1. Finally, by averaging the rows of this matrix, the criteria weight vector was calculated (Eq. 5).

$$w_i = \frac{\sum_{k=1}^{n} \overline{a_{ik}}}{n} \tag{5}$$

Since this vector was normalised, the weight values sum up to 1, and this vector shows the relative weights for the criteria that were compared.

For this study, the sample of stakeholders was very small since there were only nine respondents. Therefore this sample was not representative, however it was useful to get an indication of the different stakeholder perspectives. This sample could be more elaborated when it would be applied to another study. In this study, the average of these weight sets was calculated and used, since the sample was too small to analyse the different stakeholders separately. Table II presents the final weights that were used in this study. These weights correspond to the expectations based on the literature. As bicycle and public transport could complement each other, it is especially important that the bicycles will be located close to public transport [18]. According to Shelat et al. (2018) [4], the combined bicycle-transit mode will be mainly attractive to commuters, which explains that both residential and offices have high weights (21% and 27% respectively).

For the criterion scores, spatial data was collected from the open source PDOK and the Kadaster [19]. This was used to calculate the distance to buildings. The surface was included as the traffic generation, that was calculated by use of traffic generation indicators from CROW [20]. For each building type, a number of traffic movements per m^2 per day was given.

For the land use, two scenarios were included. The expected scenario was based on current development plans of the municipality and land-use developers [21]. For the expected scenario, hypothetical buildings were added. The locations of these buildings were based on the availability of space and the size and function was based on the existing plans. This provided insight into the influence of the land use development on the docking station locations and enables decision making for different futures. Also, different transit network plans were evaluated. The two options that are considered are the existing train network with or without a tram connection via Den Haag Centraal to Voorburg.

TABLE II: Final set of weights for the SMCA

Importance of the distance to:	
Cycling network	21%
Public transport	45%
Buildings	34%
	100%
Importance of public transport:	
Den Haag CS	48%
Den Haag CS	29%
Voorburg	14%
Potential tram stop	9%
	100%
Importance of building types:	
Residential buildings	21%
Education	10%
Offices	27%
Shops	12 %
Recreation	10%
Health care	11%
Other/industrial	10%
	100%

To conduct the spatial multi-criteria analysis in GIS, the case study area was divided into a grid of 50 metres by 50 metres. Each criterion was represented in a new layer, as illustrated in Figure 2. For all criteria, the criteria scores were classified to a score between 0 and 4 to make the criteria comparable. For each cell in the grid, a score between 0 and 4 was assigned for each criterion. By use of the weights, the total score for each cell was calculated.

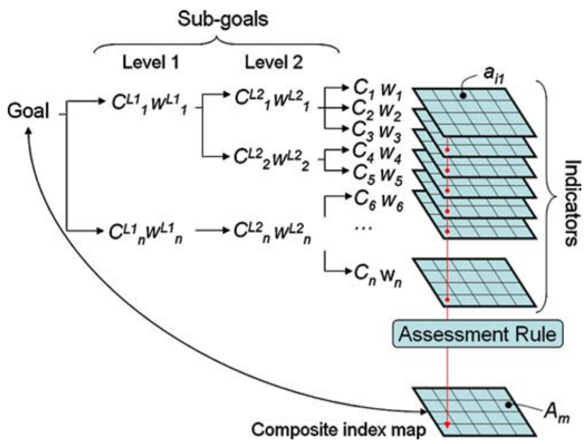

Fig. 2: Schematic representation of the calculation of a spatial multi criteria analysis [22]

The final scores for all cells was presented in a heat map, for the four different scenarios (Figure 3). These heat maps show the shared-bike potential of each location. From these heat maps it can be concluded that the shared-bicycle potential on the north of the area is the lowest. This has two reasons. Firstly, the two most important train stations are located in the north, which leads to higher scores in the north since these locations are too close to the train station for a bicycle docking station. Secondly, there were relatively few buildings located in the north. Furthermore it can be noticed

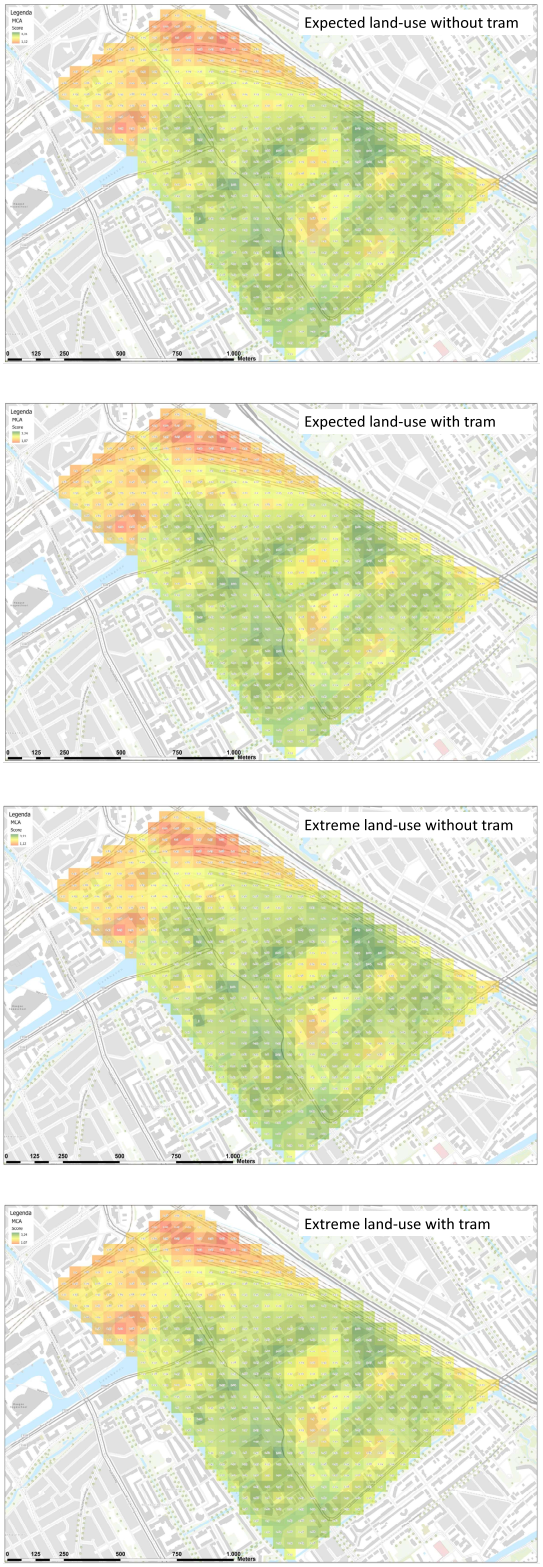

Fig. 3: Final heat maps, resulting from the spatial multi-criteria analysis in GIS

that in the scenario with tram, a higher maximum score was achieved than in the scenario without tram. Logically, in the extreme scenario the scores had increased around the new added buildings.

These heat maps were used to select the final bicycle locations. Based on the number of inhabitants, the required number of bicycle docking stations was calculated. A system of 5 bicycles per 1000 inhabitants was assumed in combination with an average of 12 bicycles per docking station ,garcia2012optimizing. It was calculated that the required number of bicycle docking stations within the area should be approximately four in the expected land use scenario and six in the extreme land use scenario. The selection procedure was conducted in an iterative way. First the location having the highest score was selected. Then, a buffer of 300 metres was created around this location, to ensure that two docking stations will not be located too close to each other. This selection process was repeated six times. Additionally, three docking stations were located at the three train stations. Since the differences between the four land-use and public transport scenarios are very small, the above described location selection steps result in the same bicycle docking locations in each scenario. The six docking station locations are shown in Figure 4.

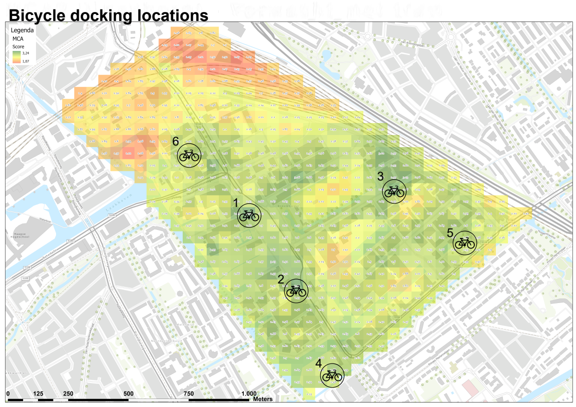

Fig. 4: Selected bicycle docking locations

By means of these bicycle docking station locations, different network designs are possible. The number of bicycle docking stations can be ranged from 0 up to 6 and the tram can be included or not. The aim of this study was to determine which network design resulted in the highest accessibility.

B. Assessment framework

Various indicators are available to measure the accessibility of an area. Therefore, a selection has been made of the indicators found in the literature, which have been combined into an assessment framework. Some indicators were included quantitatively, these indicators have been calculated in the traveller flow model. For some indicators, it was not possible to calculate them in the flow model, due to a lack of information and the limited time scope. These were evaluated qualitatively. The indicators that were included in the flow model were:

- Travel time
- (Generalised) travel costs
- Number of travellers (per mode)

The indicators that were evaluated in the qualitative assessment were:

- Un(reliability)
- Convenience and travel comfort
- Investment costs

C. Flow model

To assess the network designs, insight into the passenger flows in the Binckhorst was required. Therefore a simple flow model has been constructed. The purpose of this model was to get an idea of the traveller flows over the network for the different network designs. This flow model was based on the modelling approach of the four step model [23, 24].

First, the case study area was divided into 20 different zones. These were the possible origins of the travellers. The trip generation has been calculated for all different zones by use of travel generation indicators [20]. The destinations are assumed to be the train stations Den Haag CS, Den Haag HS and Voorburg, as it was assumed that the bicycle-transit system will be used for access and egress to the train station. In the SMCA, the total number of trips generated within the area was calculated. However, since it was assumed that the shared e-bikes will be used as access and egress to the train, only the share of train trips was relevant. It was assumed that 10% of the total trips in urban areas are made by train, so the model includes 10% of the total number of trips [25]. For the trip distribution, the following share of travellers over the three train stations was assumed: Den Haag Centraal - 16.5% of the travellers; Den Haag Hollands Spoor - 69.1% of the travellers; Voorburg - 14.4%.
In the model, four alternative situations are analysed:

1) Walk only alternative (reference situation)
2) Bike and walk alternative
3) Tram and walk alternative
4) Bike, tram and walk alternative

For the network designs, the number of bicycle docking stations could have been varied up to six. When more than one bicycle locations was included, it was assumed that travellers would use the bicycle docking station that results in the shortest total travel time (walking time to the docking station and the cycling time together).

For each of these alternatives, the travel times of all possible mode options are calculated as well as the corresponding travel costs. The travel times for both walking and cycling were calculated by use of Google Maps. The travel times for the tram are calculated according to an assumed travel speed of 25 km/h and distances between the two train stations (CS and Voorburg) and the assumed tram stop. The tram does not connect the Binckhorst with the train station Den Haag HS. The travel costs for cycling and tram are based on the fares of comparable transit and shared bicycle systems [26, 27].

With these travel times and costs, the modal split was calculated by use of an RUM MNL model. Random utility maximisation (RUM) models assume that decision makers will choose the alternative that has the highest utility [28, 29]. The observed utility of an alternative can be expressed in a linear-additive form (Eq. 6):

$$V_i = \sum_m \beta_m \cdot x_{im} + \varepsilon_i \tag{6}$$

The observed utilities of all alternatives can be used to calculate the choice probabilities *P* for each mode (Eq. 7):

$$P(Y = i) = \frac{e^{V_i}}{\sum_J e^{V_j}} \tag{7}$$

The following values were assumed in the calculation of the utilities:

- β_{time} = -0.0898
- β_{cost} = -0.426
- $\beta_{transfer}$ = -0.1796
- VoT = €12.65

The values for β_{cost} and VoT were obtained from literature [30, 31], and β_{time} was calculated by use of these two parameters, since $\beta_{time} = \beta_{cost} * VoT$. By means of the modal split and the corresponding traveller flows, the total travel times and travel costs over the network were calculated. The Value of Time was also used to calculate the generalised travel costs, which is the travel time expressed as costs plus the direct travel costs. The generalised travel costs were used to calculate the savings that each mode achieves, compared to the walk-only reference alternative. This was calculated for both the expected land use scenario and the extreme land use scenario. Since both scenarios resulted in comparable reductions in travel costs and travel times, only the results of the expected scenario will be discussed.

Since for some parts of the flow model it was necessary to made assumptions, a sensitivity analysis was performed to validate these assumptions and to investigate the sensitivity of the model on these assumptions. Additionally, some policy measures or possible scenario's were evaluated by changing some parameters in the model. This policy measure analysis was performed to get insight into the influence of these measures on the mode choices, travel times and the accessibility.

III. Results

The results of the flow model showed that the tram scenario resulted in the lowest reductions in generalised travel costs and there was only a difference of three percentage points in travel cost reductions between tram + bike + walk, and bike + walk (see Figure 5). Although the tram achieves considerable travel time savings to the stations CS and Voorburg of on average 14 minutes and 6 minutes respectively, travellers to Den Haag HS still had to walk since the tram did not connect Den Haag HS and this model did not include a bus. Since the largest share of travellers

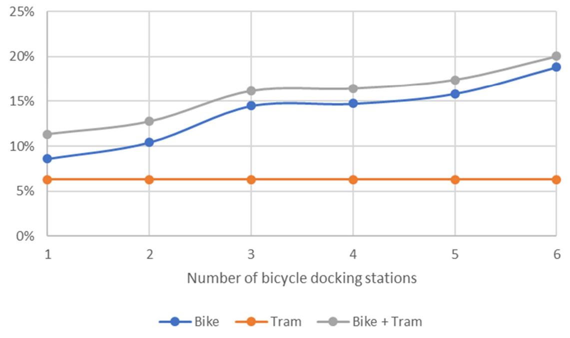

Fig. 5: Percentage gain in generalised travel costs

has Den Haag HS as their destination, only 30% percent of travellers benefits from the travel time savings of the tram.

It was also observed that the docking stations that contributed to the highest savings, were the stations 1, 2, 3 and 6 (see Figure 4). Station 4 and 5, which were both located at the edge of the case study area, only attracted travellers from a few zones and were therefore not able to achieve as much travel time reductions as the other docking locations did. This means that the highest potential, according to the SMCA, will not always result in the network that achieves the highest accessibility. When all bicycle stations were available, only 6% of the travellers that choose to cycle, used docking station 4 and only 13% used docking station 5 (see Figure 6). It was even observed that bicycle docking station 4 was for none of the origin zones the preferred docking station to all destinations. This can be explained by the fact that this docking station was located at the edge of the area, meaning that travellers first had to walk in the opposite direction to pick up the bicycle, which increases their travel time for most destinations.

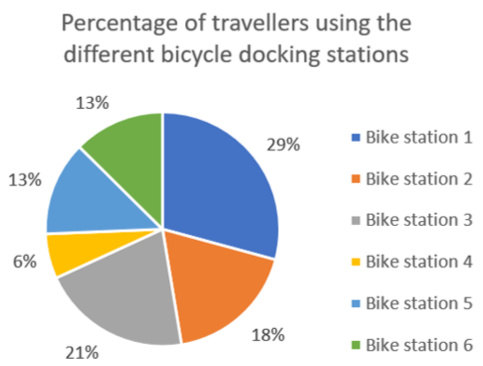

Fig. 6: Pie chart showing the use of the different bicycle stations

For some O-D pairs, adding the tram or the bicycle resulted in higher travel times instead of travel time savings. This can be explained by the fact that travellers had to walk in the opposite direction towards the bicycle docking station or the tram stop, which makes their trip longer. Because of the choice probabilities of the RUM MNL model, still some travellers chose to cycle or travel by tram, while walking would have been faster. In this way, this model takes into account different traveller preferences, such as a preference for the shortest total travel time, or a preference for walking as short as possible. There were also situations in which the new modes did achieve a travel time decrease, but these decreases were not sufficient to compensate the travel costs that were associated with these modes.

When looking at the bicycle docking station choice for the travellers that choose to cycle, it stood out that for some origins the chosen bicycle docking station was differing per destination. This means that travellers do not always pick up their bicycle at the closest bicycle docking station from their origin, but at the docking station that results in the shortest total travel time. However, these differences in travel times were in most situations only less than one minute. In reality it might be possible that travellers would prefer a shorter walk, even if that causes a slightly longer total travel time.

One important limitation of the model should be mentioned. In the presented alternatives, travellers had only one, two or three mode options: walking, cycling or travelling by tram. It was not taken into account that people could travel by bus and also no distinction was made between shared bicycles and private bicycles. This means that in the tram alternative, travellers to Den Haag HS have to walk while in reality they might travel by bus or private bike. Therefore, the tram alternative achieves relatively low travel time savings. It should be taken into account that the observed number of travellers that was walking in the model will be lower in reality, and that only a share of the travellers that are assumed to cycle, will use the shared bicycle instead of a private bicycle.

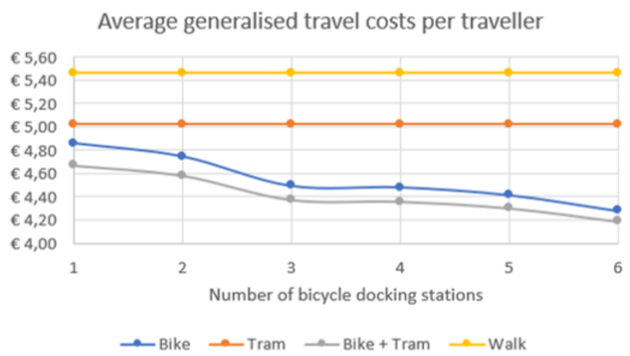

Fig. 7: Average generalised travel costs per traveller for each alternative

In terms of travel times and generalised travel costs, the bike + tram alternative scored only slightly better than the bike alternative . The average generalised travel costs were only 10 to 20 cent lower, and the travel times were approximately one minute decreased. This indicates that implementing the tram in this case did not result in much gain. However, due to the fact that a tram has additional advantages such as comfort and travel convenience, this alternative should not be excluded before further research has been performed. For example for travellers who have difficulty walking or cycling, which is 6% of the population [32], cycling might not be possible. Also when carrying heavy luggage or when the weather is bad, travellers may prefer the tram over cycling. An advantage of a shared bicycle system in comparison to the tram, is that the investment and operational costs are significantly lower.

Based on this study, it was concluded that bicycle stations 1, 2, 3 and 6 will achieve the most travel time and cost gains. Although logically more bicycle stations will always result in travel time gains for at least some travellers, distributing the same number of bicycles over more shared bicycle stations also increases the chance that bicycles will no longer be available at a specific station. This reduces the reliability of the system. Therefore, adding two more bicycle docking stations is not recommended.

IV. Evaluation and discussion

The approach consists of three comprehensible steps that can be adapted individually according to the characteristics and goals of the case study. This approach facilitates the design of bicycle-transit systems, and provides a clear foundation for the final design. This could contribute to a faster implementation of a bicycle-transit system, which is desirable for stimulating cycling.

As a consequence of this approach, travellers could benefit from bicycle stations at the most attractive locations to reduce their travel times. For operators, it is advantageous to know where to build bicycle stations and to evaluate the influence of different systems on the profit that could be achieved. For the authority, this approach provides a total overview of all modes in one model. This is useful for the authority, to compare the accessibility of different zones and to evaluate which different modes of transport should be offered. Lastly, the land-use developers could benefit from this approach, as it provides insight into the performance of different systems while the context could be varied. This makes it possible to evaluate hypothetical transit modes for an area that has yet to be developed, by for instance different land-use scenarios. Overall, it can be concluded that the developed approach contributes to the decision making process for designing an integrated bicycle-transit network.

It should be considered that the model still contains some limitations that may have influenced the results. First, it should be taken into account that the results of the extreme land-use scenario in the SMCA are heavily dependent on where these additional buildings are located and what their function and corresponding trip generation will be. This has a direct impact on the results of the SMCA, although it was found in this study that for the selection of the bicycle docking locations, it made no difference.

Another limitation of this study is that the sample that was asked to determine the weights was very small. For this study, this sample was used to obtain a first insight into different stakeholder perspectives. However, if these weights would be used to draw conclusions about the different preferences of stakeholder groups, this sample has to be expanded to become a representative sample.

In addition, it should be taken into account that the proposed docking locations are only based on the results of the SMCA. Before these docking stations can actually be realised at these proposed locations, it should be investigated whether this space is available.

The flow model also contained some limitations, which could have influenced the results. As mentioned before, not all possible modes are included in the flow model. In particular, the distinction between shared bicycles and private bicycles will be an important improvement. Since these two modes have common characteristics and therefore a comparable utility, including this distinction is expected to mainly affect the share of cyclists that followed from the model. The tram alternative will probably also achieve better results, because when private bikes are added as an mode option, travellers to Den Haag HS could cycle to HS instead of only walking. Therefore, in order to obtain more insight into the performance of the tram alternative and the actual demand for shared bicycles, the private bike must also be included as an option in the model.

Finally, another important limitation of the model is that the share of train travellers that was used as input for the travellers in the model is fixed. An important objective of implementing a bicycle-transit system is to encourage travellers to use these modalities instead of the car. To be able to see whether the implementation of this system also has this desired effect, the model could be further improved in a way that the total number of travellers can also increase or decrease.

V. Conclusion and recommendations

From the literature review, it was concluded that students and commuters are most likely to make use of a shared-bicycle system [4]. In addition, shared bicycles are mainly of added value for the egress part of a trip, because for the access part, most travellers use their own bicycle [2]. Since neither cycling or public transport offers a sufficient alternative to the car, a connection between these two modes is extremely important. While public transport has a large spatial reach because of the high speed, cycling can be used on the last-mile for the door-to-door accessibility.

Based on this study, it could be concluded that an increase in land-use development does not have a major impact on the bicycle docking locations, because the potential of these locations depends on multiple factors. If there would be a more extreme change in land-use development, this could lead to different results but this was not analysed in this research.

It can also be concluded from this research, that the location that achieves the highest potential according to the SMCA, will not always lead to the best performing network when analysing the passenger flows over the network and the accessibility of the area. The catchment area of a shared bicycle location is also found to be important, because this determines the number of travellers that potentially will use this shared bicycle station.

Lastly, an important conclusion that follows from this research, is that the bicycle docking station that is closest to a traveller origin, not always results in the shortest total travel time. For some trips, the total travel time was shorter when walking to a bicycle docking station that is located further away. This means that the shared bike stations should not necessarily be located as close as possible to attractive locations, if they will provide more travel time savings when they are located somewhere else.

From the results of the flow model, it can be concluded that the optimal design for the Binckhorst consists of a tram line between Den Haag CS and Voorburg, and four bicycle docking stations, located at the docking locations 1, 2, 3 and 6. These four docking stations achieve the highest travel cost reductions, and adding two more stations will not be profitable. The tram alternative seemed to score relatively poorly in the model, which can be explained by the fact that most travellers have Den Haag HS as their destination while the tram is not connected to that destination. However, it was observed that significant travel time savings were achieved for the other two destinations. It should also be taken into account that in reality, travellers can also use their own bicycle when travelling to Den Haag HS. This means that not all travellers will be walking, as was observed in the flow model. Therefore, in reality the tram-alternative will achieve higher travel time savings than this model indicates.

For further research, it is recommended to improve the model by including all possible modes, and especially private bicycles and the bus. By means of the improved model, the more realistic mode shares could be observed. To get insight into the demand of shared bicycles, also a stated preference experiment could be conducted in which potential users have to indicate their preferences between different alternatives.

Another recommendation for further research, is to apply the approach to a larger-scale case study to investigate the influence of the combination of bicycle and tram on the network design. That means using the bicycle as access for the tram. This was not investigated in this study as the assumed case study area was too small and therefore the travel times were too short to combine cycling and the tram.

Lastly, this research did not explicitly investigate the costs of different network designs. By calculating the investment and operational costs of different systems, for example it becomes possible to evaluate whether higher costs outweigh the travel time reductions that will be achieved.

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1 Introduction

Worldwide, an attraction to urban areas can be seen. This trend in urbanisation is also taking place in The Netherlands. In the years between 1990 and 2020, the Dutch population increased from 14.9 million to 17.4 million people, which is 16.7 percent (CBS, 2020). This growth was the highest in the Randstad (18%), and lowest in the periphery (5%) (de Beer et al., 2018). The prognosis for the next 25 years is that even more people will be living in cities. The four big cities in the Netherlands (Amsterdam, Den Haag, Rotterdam and Utrecht) will keep growing while the number of people living in the countryside will decrease.

When there are more people living in cities, there will also be more transport movements in and around cities. Therefore, the challenge is to keep cities accessible by modalities that efficiently use the public space: walking, cycling and public transport (Litman & Burwell, 2006). In 2019, the number of traffic jams in The Netherlands has increased by 17% (ANWB, 2019). Cars not only contribute to traffic congestion, but also cause air pollution and increase the risk of injury and death to all road users (Ogilvie et al., 2004). To keep the city liveable and accessible despite the increasing number of inhabitants and the corresponding transport movements, car dependency must be reduced (Litman & Burwell, 2006). Also, since bicycles require less space for parking and manoeuvring, bike parking is more efficient than car parking for highly valuable land. In recent years, travel behaviour among people in industrialised countries around the world have changed, resulting in a decreased car use and reduced total displacement (Kuhnimhof et al., 2012). According to Mattioli (2014), in cities the 'mobility gap' between car-owning households and households without a car, is considerably smaller than in the surrounding areas, because in cities there are multiple alternatives for the car. This implies that the car dependency could only decrease if a viable alternative is offered.

On a metropolitan and regional scale, a possible alternative for car usage is a bicycle-transit system. A bicycle-transit system means that bicycles can be used for access and egress to transit stations where travellers can make use of rapid, high-level public transport. For this system, it is required to provide the adequate cycling infrastructure including parking facilities, to attract more travellers to use public transport. Consequently, travellers benefit from comfortable door-to-door travel and high frequency rail services. According to Krizek & Stonebraker (2010), improving the cycling infrastructure and parking facilities around train stations results in an increase in train users.

Since public transport does not provide door-to-door accessibility just as the car, and cycling has lower speed and smaller spatial reach, these single modes can not compete with the car. However, the combination of both modes could be. In order to attract car users to make use of bicycle-transit it is important to create an effective combination of the strengths of both bicycles and public transport (Shelat et al., 2018). The car is mostly attractive because of the long distances that can be travelled, although it is less attractive in urban areas due to the congestion and slow speeds. Cycling is highly attractive for short distances and is almost independent on the density of urban areas. Since busses encounter the same congestion issues as cars, combining busses with bicycles would not be attractive. To avoid these urban congestion issues, the highest benefits can be achieved by combining the bike with rail transit. The advantage of rail transit is the high speed and therefore large spatial reach, while the advantage of the bicycle is the door-to-door accessibility. The infrastructure costs for different rail transit modes are the highest for train, followed by metro and lastly tram (van Oort, 2018). Busses have the lowest costs since there is no dedicated infrastructure required. However, the operation of a tram is less expensive than a bus and according to Shelat et al. (2018), access and egress trip distance positively correlate to a larger main mode distance and a higher frequency of the main mode. This shows that the potential for the combined mode is greater for high level transit services. Therefore, the transit mode that will be focused on in this research is the tram. Combining this with cycling results in a system with high speed and high accessibility, making it competitive with the car (Brand et al., 2017, Kager et al., 2016).

According to Kager et al. (2016), 47% of the train users in the Netherlands uses the bicycle for access while only 12% of the travellers uses the bicycle for egress. The share of the bicycle use on the access side can be increased by providing parking facilities and on the egress side by providing bike-sharing and bike-renting or shared bicycle opportunities (Brand et al., 2017). Also Shelat et al. (2018) mention the potential of the combined bicycle-transit mode. Mainly the egress trip of the activity end can be improved by increasing the availability of bicycles. A shared bike system could contribute to increase the share of cyclists at the egress side. Additionally, a trend in shared mobility can be seen. For instance, different concepts of shared bicycles showed up in the last years. Shared mobility is increasingly accepted and more people are using it. Another advantage of shared mobility is that it requires less parking space. For this reason, bicycle-transit is a promising concept for high-urban areas that are being (re)developed where limited space is available. These types of areas require efficient mobility options. An adequate mobility plan is even considered as a precondition for area development (Rottier, 2020). Area development offers the possibility to directly provide an efficient mobility system, so that travellers are immediately encouraged to use it. Changes in the built environment may increase the use of bicycles (Beenackers et al., 2012).

An effective integration of bicycle-transit services will result in increased efficiency of transit and increased cycling demand (Krizek & Stonebraker, 2010). Integrating both modes means not just creating two isolated networks, but also make adaptations to both networks to achieve an integrated network. Still, most research that is conducted before either focuses on public transport network design (e.g. van Nes (2002), van Oort & van Nes (2009)), cycling network design (e.g. Hull & O'Holleran (2014)) or bicycle sharing systems (e.g. García-Palomares et al. (2012), Lin & Yang (2011)). Most of these studies consider a stand-alone bicycle system or a stand-alone transit system. In recent years, more and more research has been done into the combination of these two modes (e.g. Brand et al. (2017), Kager et al. (2016), Krizek & Stonebraker (2010)). However, these studies mainly focus on user and trip characteristics (Shelat et al., 2018) or the factors influencing the use of this mode (van Mil et al., 2018). In some studies the emphasis was on the stakeholder dilemma (e.g. Sochor et al. (2015), van Nes (2015), van Nes & Bovy (2000)). This dilemma describes how the different perspectives of stakeholders result in different optimal network designs. With the insights from these previous studies it was possible to take the next step, which was applying this knowledge to the design of an integrated bicycle-transit network. This research therefore focused on developing an approach for designing an integrated network. This approach was applied to design an integrated bicycle-transit system for a case study area, which was the Binckhorst in The Hague.

1.1. Research question

There are many challenges in designing these integrated systems and a structured way to do this is lacking. Therefore the research question in this study was twofold: before it could be investigated what the optimal design for an integrated bicycle transit system should look like, a structured approach for designing such an integrated bicycle-transit system had to be developed. As the main part of the design depended on the locations of the bicycle docking stations, the first step in this study was to determine where these bicycle docking stations should be located. After determining these locations, different designs were assessed on their contribution to the accessibility, to find the optimal network design. Therefore, the main question in this study was:

Which approach should be used to design an integrated bicycle-transit network and how should this design look like?

1.2. Sub-questions

To be able to answer this question, four sub-questions were formulated and are shortly explained below. Chapter 2 discusses the research methods that were used to find an answer on these questions.

1. *What are the main findings from previous research into bicycle-transit?*
   The first sub-question was to get an overview of all the knowledge that is currently available about bicycle-transit. This was an important basis for the rest of the research. This question was divided into three sub-questions, because it has become clear from an initial literature study that three components are important in determining the location for the docking stations: the cycling environment, the activity pattern and locations, and the relation between the bicycle network and the public transport network.

   (a) *Which factors determine an area's suitability for a shared bicycle network?*
   The first step was to investigate which factors contribute to an attractive cycling environment and which places are attractive and accessible by bike. For a shared bicycle system, these factors may influence the docking station locations.

   (b) *What characterises the activity pattern of the prospective users and where do the activities take place?*
   To evaluate potential docking locations, it was important to know where the activities of prospective users take place. The bicycle-transit system aimed to facilitate the last-mile of a trip, so both origins and destinations were analysed.

   (c) *What is the effect of bicycles as access and egress mode on the catchment area of transit stops and how does this influence the transit network design?*
   When shared bicycles are available for all travellers, this may encourage a change in travel behaviour for the access and egress towards the transit stops. Therefore it was investigated whether this change in feeder mode affects the transit network design, compared to a network design that assumes a walking catchment area.

2. *How do these previous findings influence the design of an integrated bicycle-transit network?*
   The results of sub-question 1 (a), (b) and (c), gave an overview of the factors that had to be considered when designing an integrated network. This was used to determine where the bicycle docking stations had to be located.

3. *How should an integrated bicycle-transit network be designed according to the previous findings?*
   The possible bicycle-transit network designs that were acquired in the previous questions, then were compared to draw a conclusion about the final design. To assess the different designs, indicators from literature were used.

4. *How can this approach contribute to the decision making process?*
   In this study, the design approach was applied to a specific case study. On the one hand, the question was thus to what extent the results of this study could be used in the decision making for this case study. In addition, the limitations and possible improvements of this approach were investigated to evaluate how this approach could be applied to other cases.

1.3. Scientific and societal relevance

The combination of bicycle and transit has increasingly drawn attention in recent research, as it is supposed to be a solution to reduce the negative consequences of urban mobility. Even though there are different studies and also real-life examples of this combined modality in the Netherlands, there is still a lot unknown about it. As explained in Chapter 3, there are relevant previous studies that all describe different aspects of this topic. However, in previous studies either the (shared) bicycle system is analysed or the public transport system. There are only few studies that focus on bicycle-transit as an integrated system. These studies investigated for instance factors that influence the use of such a system, trip and user characteristics. Still, the actual design of an integrated system is a quite unexposed subject, while this is an important aspect for the success of such a system (Frade & Ribeiro, 2015, García-Palomares et al., 2012).

This study was not only motivated by the scientific gap, but also by the existing need to support decision making in designing multi-modal networks, in order to increase the share of this mode and consequently enable more sustainable transportation. Nowadays, more and more systems for shared mobility arise. To make optimal use of shared bicycles, this system should complement the public transport system. Policy makers are interested in encouraging cycling, as it is a healthy and cheap way of transport, which in urban areas can be faster than other modes as it can avoid traffic jams (Heinen et al., 2010). Cycling also has advantages for the environment, since it has no direct emissions of pollutants, CO_2 or noise. Also, BAM Infraconsult is more and more focusing on an integrated approach that includes not only building the required infrastructure, but also keeping into account the services that are provided and the user behaviour. This research was in line with this integrated approach, since it investigated the mobility as an integrated system instead of just the infrastructure. The aim of this integrated approach is to build infrastructure not only for the mobility issues that travellers encounter nowadays, but also for the mobility of the future.

1.4. Objective

In this research, an approach was developed to design an integrated bicycle-transit system. The first part of the study aimed at determining the factors that influence the bicycle docking locations and therefore the bicycle-transit network design. The goal of the second part of the research was the assessment of different network designs to draw conclusions and recommendations about the final design. The aim of this research was to design a bicycle-transit network in a structured way and consequently develop a general approach. In this approach, different stakeholder perspectives were considered as well as different design criteria and assessment indicators. In this study, the developed approach is applied to a case study and then evaluated, taking into account the stakeholders.

1.5. Scope

To overcome the problem that not all travellers have a bicycle available for their egress trip, the bicycle-transit network as considered in this study assumed a shared bicycle system. That means that there are public use bicycles distributed around a city that can be used at low cost for short-term (García-Palomares et al., 2012). These bicycles can be picked up at a bicycle station and returned to any other bicycle station, which makes it a back-to-many system (Cannegieter et al., 2018).

This study focuses on electric bicycles, as they have the potential to reduce barriers that are experienced with conventional bikes such as heavy wind or health problems. According to Lee et al. (2015), people prefer electric bicycles as they are easier to use and more comfortable. Also, people are willing to cycle longer distances on an electric bike than on a conventional bike. To increase the potential use of bicycles, electric bicycles are assumed. That means that the bicycles always have to be parked in a docking station, since they bicycles have to recharge at these stations. Only trips where the bicycles are used as a feeder mode for public transport were assumed.

Since the cycling culture differs from country to country, for this study it was decided to focus on The Netherlands. In The Netherlands most people are used to cycling and there is sufficient infrastructure for cyclists (Haustein & Nielsen, 2016). When a comparable study will be conducted for a country where cycling is less usual, the potential of the system may be different (Martens, 2004).

The transit aspect in this study contained train and tram. Research into the case study area, shows that a (high-quality) bus connection does not offer sufficient capacity for future traveller demand (Lek & Postma, 2018). Because tram and train also offer high-quality public transport and have a larger capacity than bus, these modes were considered in this research. There are three train stations near the Binckhorst included, being Den Haag Centraal, Den Haag HS and Voorburg. A new tram line could be connected to the existing tram network around the Binckhorst (Lek & Postma, 2018) and was therefore interesting to consider.

There were two definitions of bicycle-transit that had to be mentioned (Singleton & Clifton, 2014). The first one was bike-and-ride, which means that travellers cycle to the station or transit stop and park their bicycle. For the egress from the station to their destination, travellers can make use of another bicycle. Another option of bicycle-transit is to take the bicycle on board at the train or transit, to use the same bicycle for the access leg as the egress leg. In this research only bike-and-ride was considered, because it assumes shared bicycles that have to be parked at the train station so that other travellers can pick them up again. Also, bike-on-board brings additional challenges as the space available for bicycles in trains is often limited (van Mil et al., 2018). While the focus in this research was on the combination of bicycle and transit and on trips that combine both modes, it was inevitable that some users only use the bicycle or only travel by public transport. However, this was not explicitly included in this study.

1.6. Introduction to case study

As a case study for this research, the former industrial district Binckhorst in The Hague is used (see Figure 1.1 (Gemeente Den Haag, 2019b)). In recent years, a start has been made on a complete redevelopment of this area. The municipality of The Hague has the ambition to transform the Binckhorst into a lively mixed urban area where people live and work. From an industrial area with the main traffic load during peak hours, it will change to an area with mixed land use and therefore also a traffic pattern that is spread more evenly throughout the day and the days of the week. There will also be less investment in cars in the area in favour of walking, cycling, public transport and new forms of (shared) mobility. The emphasis will be on the livability of the city and the quality of the public space and thus limiting the traffic nuisance. The Binckhorst was chosen as the case study area, on the one hand because of the plans for urban development in the area, that cause a demand for sustainable mobility solutions for this area. The fact that the area is now under development, makes it easier to implement new systems. Therefore, this might be a suitable area for a bicycle-transit system. In addition, this case study was interesting to analyse, because there are several public transport connections nearby to which the bicycle system could be connected.

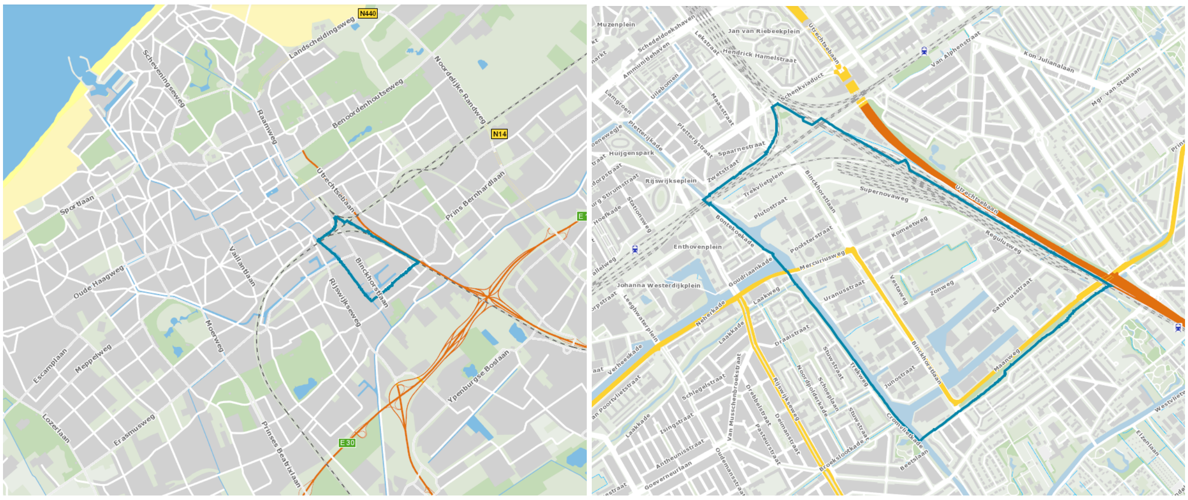

Figure 1.1: Maps of the Binckhorst, The Hague (area inside the blue rectangle)

The *MIRT Verkenning Schaalsprong Regionale Bereikbaarheid CID - Binckhorst* (Lek & Postma, 2018) described the exploration of the plans for the future of the Binckhorst. The ambition is to create around 10,000 homes and 5,000 jobs before 2040. The first 3,600 homes are expected to be completed by 2022. A significant proportion of future travellers to and from Binckhorst are expected to have a supra-regional origin or destination (38%). This share is larger than the number of expected travellers from the region (22%) and comparable with the expected share of local travellers (40%).

If the area continues to develop without changes to the current mobility system, the number of car journeys in and around the area will increase by 161,000 to 180,000 per day. In 2040 this means a 66% increase in car journeys in and around the area compared to the situation without area development. To facilitate this increase in car journeys the Rotterdamsebaan, a connection between the A4/A13 and the ring road, is being built. Although the construction of this connection was needed to keep the area accessible for the increasing traffic, the aim is to offer other modalities as well, to ensure that not everyone will travel by car.

To discourage car usage, another goal is to strengthen public transport connection in and around The Hague. Experts expect that the number of public transport users after the area development will increase from 200,000 to around 280,000 per day. This is an increase of 40% compared to the current number of travellers. Currently, two bus lines are serving the Binckhorst (see Figure 1.2 (HTM, 2019)). Line 26 (Den Haag Kijkduin - Station Voorburg) and line 28 (Station Voorburg - Den Haag Zuiderstrand). Line 26 stops at train station Den Haag HS and line 28 stops at train station Den Haag Centraal. Both lines stop at train station Voorburg. Within the Binckhorst, both lines stop at the following bus stops: Station Voorburg - Maanweg - Saturnusstraat - Melkwegstraat - Zonweg - Wegastraat. Line 28 also stops at Poolsterstraat.

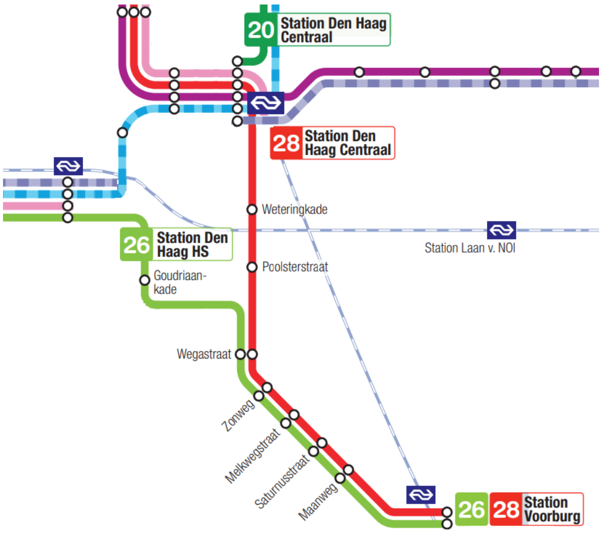

Figure 1.2: Bus lines serving the Binckhorst

Ideas to improve the public transport network include expanding the existing tram line from Scheveningen, via The Hague central station, through the Binckhorst to Zoetermeer, Delft and Rotterdam (Lek & Postma, 2018).

Due to the barriers of the A12, the railway lines and the Trekvliet, there is currently only a limited number of through-cycle routes through the Binckhorst. The main cycle routes are: Supernovaweg - Regulusweg, Laakweg - Mercuriusweg - Zonweg - Regulusweg and the Binckhorstlaan (Gemeente Den Haag, 2019c). An important ambition of the municipality to encourage cycling is to improve and expand the metropolitan bicycle network. Improvements to the regional bicycle networks are necessary to create a good connection between the major residential areas and the economic centre of The Hague and the surrounding area. To offer an alternative to regional car traffic, a high quality bicycle network that is connected to the right locations with little delay is essential.

1.7. Stakeholders

There are multiple stakeholders involved in the design of a public transport system. All of these stakeholders have their own perspective on the optimal network design. In the literature (see Section 3.1), three main stakeholders are considered in public transport network design. For an integrated bicycle-transit system, the same stakeholders can be assumed. These stakeholders are the traveller, the operator and the authority (van Nes, 2015).

The traveller, or the user of the system, is the first stakeholder that is involved in public transport network design. The main interest of a traveller is to reach their destination as quickly as possible. In this case that would result in multiple bicycle docking stations to minimise the walking distance and a fully connected public transport network with high frequencies to reduce the total travel time. The second stakeholder is the operator of the public transport system or the shared bicycle system. To increase the integration of both modes, it is possible that both systems are operated by the same company. In both cases, the operator's objective is to minimise the total operational costs. This objective may be conflicting with the travellers' preferences as it results in a smaller network. The last stakeholder that is involved, is the authority that is responsible for the regulation of transport services in a specific area. In the case of the Binckhorst, this responsibility is for the municipality of The Hague and the Rotterdam-The Hague metropolitan area (MRDH). For this case study, the land use development plays an important role. As the case study area is going to be completely redeveloped, this allows for simultaneously development of the area itself and improvement of the accessibility by implementing a shared bicycle and public transport system. Therefore, the area developers should also be considered. For the authority, the objective for public transport network design is maximising social benefit. This includes benefits for both the traveller and the operator. Because of their conflicting interests and perspectives, it is relevant to consider the different stakeholders during this research.

1.8. Thesis outline

This section explains the outline of this thesis. First, Chapter 2 describes the methods that were used in this study. As the goal of this study was to design an integrated bicycle-transit network, the first method was used to find the potential bicycle locations in combination with different transit network suggestions. The second method enables the comparison of different integrated designs by analysing the traffic flows on each network. After the methodology, the literature study that was conducted to determine the state-of-the art of this topic and to gain more insight into closely related topic was described in Chapter 3. After that, Chapter 4, 5 and 6 show the set up of the spatial multi-criteria analysis, the assessment framework and the traffic model respectively. Consequently, the design approach will be evaluated in Chapter 7. The thesis will be concluded with discussing the results (Chapter 8) and presenting the conclusions and recommendations in Chapter 9.

2 Research methodology

This chapter explains the methodology that was used to find an answer on the research questions. Since the research question comprises, on the one hand, how an integrated network should be designed and, on the other hand, what this design should look like, the methodology used for this research has also been split into two parts. The first method describes how integrated network designs can be established by use of a spatial multi-criteria analysis. This method is used to find potential locations for the e-bikes in combination with different spatial development scenarios and transit networks, resulting in different integrated network designs. The second goal is to evaluate these integrated network designs, by analysing the traffic flows on these networks. For this part, a transport flow model is constructed. The last section of this chapter describes this flow model.

2.1. Spatial multi-criteria analysis

The bicycle-transit system that was assumed in this study consists of (a varying combination of) shared e-bikes, train and tram. These e-bikes have to be picked up and parked in docking stations where their batteries will be charged. The location of these docking stations is an important element for the success of a shared bike system (García-Palomares et al., 2012). Accordingly, the first step in this research was to figure out which locations are suitable for these shared e-bike docking stations, in combination with different public transport network designs. This section describes how the potential locations for these docking stations were determined. To find these locations, a spatial multi-criteria analysis was performed. The subsections 2.1.2 to 2.1.5 describe the different steps of the spatial multi-criteria analysis.

2.1.1. Introduction

The method that was used to determine the potential locations was a spatial multi-criteria analysis (SMCA). A multi-criteria analysis (MCA) is a systematic method for the comparison of different alternatives. In this study it was used to find potential locations for the e-bike docking stations. A multi-criteria analysis is able to integrate goals, objectives, spatial data and stakeholder preferences in a systematic method (Strager & Rosenberger, 2006). A spatial multi-criteria analysis is the application of a multi-criteria analysis in spatial contexts where alternatives, criteria and other elements of the decision problem have spatial dimensions (Chakhar & Mousseau, 2008). Usually, spatial decision problems contain large sets of alternatives and multiple, diverse and conflicting criteria.

The combination of attribute measures for criteria (scores) and measures of decision makers' preferences (weights) can be expressed in a weighted linear calculation as the suitability index S, which is the sum of the preference weights w_i and criterion values x_i (see Eq. 2.1):

$$S = \sum w_i x_i \tag{2.1}$$

The criterion scores e for I criteria over J alternatives can be expressed as the evaluation matrix E (Eq. 2.2) and can be combined with the preference weight vector W (Eq. 2.3).

$$E = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix} \tag{2.2}$$

and

$$W = (w_1, w_2, ..., w_I), \qquad \sum_{i=1}^{I} w_i = 1 \tag{2.3}$$

This results in the weighted linear combination expressed in Eq. (2.4).

$$\begin{bmatrix} s_1 \\ \vdots \\ s_I \end{bmatrix} = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix} * \begin{bmatrix} w_1 \\ \vdots \\ w_I \end{bmatrix} \tag{2.4}$$

This weighted linear combination can be integrated in a geographic information system (GIS) by use of raster-based spatial analysis to enable spatial multi-criteria decision making (Chakhar & Mousseau, 2008). GIS allows the inclusion of spatial data in a decision support system. Multi-criteria decision analyses provide techniques and procedures for structuring decision problems and designing, evaluating, and prioritising alternative decisions (Malczewski, 2006). A drawback of a SMCA in GIS is that the output is dependent on the amount and quality of accessible data. Further, results may change when the criteria are weighted differently. To take account of this uncertainty, the weighting is done by different stakeholders with different perspectives. Also, different scenarios for the development of the Binckhorst are included to assess the influence of the land use data on the results. The next subsections successively describe how the criteria are defined, weighted and scored, and applied to GIS.

2.1.2. Defining criteria

The first step of the SMCA was to determine the criteria that influence the location choice. To find these criteria, literature was used. Google Scholar and ScienceDirect were used to search for literature about the factors that influence the use of bicycle-transit, shared bicycle systems, cycling in different countries with different built environment characteristics, and differences between conventional bikes and e-bikes. A selection of papers was made based on the relevance of the abstracts of the papers. While reading the selected papers more closely, the snowballing technique was used for finding relevant papers that were mentioned in the selected papers. From these studies, all factors that influence bicycle-transit were summarised. After that, only the factors that affect the location of the bicycle docking stations were taken into account as the criteria for the SMCA. The aim of this literature study was to get insight into the factors that influence the location for shared bicycle docking stations.

2.1.3. Weighting the criteria

The weighting of the criteria was done by different stakeholders, to include their perspectives in the multi-criteria analysis (see Section 4.2). Different people representing the traveller, the municipality, the operator of the shared bicycles and the developer of the Binckhorst were asked to assign weights to the criteria by filling in questions about weighting the criteria. In this form, the criteria that were determined before are presented. The stakeholders have been asked to divide 100 point over a set of criteria, to indicate the ratio between these criteria.

However, for some criteria it was harder to indicate the ratio like this, since the difference between these criteria was smaller. To assign weights to the criteria that are more difficult to compare in a structured way, the Analytic Hierarchy Process was used. By use of this method, a weight for each criterion was determined according to a pairwise comparison of the criteria (Mocenni, 2007). The total number of comparisons can be calculated as described in Eq. (2.5), with n being the number of criteria (Teknomo, 2006).

$$\frac{n(n-1)}{2} \tag{2.5}$$

The pairwise comparisons can be expressed in a matrix A, which is an nÖn matrix. Each a_{ij} in the matrix represents the relative importance of criterion i over j. If $a_{ij} > 1$, criterion i is more important than j and the other way around. If $a_{ij} = 1$, both criteria have the same importance (Mocenni, 2007). Therefore, the following constraint should be satisfied (Eq. 2.6):

$$a_{ij} \cdot a_{ji} = 1 \tag{2.6}$$

For the diagonal of the matrix, all criterion scores are equal to 1, and the lower triangular matrix is filled with the reciprocal values of the upper part, according to Eq. (2.6) (Teknomo, 2006).

To obtain the normalised relative criteria weights from this pairwise comparison matrix, all elements were divided by the sum of its column. This results in the normalised relative weight matrix in which the sum of each column is equal to 1. Finally, by averaging the rows of this matrix, the criteria weight vector was calculated (Eq. 2.7).

$$w_i = \frac{\sum_{k=1}^{n} \overline{a_{ik}}}{n} \tag{2.7}$$

Since this vector was normalised, the weight values sum up to 1, and this vector shows the relative weights for the criteria that were compared.

2.1.4. Determining criteria scores

To assess the different locations on the criteria that were defined before, the criteria scores were determined. For this, it was first necessary to determine which units should be used to measure the criteria. After that, the required data was collected. The criteria scores were obtained via open data sources such as OpenStreetMap, PDOK, Kadaster and Google Maps. The advantage of these open data sources is that the data can be directly loaded into GIS. The disadvantage is that these sources only contain information about the current situation. However, for this study the development of the Binckhorst was necessary to include. As the population in the Binckhorst has increased from about 300 in 2014 to about 2.300 in 2019 (Gemeente Den Haag, 2019a) and more houses are currently being built, the expectation for the future scenarios is that the population will keep rising. Analysing a future scenario inherently means that there is, to some extent, uncertainty. To deal with this uncertainty, different scenarios were considered and compared. First, the data of the current situation as was available was loaded into GIS. Two different scenario's were then defined including the new buildings and their corresponding destinations. The first scenario is based on the currently available development plans, this is the expected future. The second scenario is based on a higher degree of land use development. Therefore, in this scenario additional buildings are assumed. By considering the current development plans and the locations that are still available, an assumption has been made for what type of buildings could be added and at which locations. By evaluating the expected future situation and a more extreme developed scenario, a certain bandwidth of uncertainty was included. This gave insight into the influence of the land use development on the docking station locations and enables decision making for different futures. Also, different transit network plans were evaluated. The two options that are considered are the existing train network with or without a light rail via Den Haag Centraal to Voorburg.

2.1.5. Application to GIS

After defining criteria scores and weights, the multi-criteria analysis was applied to GIS to enable multi-criteria decision making. Using GIS, the area was divided into a 50 meters by 50 meters grid in which the "docking station potential" could be calculated for each of these squares, based on the above mentioned criteria. As illustrated in Figure 2.1, all criteria are represented in one of the layers. The criteria scores are all classified as a value between 0 and 4, to make it possible to compare different layers. Combining all these layers in combination with an assessment rule results in heat maps in which the total score is displayed for each cell. This heat map shows the shared-bike potential of each location.

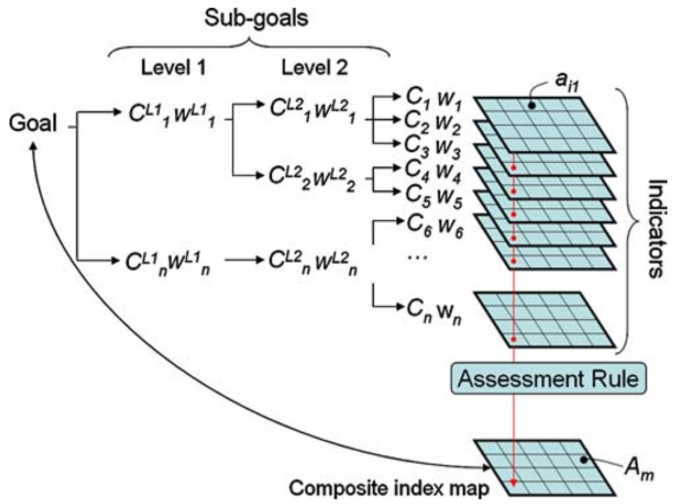

Figure 2.1: Schematic representation of the calculation of a spatial multi-criteria analysis (Abella & van Westen, 2007)

There were two different development scenarios included in this analysis. The first scenario was constructed by use of all the development plans for the Binckhorst that have already been published. After that, a second scenario was created to which additional area development was added, on top of the plans that were already known. This scenario could be used to gain insight into the impact of urban area development on the integrated bicycle-transit system. In Chapter 4 can be found how each of these scenarios was defined.

Both scenarios were analysed in a situation that only includes the current train stations and in a situation in which a potential tram network is added. This was done to analyse the influence of the tram network on the potential bicycle locations, to evaluate different integrated bicycle-transit networks. Chapter 4 describes the different scenarios and network variations.

2.1.6. Selection of bicycle docking locations

The last step of this part was the selection of the bicycle docking station locations. Based on García-Palomares et al. (2012), the required number of bicycles and docking station was estimated. After that, the docking locations were selected. This is performed as follows: first, the cell having the highest score in the MCA is chosen. This is the first location for a bicycle docking station. Consequently, a buffer is built around this location. Within this buffer, it is not desirable to place another bicycle docking station as these two stations then will attract the same travellers and the density of bicycle stations will become to high. Of all the remaining cells, the one with the highest score is selected again. Again, a buffer has been created around this. This selection process is repeated as many times as required. On top of this selection process inside the Binckhorst, it was also assumed that the three train stations all have a bicycle docking station.

2.2. Assessment framework

The multi-criteria analysis resulted in a number of possible bicycle-transit networks. The next step in this study was to evaluate the different network designs. It was assumed that the networks should be analysed on their contribution to the accessibility of the Binckhorst. Because accessibility can be defined in different ways, an assessment framework has been made. This framework consists of the indicators that were used in this study to test how each of the various networks scores. This framework was used to create guidance and identify which indicators were used to assess the different bicycle-transit designs resulting from the possible bicycle locations. The framework is discussed in Chapter 5.

2.3. Traffic flow model

To gain insight into the traffic flows in the Binckhorst, a simple flow model has been built. The purpose of this model is to get an idea of the traffic flows over the network for the different network designs. These flows are required to compare the different networks using the assessment framework. This flow model is based on the modelling approach of the four step model (de Dios Ortúzar & Willumsen, 2011, McNally, 2000). Figure 2.2 illustrates the steps of a four step model. The next sections discuss the theory behind the flow model. A more detailed explanation of the application of the flow model, including calculations, modelling choices and assumptions, is described in Chapter 6. Since the bicycle-transit system as considered in this research does not include a network, the last step (traffic assignment) is not included in this model.

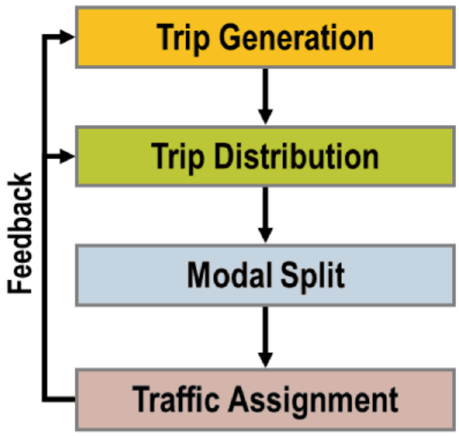

Figure 2.2: Four step model (Rodrigue, 2016)

2.3.1. Trip generation

The first step in this modelling approach is the trip generation. In this step, the origins and destinations are determined, and the corresponding number of trips is calculated. It was decided to only focus on the trips of travellers who travel by train to or from Binckhorst. Internal trips within the Binckhorst and car trips are not relevant for this model, as these travellers are assumed not to be potential users of the integrated bicycle-transit system. This means that there are three possible destinations to be included in this model: The Hague CS, The Hague HS and Voorburg. The only trips that were relevant for this model are the trips originated in the Binckhorst. To be able to analyse the accessibility of various locations within the Binckhorst, the area was divided into multiple zones. The trip generation has been calculated for all different zones by use of travel generation indicators (CROW, 2018).

2.3.2. Trip distribution

The second step, the trip distribution, is about the distribution of travellers over the destinations. Train passenger data was used to determine the distribution of travellers among the different train stations (D. Ton, personal communication, March 24, 2020). Combining these two steps results in a origin-destination matrix.

After, the travel times and travel costs for all these trips were calculated. In this model three possible modalities are included: walking, cycling or the tram. For the last two modes, travellers still have to walk a short distance from their origin to the shared bicycle station or the tram stop. This means that the total travel time for these options consists of the travel time to walk to the docking station or tram stop, and the travel time by bicycle or tram. The walking and cycling distance and corresponding travel times were calculated using Google Maps. For the tram part of the trip, the travel time was calculated based on the estimated length of the route and an estimated average speed. Travel costs for the shared bicycles were based on the average price of comparable bicycle-sharing systems (HTM, 2020a) and the travel costs for the tram were based on the prices of the existing tram system (HTM, 2020b). For the travellers using a shared bicycle, it is assumed that they will pick up the bicycle at the docking station that results in the shortest total travel time.

2.3.3. Modal split

The third step in this modelling approach is the modal split. In this step, the mode choice for the travellers is calculated. Four alternative situations are modelled: walk only, bike and walk, tram and walk and bike, tram and walk. In the first situation, all travellers are assumed to walk. In the second and the third situation, travellers have to choose between walk and bike or tram respectively. In the last situation, travellers are able to choose between walk, bike and tram.

To estimate these mode choices, discrete choice modelling is used (Chorus, 2018). The most common discrete choice model is the Random utility maximisation multinomial logit (RUM-MNL) model. RUM models assume that decision makers will choose the alternative that has the highest utility (Ben-Akiva & Bierlaire, 1999). The total utility for alternative i can be expressed as follows (Kroesen, 2018):

$$U_{in} = V_{in} + \varepsilon_{in} \tag{2.8}$$

As can be seen, the total utility consists of a systematic utility part and an error term. The systematic part of the utility function captures the utility that is observed in the model. The error term captures the unobserved utility and randomness in choices (Chorus, 2018). The observed utility has a linear-additive form:

$$V_i = \sum_m \beta_m \cdot x_{im} + \varepsilon_i \tag{2.9}$$

where β_m is the taste parameter for attribute m and x_{im} is the attribute level of attribute m for alternative i. RUM models assume that alternative i is chosen if its observed utility is higher than for all other alternatives, which can be expressed as:

$$\sum_m \beta_m \cdot x_{im} + \varepsilon_i > \sum_m \beta_m \cdot x_{jm} + \varepsilon_j, \forall j \neq i \tag{2.10}$$

The observed utilities of all alternatives can be used to calculate the choice probabilities P:

$$P(Y = i) = \frac{e^{V_i}}{\sum_J e^{V_j}} \tag{2.11}$$

The MNL model follows two assumptions. The first assumption is that the error term ε_{in} is independently and identically (i.i.d.) type I Extreme Value (EV) distributed (Kroesen, 2018). This means that there are no correlations between error terms of different alternatives and all error terms have the same variances. The second assumption of the MNL model is that each choice is independent of the presence of other choice alternatives. This is called the independence from irrelevant alternatives (IIA) property (Chorus, 2018).

2.3.4. Sensitivity analysis and policy measures

Since for some parts of the flow model it was necessary to made assumptions, a sensitivity analysis was performed to validate these assumptions and to investigate the sensitivity of the model on these assumptions. Additionally, some policy measures or possible scenario's were evaluated by changing some parameters in the model. This policy measure analysis was performed to get insight into the influence of some possible changes on the accessibility.

2.3.5. Assessment

Using the model described above in combination with the assessment framework, the different proposed network designs were compared. By means of the traffic flows, the total travel times and travel costs over the network were calculated. In addition, the accessibility of different origins or destinations was compared. This provided insight into the accessibility of the Binckhorst with different bicycle-transit networks. This was used for the recommendations for the final network design.

2.4. Method flow diagram

The different steps of this research are represented in a method flow diagram in Figure 2.3. The design approach consists of three subsequent steps, being the constructing of network designs, the constructing of an assessment framework and lastly comparing the different network designs by use of this assessment framework. This study concludes with evaluating the developed approach.

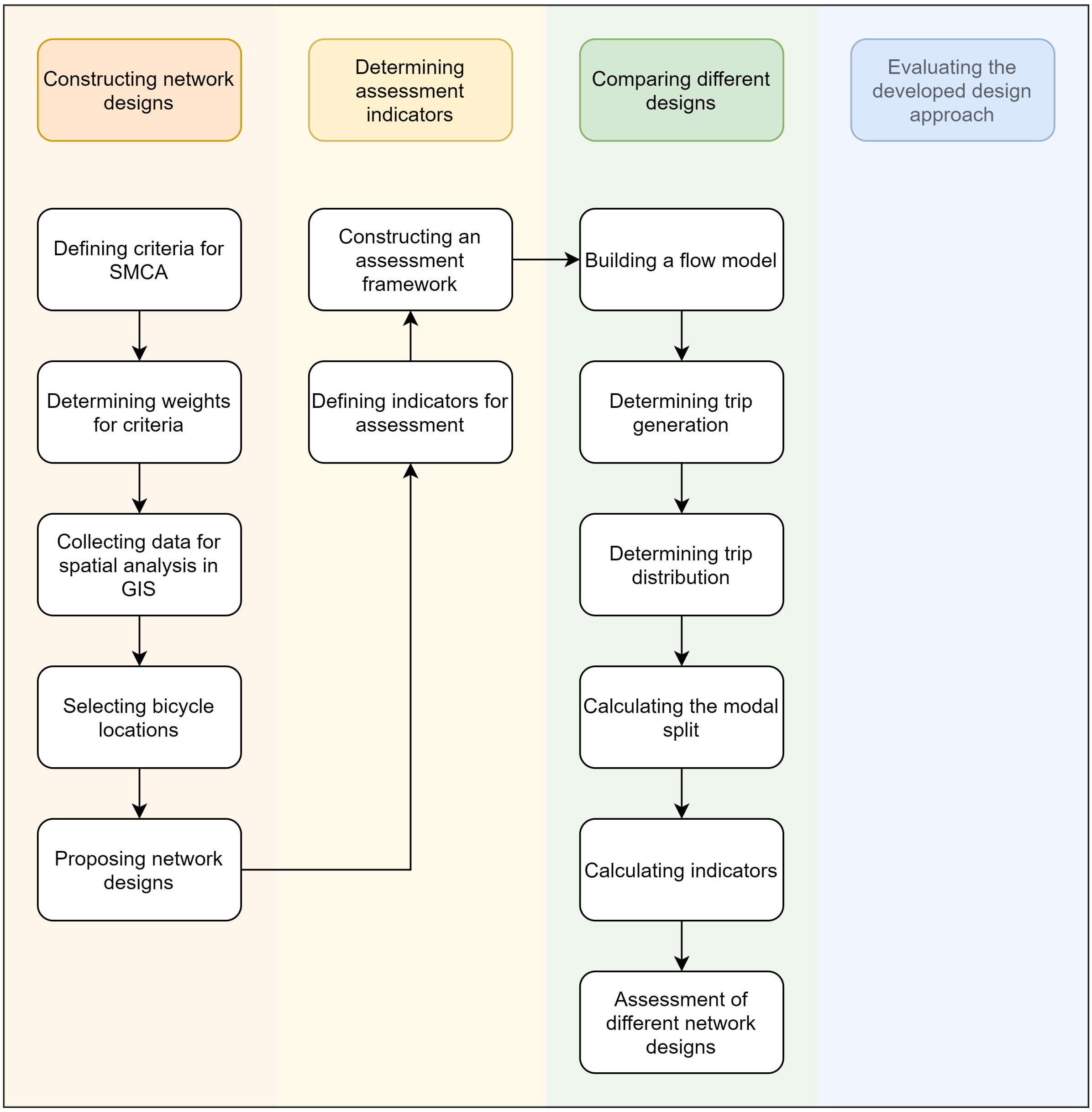

Figure 2.3: Method flow diagram

3

Literature review

While the design of a bicycle-transit network design is slightly unexposed in literature so far, there is research carried out into closely related topics. A selection of relevant previous research is discussed below to get an overview of the current findings and to discover the research gaps. In the first section, previous research about the design of public transport networks is reviewed. The second section shortly discusses some cycling-related studies. In the last section, the focus is on research about the combination of bicycle and transit.

3.1. Public transport network design

In public transport network design, three main stakeholders are often considered: the traveller, the operator and the authority. These three types of stakeholders all have their own objectives (Sochor et al., 2015). The challenge is to balance these opposing objectives, since the optimal design for one of these stakeholders is not the same as the optimal design for another stakeholder (van Nes, 2015). For travellers three components are defining their travel choices: travel time, costs and comfort. The door-to-door travel time is considered to be the most important factor. The public transport network design and the integration with the shared bicycle system influences this travel time. For a public transport network, the travel time is defined by different time elements: access time, waiting time, in-vehicle time, transfer time and egress time (van Nes, 2015). The objective of the traveller is to minimise the total travel time (van Nes & Bovy, 2000). Implementing a shared bicycle network makes it possible to decrease the access and egress time and potentially the waiting time or transfer time, as travellers are able to choose their own route and arrival time at the station. Travellers can decide to cycle to the nearest station to decrease access time, or cycle further to another station to avoid a transfer. An optimal public transport network design in the perspective of the traveller will be a fully connected network to achieve the shortest travel times. Since the use of a bicycle for access and egress influences the travel time, the availability of a shared bicycle system may influence the public transport network design.

The operator, however, aims to have the smallest network possible to reduce costs since the most important interest is the profitability. This means that their objective is to maximise the profit, cost efficiency or revenue per unit of costs. This is defined as revenue divided by operational costs (van Nes, 2015). The operational costs can be reduced by operating a system with less docking stations and bicycles, lower frequencies or reduce service qualities. This indicates that travellers and operators have different perspectives about the optimal network (see Figure 3.1)

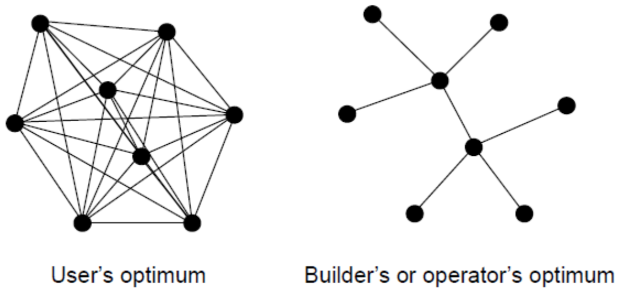

Figure 3.1: Difference in optimal network designs (van Nes, 2015)

The last stakeholder that is involved is the authority. This group consists of the municipality, the government and other public institutions that are responsible for the regulation of transport services. From a societal point of view, their objective is to maximise social benefit (van Nes, 2015). This is profitable for both the traveller and the operator. The objective can be formulated in two ways:

- *Minimise total costs*: this includes the sum of the costs involved in travelling (the total door-to-door travel time, monetised using the value of time) plus the investments, maintenance and operating costs.

- *Maximise social welfare*: this can be defined as the sum of the consumer surplus and producer surplus. The consumer surplus consists of the benefits of all travellers that are able to travel for a lower price than they are willing to pay, and the producer surplus means the profit.

Another difficulty in public transport network design is the choice between line density and stop density (see Figure 3.2). For a network with a high frequency and therefore minimal waiting times, the stop density and line density should be minimised. For the shortest access distance, both should be maximised. For the shortest in-vehicle time or highest speed, the stop density should be minimised while the line density should be maximised (van Nes, 2018).

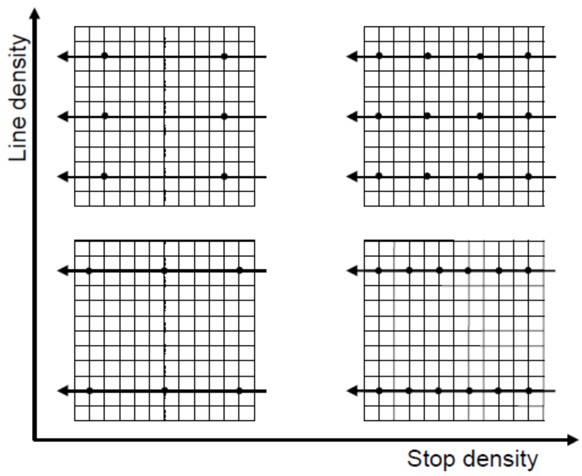

Figure 3.2: Line density versus stop density

According to van Nes (2018), the optimal stop spacing will be between 600 and 650 meters. The optimal line spacing will be between 700 and 750 meters, and the optimal frequency will be 6-8 vehicles per hour. However, these values are based on a single level network. For a multi-modal bicycle-transit network, these values may be different. Rijsman et al. (2019) showed that when bicycle-transit is better integrated, catchment areas can increase the bicycle can cover larger distances. Since public transport operators always have to balance between short access and egress distances and short in-vehicle times, the network can become coarser when access and egress distances become larger.

3.2. Cycling as access and egress mode

Since bicycles are playing a more dominant role for sustainable transport in cities, research is more and more focusing on bicycles as well. Different aspects of bicycles are investigated in the past years. In this section, a selection of studies about bicycles will be discussed that all have a different approach or emphasis.

Access and egress

The bicycle plays an important role as access and egress mode for public transport. van Mil et al. (2018) examined the factors that influence the access and egress to railway stations by bike. With these factors, a conceptual framework to assess railway stations on their suitability for bicycles as access and egress is developed. Since this tool is very useful to determine the potential of different railway stations it would also be interesting to create a tool that investigates the potential for a bicycle-transit system in relation to the public space in a similar way. This tool investigated the potential of a specific station to attract cyclists, while in order to invest in a bicycle-transit system it is required to have insight in the potential of the area in which this network will be built, not only the stations. Therefore, more emphasis on land-use and catchment area shape and size will be interesting for further research.

Rijsman et al. (2019) studied which factors determine the feeder distance and mode choice for trams. One of the main findings of this study is that there are three main barriers for bicycle-tram use: unavailability of bicycles, insufficient bicycle parking spots and unsafe bicycle parking spots. Especially the first barrier can be overcome by a shared bicycle system. Also the aspect of unsafe parking spots possibly becomes less important when people make use of shared bikes. Another finding of this research was an average feeder distance of 400 m. This can be specified into 380 m for walking and 1025 m for cycling, according to this study. This indicates that when more people make use of bicycles, the accepted feeder distance increases. This is an interesting aspect to combine with the optimal stop distances for transit networks that are assumed nowadays.

Catchment area

Cycling as access or egress mode increases the catchment area of transit stations. This is one of the main advantages of cycling compared to walking. Research showed that travelling by bicycle provides travellers more flexibility while the speed of the bicycle, car and transit is almost equal for urban contexts and distances up to 3-5 km (Rietveld, 2000). Assuming a cycling speed that is three times higher than walking (e.g. 15-18 km/hr compared to 5-6 km/hr), the distance that can be covered in the same time is three times longer. According to the law of constant travel time and trip rates (Hupkes, 1982), faster transport results in a larger

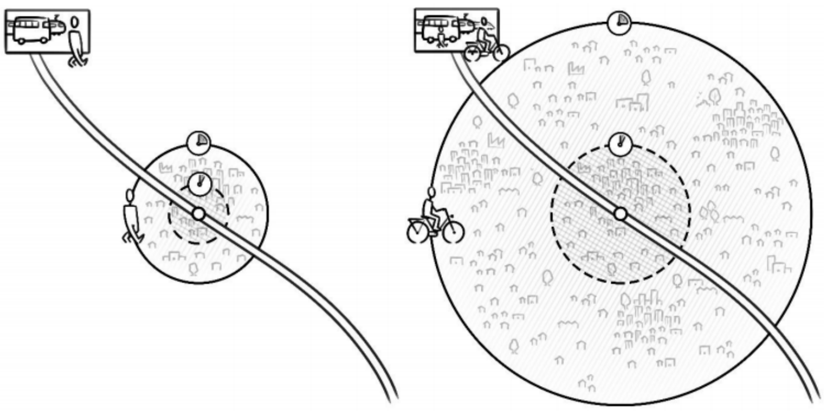

Figure 3.3: Catchment areas for walking and cycling

catchment area. This law states that people will always be willing to travel about the same amount of time, independent on their travel speed. Thus, when they are able to move faster, they will not be travelling shorter, only farther. Figure 3.3 illustrates that the catchment area for cycling will therefore be nine times larger than for walking (Kager & Harms, 2017). In addition, this increase in catchment areas means that there will be overlap in catchment areas of nearby stations. This overlap increases the station choice, which is interesting because of the hierarchy that can be found in public transport services. Typically the faster, more comfortable, direct or frequent services stop only at selected stations. Therefore sometimes access or egress stops that are further away from the origin or destination are preferred above the closest stop because of better journey attributes (Kager & Harms, 2017). For instance, most cyclists prefer cycling further and pass by slower service stations if that means that they can access a station with a higher hierarchy service (Krizek & Stonebraker, 2010).

However, van Nes (2002) concluded that introducing cycling as an alternative access mode only has a small impact on the network design. This can be explained by the fact that mainly on the egress side, most people do not have a bicycle available. Since the influence of bicycles on the catchment area is evident, it would be interesting to investigate whether the availability of shared bicycles influences the transit network design. Previous studies still have not dealt with this influence. Research that was conducted by Claessens (2019), concluded that for travellers cycling 'upstream' (the same direction as their transit route) to a transit stop, the catchment area has a radius of 1000 m, while for travellers cycling 'downstream' this radius will be 2000 m. Therefore it will be interesting to include asymmetric catchment areas. This study also shows that it should be investigated whether it is necessary to have transit stops within walking distances instead of cycling distances. This study did not assume the use of a shared bicycle system, so this will be interesting to investigate.

3.3. Bicycle sharing systems

Since bicycle-sharing systems are becoming more popular, more research is being conducted about different types of bicycle-sharing schemes. Existing bicycle-sharing systems are continuously changing and being improved due to the emergence of new techniques and innovations. The evolution of bicycle sharing systems can be explained by fives generations: (1) free bike systems, (2) coin-deposit systems, (3) smart systems with smart stations, (4) smart bicycles and (5) flexible systems (Bronsvoort et al., 2020, Cannegieter et al., 2018, Shaheen et al., 2010).

The first generation of shared bicycles, was based on the White Bikes in Amsterdam. In this concept, fifty white-painted bikes were distributed over the city and were permanently unlocked so that they can be used freely (Shaheen et al., 2010). However, this concept failed soon due to the problem that the bicycles were often stolen or damaged as there were no incentives to return these bicycles in good condition (Midgley, 2011). Despite these drawbacks, this system was the basis for the first-generation shared bikes. This first generation of free bikes can be characterised as bicycles that are usually painted one colour that are placed unlocked throughout a city for free use.

To overcome the problems of bicycle theft, the concept of Bycyken was introduced in Denmark. This system included locked bicycles that were placed throughout Copenhagen, at designated bike-racks (Shaheen et al., 2010). The bicycles could be unlocked by use of a coin deposit that was refunded after the bicycle was returned. This was the beginning of the second generation bicycle sharing systems, the coin-deposit systems. This generation consisted of distinguishable bicycles (by colour or design), that had to be parked and locked at bicycle docking stations. To unlock these bicycles, the user had to pay a small deposit that was returned after usage (Shaheen et al., 2010).

The third generation of bicycle-sharing systems improved the existing concepts by incorporating advanced technologies for bicycle reservations, pick-up, drop-off and information tracking (Shaheen et al., 2010). This system also consisted of bicycle docking stations where the bikes had to be picked up and dropped-off (Cannegieter et al., 2018). These systems made use of smart cards or magnetic strips cards to unlock the bicycles at the docking stations. Sometimes GPS was used to track the bicycles to prevent theft (Midgley, 2011).

Later, this information technology was not only used for the bicycle stations, but even integrated in the bicycles (Cannegieter et al., 2018). This innovation was possible since the introduction of mobile payments on smartphones and the development of smart locks, including GPS and wireless mobile communication (Boor et al., 2019). These developments made it possible to develop a bike-sharing system without docking stations. This concept is described as the fourth generation of bicycle-sharing systems.

The fifth generation of bicycle sharing systems, consists of the most recent developments. This system includes free-floating bicycles that can be electronically unlocked by use of a a smartphone application (Bronsvoort et al., 2020).

For the pick-up and drop-off of shared bicycles, different systems are possible (Bronsvoort et al., 2020). The first system is a back-to-one system, where the bicycles should be returned to the same station as where they were picked up. Due to this, this system is only suitable for users that have to return to the same location after using the bicycle. In this system, the bicycle is available to the user until the moment of return and is not available to other users in the meantime. An advantage for the operator is that the bicycles will always be returned to the station (Cannegieter et al., 2018).

Another option for docked systems is a back-to-many system (Cannegieter et al., 2018). In a back-to-many system, bicycles can be picked up and returned at multiple locations. The drop-off station does not have to be the same as the pick-up station, making this system also suitable for users who do not want to return to the same location. An advantage of this system is that the bicycles can be used several times a day, however, this system also ensures that the bicycles must be redistributed among the stations.

The last option is a free-floating system, where the bicycles can be dropped-off anywhere (within a specified geographical area). Free-floating is possible since the introduction of smart bikes that can be unlocked via smartphone applications (Boor et al., 2019). An advantage of a free-floating system for the users is that the bicycles can be dropped-off at their destination. However, a free-floating system has negative impacts on the organisation of the public space and for the user, it can sometimes be difficult to find a bicycle (Cannegieter et al., 2018).

Factors influencing the use of bicycle-transit

The first important and often mentioned factor, is how far travellers have to cycle to the station (Claessens, 2019, Rijsman et al., 2019, van Mil et al., 2018). The distance that people are willing to cycle varies between 1 and 3 to 5 kilometers. For trips shorter than 1 kilometer, people are more keen to walk to the station. This distance varies for different types of transit. People are willing to cycle further to more direct transit services (van Mil et al., 2018). Also, it is found that distance travelled by bike is greater when people cycle in the same direction as their destination, and shorter for cycling trips that are in the opposite direction (Claessens, 2019).

In their study, van Mil et al. (2018) also found that the level of transit service influences the attractiveness of the stop. For instance, stations that offer a direct route to people's destination, where no transfers are required, are preferred. Additionally, services with a greater distance and a higher speed attract more users (Brand et al., 2017).

Another often mentioned factor that should be taken into account in defining the potential location for the e-bike docking stations is the level of hills in the area. Also, van Mil et al. (2018) showed that hills cause a decrease in the attraction of cyclists in that area. Therefore, docking stations should be located along routes that are relatively flat and where there is sufficient bicycle infrastructure. However, in the Netherlands this factor is less relevant, since there are not many height differences. Moreover, the quality and the amount of cycling lanes influences the amount of cyclists (Krizek & Stonebraker, 2010, van Mil et al., 2018). It is also concluded that unsafe cycling lanes discourage cycling.

In addition, some user characteristics influence the use of bicycle-transit and therefore the locations for bicycle docking stations should be according to this user demand. Multiple studies Jonkeren, Kager, et al. (2019), Plazier et al. (2017), Shelat et al. (2018), van Mil et al. (2018) showed that both students and commuters are most likely to make use of bicycle-transit for utilitarian trips. Most of the bicycle-transit trips are work-related or home-based. This should be taken into account when defining potential locations for the shared bicycle system. Also shops, supermarkets and recreational attractions such as museums, sport facilities, bars and restaurants are often mentioned destinations. Since a large part of the trips is home-based, the population density in an area and around a transit stop is an important factor to include.

Another factor that is mentioned in multiple studies, is about safe and sheltered bicycle parking (Krizek & Stonebraker, 2010, Pucher & Buehler, 2009, Rijsman et al., 2019, van Mil et al., 2018). One constraint for cycling to the transit station is the possibility to park the bicycle in a safe place on an acceptable distance to the platform. Also, according to Bachand-Marleau et al. (2012), one of the reasons why people prefer shared bicycles is the reduced risk of theft compared to using a personal bike. Therefore the safety aspect of the bicycle parking is less important for shared bikes. However, the above mentioned factors do not influence the potential location for the docking stations, but bicycle parking remains an important aspect for a bicycle-transit system. Also for a shared system there should be sufficient parking spots to prevent situations in which people are not able to drop their bike since there are no spots left. An overview of the factors that were found to be influencing the docking station location is shown in Table 3.1.

Table 3.1: Factors influencing the use of bicycle-transit

Cycling	
Bicycle parking facilities	Krizek & Stonebraker (2010), Pucher & Buehler (2009), Rijsman et al. (2019), van Mil et al. (2018)
Safe cycling infrastructure	Krizek & Stonebraker (2010), van Mil et al. (2018)
Quality of cycling lanes	Krizek & Stonebraker (2010), van Mil et al. (2018)
Quantity of cycling lanes	García-Palomares et al. (2012), van Mil et al. (2018)
Hills	van Mil et al. (2018)

Transit	
Distance between 1 and 3-5 km	Claessens (2019), Shelat et al. (2018), van Mil et al. (2018)
Level of transit service	García-Palomares et al. (2012), van Mil et al. (2018), Brand et al. (2017), Jonkeren, Kager, et al. (2019), Krizek & Stonebraker (2010)

Built environment/Activities	
Population density	García-Palomares et al. (2012), van Mil et al. (2018)
Number of students/schools/ universities	García-Palomares et al. (2012), Plazier et al. (2017), van Mil et al. (2018)
Number of commuters/ companies/office buildings	García-Palomares et al. (2012), van Mil et al. (2018), Jonkeren, Kager, et al. (2019), Plazier et al. (2017)
Supermarkets	Jonkeren, Kager, et al. (2019), Plazier et al. (2017)
Shops	Jonkeren, Kager, et al. (2019), Plazier et al. (2017)
Parks	García-Palomares et al. (2012)
Recreational attractions (museums, theaters, sport, restaurants)	García-Palomares et al. (2012), Plazier et al. (2017)

Reasonably, there are more factors that do influence the bicycle-transit demand, but are not related to the potential bicycle docking station locations. For instance, van Mil et al. (2018) found that the attitude of people towards transit, cycling and cars plays a role in the demand per mode. Also, a study that compared cycling in different countries (Martens, 2004) showed that the weather in a country influences the share of cyclists. Low temperatures and rainy weather have a negative influence on the attraction of cyclists. However, these factors do not have any influence on the location of a docking station as these are constant for the area in which a system will be implemented.

Location allocation modelling

One of the most crucial elements for success in bike-sharing programs turns out to be the station location (García-Palomares et al., 2012). It is important to locate the stations near the residential areas, activities and the public transport network. On top of this, the distances between the stations should be suitable for cycling trips. Lin & Yang (2011) developed a mathematical model to optimise the location of bicycle station. This mathematical model includes a set of origins, destinations, candidate sets of stations and the travel demands to optimise the location of bicycle stations, bicycle lanes, and the paths that should be used from origin to destination. However, it does not include the characteristics of the built environment and street network in order to determine the station locations.

Some previous studies use geographical information systems (GIS) for spatial analysis to investigate possible locations. For instance, García-Palomares et al. (2012) developed an optimisation method for the location allocation for bicycle sharing systems. They proposed a GIS-based method to calculate the spatial distribution of the potential demand for trips. With that, they can locate stations and determine the capacity of these stations. While this study leads to important insights into the station allocation for shared bikes, there is one element that is not taken into account. Both studies assume a given and fixed public transport network. However, to develop an integrated bicycle-transit network, it would be interesting to investigate the possibilities to take into account different public transport network designs.

3.4. Bicycle-transit

In the last years, more research is done into the integration of public transport and bicycles. A literature review conducted by van Mil et al. (2018) investigated the factors influencing the bike-transit combination. These factors are merged into three categories: Transit related factors (system & service, journey and station typology), first/last-mile factors (the regions bikeability, bicycle journey and competition of other modes) and lastly the context factors (culture & attitude and user characteristics). While this paper gives a clear overview of the important factors influencing the bike-transit demand that can be found in existing literature related to this topic, it does not mention how these findings should be applied in practice.

Brand et al. (2017) have developed an assessment framework to compare different bus systems. Such a framework could also be useful for analysing bicycle-transit systems. This framework was used to identify characteristics of different system elements and the influence of these elements on the network integration. The assessment of different bus lines showed that systems with a higher frequency and speed, can attract twice the amount of cyclists on access and egress sides. For access, cycling is more important than for egress. This can be explained by the fact that most people have a bicycle available at the access side of the trip, while at the egress sides bicycles are often not or less available. Therefore it would be interesting to include shared bicycles in this framework. The availability of shared bikes at the egress stations could potentially influence the results of this assessment. Another addition to this framework could be including other modes such as light rail or train, to assess different types of networks.

Only a few studies are focusing on the trips or the travellers. Therefore, in a study conducted by Shelat et al. (2018) the user and trip characteristics of the combined mode are analysed more in-depth. This is an important aspect, as the series of activities that travellers would like to perform has an impact on their mode choice. For example, travellers who bring their children to school on their way to work are more likely to use the car, because of its higher capacity and the number of transfers they would have when travelling by public transport. In this study, bicycle and transit users are clustered. They found that most users of the combined mode are highly educated, have higher incomes and are within the age group from 17-27 years. This finding can be used for estimating the potential of a bicycle-transit system in a specific area. The results also indicate that the market share of the combined mode can be increased by improving the egress trip part. Egress trips have a smaller average distance, since most travellers do not use a bike for this part. Shared bike systems will play a major role in increasing the bicycle use at the egress end. Therefore, they conclude that an integrated design of bicycle infrastructure (both paths and parking facilities) and transit services (including stopping distance and level of service) is required. However, none of the above mentioned studies actually investigates how such an integrated network should be designed.

3.5. Conclusion

The overview of factors influencing the bicycle-transit demand as mentioned by van Mil et al. (2018), is considered in this research. Since the study of van Mil et al. (2018) did not focus on how to apply these findings in practice, this study aimed to investigate that. Their assessment tool was used to analyse the potential of a specific station to attract cyclists, while this research focuses on investigating the potential for a bicycle-transit system, for the area in which this network will be implemented.

From the research of Claessens (2019), it became clear that catchment areas are asymmetric. However, this is not included in this study. Claessens (2019) also mentioned that it should be investigated whether it is necessary to have transit stops within walking distances instead of cycling distances. By assuming that cycling distances can be used as a reference, the range of accessible stations will increase. By means of this research, it will be analysed whether the availability of shared bicycles leads to an increase in accessibility.

Another research that was focusing on location determination of shared bicycle systems, was the study of García-Palomares et al. (2012). Their mathematical model included a set of origins, destinations, candidate sets of stations and the travel demands, to optimise the location of bicycle stations, bicycle lanes, and the paths that should be used from origin to destination. However, it did not include the characteristics of the built environment and street network. Since other studies showed that, to develop an integrated bicycle-transit network, these factors are of influence, this research will include them. García-Palomares et al. (2012) also did not include the connection to the public transport, while this is a major component of this study.

From Shelat et al. (2018), the user and trip characteristics of the bicycle-transit mode became clear. These insights are used in this study, for estimating the potential of a bicycle-transit system in a specific area. However, this study did not investigate how such an integrated network should be designed, according to the trip and user characteristics. This study will therefore focus on this design, by taking into account the potential users.

4

Spatial multi-criteria analysis

This chapter discusses the application of the spatial multi-criteria analysis that was conducted to find potential locations for the shared e-bike docking stations. First, the factors that influence the location are described. These factors are used as the criteria for SMCA. Subsequently it is explained how the weights for the criteria were determined. After describing the criteria and their weights, the next section shows how the data for GIS was collected and which scenarios were analysed. Finally, the integral network designs following from the spatial multi-criteria analysis are presented.

4.1. Factors influencing the docking station location

Many different factors that influence the demand for bicycle-transit and the design of a shared bicycle system were found in literature (see Section 3.3). These factors were used to define the criteria in the multi-criteria analysis to determine the potential locations for the bicycle docking locations.

There were three main factors found to be relevant for the docking station locations, namely the cycling network, the public transport network and the built environment. For the cycling network, it was assumed that only the quantity was important in this study. The quantity was calculated by the distance to the cycling network from each point in the case study area. The quality of the cycling network is assumed to be constant throughout the area and is therefore not taken into account. Also, the safety level of the cycling lanes is assumed to be equal for the total study area. Another factor that is not taken into account is the availability of parking spots. As in this study a docked system is analysed, where parking spots are reserved for these shared bicycles, the problem with finding a place to park is reduced.

For the public transport network, both the distance to the stations or stops and the level of service are considered. There are two modalities that were analysed, namely the train and a the tram. The level of service is included by the assignment of different weights to each stop. The following train stations are included in the analysis: Den Haag CS, Den Haag HS and Voorburg. It is decided to exclude Den Haag Laan van NOI, as this station is poorly accessible from the Binckhorst and it serves the same destinations as at least one of the other stations. In two scenarios a potential new tram line is added. For this new tram line one stop is analysed, located at the Binckhorstlaan near the Zonweg (Lek & Postma, 2018).

The last category is the built environment. For this, the distance to buildings as well as their surface are taken into account. Seven different functions are distinguished for the buildings: residential, education, offices, shops, recreation, health care and industrial/other. The first six functions were mentioned in literature. Since there were buildings that did not fit any of the specified categories, an extra category “other” was added. For this case study area, there are relatively many buildings having an industrial function. As this function was not explicitly discussed in the literature as being an important attraction for cyclists, this category was combined with “other”. Table 4.1 presents the factors that are taken into account and how these factors are quantified in GIS.

Table 4.1: Factors MCA and measurement units

Factor	Measurement unit
Cycling network	distance [m]
Public transport stops	distance [m]
Residential buildings	distance [m] and surface [m^2]
Offices	distance [m] and surface [m^2]
Shops	distance [m] and surface [m^2]
Education	distance [m] and surface [m^2]
Health care	distance [m] and surface [m^2]
Recreation	distance [m] and surface [m^2]
Other/industrial	distance [m] and surface [m^2]

4.2. Assignment of weights

Since the different stakeholders involved in public transport have different preferences for the optimal design, these preferences were included in the weights of the multi-criteria analysis (Strager & Rosenberger, 2006). For each of the four stakeholder groups a few representatives have been asked to fill in a form. These representatives were contacted after an information meeting about the development of the Binckhorst where they were present. In addition, two residents of The Hague were asked to represent the travellers. With these results, a set of weights was determined for each of these stakeholders. Although it was interesting to see the different preferences between the stakeholders, it was chosen to use just one set of weights to reduce the number of different scenarios that should have been analysed. Since the aim was to design a system that is suitable for all stakeholders, the results were averaged two times: first within each stakeholder group and then over all groups. The average of all obtained weight sets per stakeholder group was used for the final analysis, assuming that the preferences of all stakeholder groups count equally.

The stakeholders that have been asked to assign weights were travellers, experts from the municipality, tram and shared mobility operators and land use developers. The respondents consists of four people from the municipality, one land use developer, one shared mobility operator, one public transport operator and two travellers (see Table 4.2).

Table 4.2: Overview of surveyed stakeholders

	Company/Organisation	Stakeholder
A	Municipality of The Hague	Authority
B	Municipality of The Hague	Authority
C	Municipality of The Hague	Authority
D	Municipality of The Hague	Authority
E	APPM	Spatial developer
F	HTM	Operator
G	Next Urban Mobility	Operator
H	Local resident	Traveller
I	Local resident	Traveller

In the form, the stakeholders first had to indicate how important they considered different aspects of the built environment for the location of bicycle docking stations. Therefore, they had to divide 100 points between the three main subjects: the distance to the cycling network, the distance to public transport stops and the distance to buildings. Consequently, they had to assign weights to the public transport stations (Den Haag CS, Den Haag HS, Voorburg and a potential tram stop) in the same way. Table 4.3 shows how the respondents were asked to divide these points to indicate the weights.

After that, they had to assign weights to different types of buildings. Since seven types of buildings have been distinguished, it was difficult to indicate weights directly. Therefore, it was decided to use the Analytic Hierarchy Process (AHP). In this process, all different types of buildings were compared in pairs. Because there were seven different types of buildings to compare, the total number of comparisons was 21 (see Eq. 2.5). The complete form that had to be filled in can be found in Appendix A.

Table 4.3: Example of the weight assignment by dividing 100 points

How important is the distance from the bicycle docking stations to ...	
Cycling network	...
Public transport	...
Buildings	...
Total points	*100*

How important is the distance from the bicycle docking stations to the following stations?	
Den Haag CS	...
Den Haag HS	...
Voorburg	...
Potential tram stop in the Binckhorst	...
Total points	*100*

The weights resulting from the form are shown in Table 4.4. The letters above the columns correspond to the stakeholders from Table 4.2. As can be seen, there is a wide variation in the preferences of the stakeholders. This difference does not seem to be directly related to their function or experience from which they were asked to complete the form. For example, there is a lot of difference between the various experts from the municipality (A to D). However, this is only a small sample in which only a few people have been asked to fill in their perspectives. To more accurately draw conclusions about the perspectives of different stakeholders, more people would have to fill in the form. Consequently, it can be seen how the weights are distributed within each stakeholder group. In this research, the focus was not on analysing the results from different perspectives. This stakeholder input was used to get insight into the overall importance of the criteria.

Although this was a relatively small sample, there were some differences observed between the stakeholders. It can be seen that for all stakeholder groups, the same two categories of buildings were assigned high weights: residential buildings and offices. It was interesting to see that the travellers assigned slightly less weight to the distance to residential buildings than offices; this indicates that travellers consider shared bicycles mainly as a mode of transport that they would use in another city. This is consistent with the finding that travellers consider the connection with public transport very important, while the operators indicated that the distance to buildings is very important. Finally, it can be seen that the travellers and the authority consider HS and CS as equally important, while the developer and operator consider CS as more important. However, only one set of weights was used for this analysis and therefore the average of the four stakeholder groups was calculated. However this sample was not large enough to be representative, it was used to give an indication of possible weights and sketch a possible approach to collect weights. When this approach will be used for decision making, the sample should be enlarged. When having a larger sample, it will also be possible to perform the MCA with different weights per stakeholder group and compare the results for different stakeholder. However, that did not fit within the scope of this research.

The final set of weights resulting from averaging these sets, is used for the multi-criteria analysis. This is presented in Table 4.5. These weights correspond to the expectations based on the literature. As bicycle and public transport can complement each other (Kager & Harms, 2017), it is especially important that the bicycles will be located close to public transport. According to Shelat et al. (2018), the combined bicycle-transit mode is primarily attractive to commuters, which explains that both residential and offices have high weights (21% and 27% respectively). Shared bicycles are especially of added value on the egress side of a trip, because most people already have a bicycle available at the access side. After public transport, the distance to the buildings is the most important. The weight distribution for the train stations and potential tram stop corresponds to the order of size of these stations in terms of passengers per day.

Table 4.4: Weights of different stakeholders

Stakeholder	A	B	C	D	E	F	G	H	I
Cycling network	10%	20%	10%	30%	30%	5%	30%	10%	30%
Public transport	30%	20%	70%	60%	60%	20%	20%	60%	50%
Buildings	60%	60%	20%	10%	10%	75%	50%	30%	20%
	100%	100%	100%	100%	100%	100%	100%	100%	100%
Den Haag CS	50%	40%	30%	40%	80%	25%	45%	40%	30%
Den Haag HS	50%	50%	30%	30%	10%	25%	30%	40%	40%
Voorburg	0%	10%	15%	20%	10%	25%	15%	10%	20%
Potential tram stop	0%	0%	25%	10%	0%	25%	10%	10%	10%
	100%	100%	100%	100%	100%	100%	100%	100%	100%
Residential buildings	26%	30%	14%	10%	20%	41%	11%	7%	22%
Education	9%	9%	9%	10%	7%	5%	16%	13%	10%
Offices	16%	25%	19%	16%	34%	26%	23%	37%	24%
Shops	16%	9%	9%	14%	13%	5%	14%	17%	9%
Recreation	11%	10%	12%	18%	11%	6%	17%	8%	9%
Health care	10%	10%	26%	18%	9%	6%	9%	8%	18%
Other/industrial	13%	7%	10%	14%	8%	12%	10%	9%	7%
	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4.5: Final set of weights for the SMCA

Cycling network	21%
Public transport	45%
Buildings	34%
	100%
Den Haag CS	48%
Den Haag CS	29%
Voorburg	14%
Potential tram stop	9%
	100%
Residential buildings	21%
Education	10%
Offices	27%
Shops	12 %
Recreation	10%
Health care	11%
Other/industrial	10%
	100%

4.3. Data collection in GIS

Two hypothetical spatial development scenarios were evaluated in the multi-criteria analysis. To deal with uncertainty in the land use development plans, different scenarios were included. These scenarios were used to see whether the extent of area development influences the location choice. The scenarios that were considered are one scenario consisting of the available development plans and another scenario with additional development plans. The scenarios are described in more detail below. The first step was to define the current situation and collect the required data in QGIS. This was used as the base data set. To create the first scenario, the current land use plans for the Binckhorst were collected and this information was added to this base year scenario. For the second land use scenario, an assumption was made for additional development plans. New buildings have been added that are similar in function and floor space to the existing plans.

4.3.1. Setting up the data

The first step was to search for the current road network in the open data source PDOK. This was used for the criterion that the docking station has to be located close to the cycling network. To see which roads are being cycled, CyclePRINT has been used (The Urban Future, 2016). This shows the bicycle intensities of a week of counts in 2016. The map with these intensities was compared to the map that was downloaded from PDOK. As can be seen in figure 4.1, the map from PDOK contained more roads than the map with cycling intensities. This may indicate that not all roads were cycled during this counting week. However, since the traffic in and around the Binckhorst has increased in recent years because there are more residents, it is likely that in the current situation more (different) roads will be used by cyclists. It was therefore assumed that the map that was loaded from PDOK represents the current bicycle network and could be used in the analysis. Figure 4.1 shows the map with bicycle intensities on the left (The Urban Future, 2016), and the map from PDOK that was used on the right.

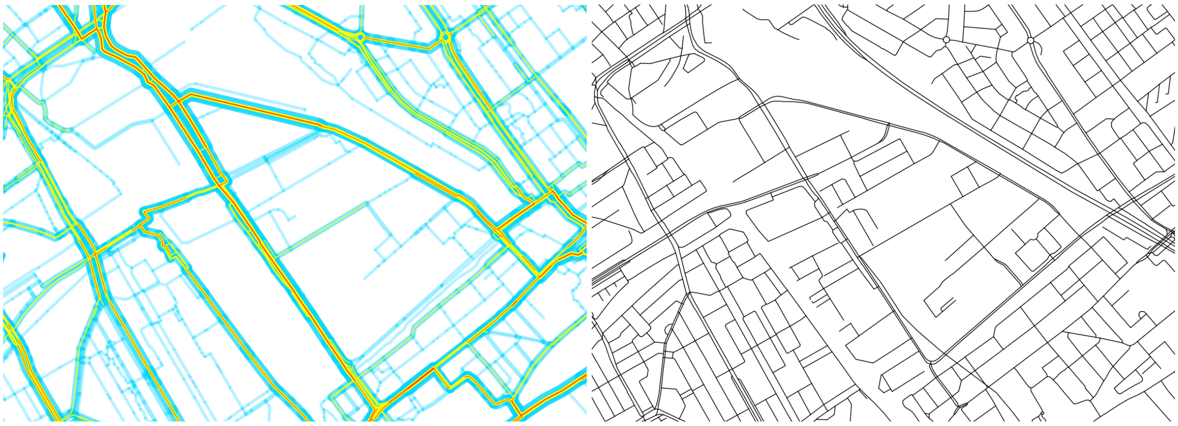

Figure 4.1: Cycle network in CyclePRINT (left) and PDOK (right)

After that, the buildings and corresponding addresses in the study area were collected. These were obtained from the Basisregistratie Adressen en Gebouwen (BAG) from the Kadaster (2019). The buildings were used to see the actual location, and the addresses were used for the analysis as these include information about the locations. Information that was available for each address included the total floor area (m^2) and the purpose of use (for instance: residential, offices, education, shops). This information was used to calculate the number of trips each address produces and attracts. Lastly, the train stations in the Netherlands were loaded in GIS. The train stations that are taken into account in this analysis are Den Haag CS, Den Haag HS and Voorburg. There are no other public transport modes included in the base scenario.

It has been decided to use the gross floor areas of all buildings to calculate the number of trips generated by that building. This calculation is based on the function a building has. Before calculating the number of trips, the level of urbanisation had to be determined (CROW, 2018). As the number of addresses per km^2 in 2019 in the Binckhorst was 3.473 according to CBS StatLine (2019), the area can be classified as extremely urbanised (see Table 4.6). In areas with this level of urbanisation, the car use is about 26% in general (CROW, 2018). However, the car use differs per purpose. For instance for travelling to work 41% car use can be seen, while for social and recreational purposes this is only 21%. There is also made a distinction between the city centre, the centre edge, the built-up area and the rural area. The Binckhorst is considered to be in the second category, as it adjoins the city centre.

Table 4.6: Degree of urbanisation (CBS, 2019)

Degree of urbanisation	Number of addresses per km^2
Extremely urbanised	More than 2500
Strongly urbanised	1500 to 2500
Moderately urbanised	1000 to 1500
Hardly urbanised	500 to 1000
Not urbanised	Fewer than 500

After defining this classification, it was determined how much car traffic different locations generate. This is determined on the basis of the function of a building. CROW (2018) published traffic generation numbers for many different building purposes, subdivided into six main categories namely: residential, office, shopping, sport, culture and leisure, food service industry, health care and education. Within these categories again a distinction is made for instance for different types of houses (e.g. bungalows, apartments, rental or owner-occupied homes). However, since the data that was obtained from the Kadaster (2019) does not contain this level of detail, in some cases it was needed to take an average of multiple subcategories or it was needed to make an assumption about which category most closely matched the actual purpose.

CROW (2018) also defined a percentage of car use for different types of trip purposes. These percentages are used to calculate the total number of trips that are generated by different buildings, instead of only car trips. Table 4.7 shows the results of these calculations[1].

For residential buildings, CROW (2018) defined 14 types of houses. For all these different types of houses, an estimation for the average number of car trips is given. For the Binckhorst, a mix of different types of houses is assumed. Therefore, the average of all these values is used to calculate the total number of trips per household. For this category, the number of trips was thus calculated per household instead of per 100 m^2 gross floor area.

For offices, the CROW (2018) presented a traffic generation indicator of on average 9,4 trips per 100m^2 floor space. This was used to calculate the traffic for each building.

For education, no traffic generation indicators were presented, only parking indicators. Therefore, it was necessary to make an assumptions for the number of trips per day. For the current situation the type of education was unknown, but for the future plans it concerns primary education. Therefore, the estimation of this indicator is based on primary education. It is assumed that each student generates four trips per day, which is calculated as follows: first of all, there are four trips a day for the person who brings and picks up the children (to school and back in the morning, and to school and back in the afternoon). The children themselves go to school in the morning and back home in the afternoon, which means two trips a day. Assuming that parents bring on average two children, this results in eight trips per two children. For this reason, an average of four trips per child per day was assumed. Combining this with the assumption that on average one child per 4.9 m^2 is considered for primary schools (OCO, 2012), results in 20.4 children per 100 m^2, and thus 81.6 journeys per 100 m^2 gross floor area (GFA).

For shops it was assumed that the Binckhorst can be considered as the centre of an urban district. Therefore, the traffic generation indicators for this type of shops were used.

The purpose recreation was constituted by three types of functions: meeting, sports and lodging. It was chosen to calculate the average of these three purposes. For sports, again a wide variation of options was presented. In this case, the values for a sports hall were used as this was assumed to be the most general of all options, making it most applicable for different sport-related locations. For lodging, the third category for hotels was chosen as there were different locations with this function, while there was no information about the type of accommodation. This third category was described as middle-class hotel. For buildings with a meeting function, there were no values presented. For that reason, the average of the above mentioned two functions was calculated and used.

[1] These numbers represent car use on an average weekday (CROW, 2018).

For health care, also different types are specified. This varies from general practice to dentist, hospital or pharmacy. It was chosen to use the values for a health care centre, since this was described as a location with various types of health care in one building. Because it was not known what type of health care was located in each building, this value was used for all buildings with a health care function. As this indicator was expressed in number of trips per treatment room, it was needed to calculate the number of trips per 100 m^2. It was assumed that an average treatment room equals 60 m^2 (Landelijke Huisartsen Vereniging, 2014), meaning that there are approximately 1,67 treatment rooms per 100 m^2. Multiplying this with the 41 trips that are generated per treatment room per day (CROW, 2018), results in 68,3 trips per 100 m^2 GFA.

For the last category, other purposes, assumptions has to be made since there were no indicators for this category. In this analysis, all objects having “other” or “industrial” as their purpose, were grouped. The values for industrial purposes were used, as this was distinguished by CROW (2018).

Table 4.7 shows the calculated traffic generation per purpose. The second column shows the percentage of trips that are made by car. The values presented by CROW (2018) are the car movements only. Therefore, this percentage is used to calculate the total of all trips (all modes). Since CROW (2018) gave a minimum and maximum number of trips generated, the average is calculated for this analysis. The last column shows the units are used for the calculation.

Table 4.7: Trip generation per purpose (based on CROW (2018))

	Car use	Traffic (car only) min-max	Total traffic min-max	Average trips per day	Units
Residential	26%	3,4 - 4,1	13,1 -15,8	14,4	[/household]
Education	n/a	n/a	n/a	81,6	[/100 m^2 GFA]
Offices	41%	3,0 - 4,7	7,3 - 11,5	9,4	[/100 m^2 GFA]
Shops	20%	32,3 - 49,5	161,0 - 247,5	204,3	[/100 m^2 GFA]
Recreation	37%	6,9 - 9,2	18,6 - 24,9	21,8	[/100 m^2 GFA]
Health care	n/a	n/a	n/a	68,3	[/100 m^2 GFA]
Other	29%	6,1 - 8,1	21,0 - 27,9	24,5	[/100 m^2 GFA]

4.3.2. Land use scenarios

Since the case study that is considered in this research represents a development area, the land use will change and increase in the coming years. In order to include this uncertainty in this research and to be able to analyse the influence of the extent of area development, two different land use scenarios were investigated in the SMCA. Both scenarios will be explained below.

Land use scenario 1: Current development plans

For the first land use scenario, the base year scenario was used as a starting point. By consulting the published development plans for the Binckhorst, an overview of the plans was obtained (WeThinkBinck, 2020). These plans contain new buildings, as well as the renovation of existing buildings. For implementing these plans in GIS, they had to be expressed in terms of floor space to be able to conduct the multi-criteria analysis. This was needed for education as it was only given that there will be built one primary school. The corresponding floor area was calculated by use of the average number of children at a primary school (Onderwijs in cijfers, 2018) and the average floor space required per student (OCO, 2012). With this, all development plans were expressed as required floor space and the plans were implemented in the layer of the base year to construct the first scenario.

Land use scenario 2: Increased urban development

The second scenario is a hypothetical scenario in which assumptions have been made for additional development projects. Since large parts of the Binckhorst are not yet included in the transformation, it is likely that even more land use development will take place in a few years. To take this into account, there is a hypothetical extreme scenario analysed, including additional development plans. Three new buildings have been added. The floor spaces and functions of these buildings are based on current plans. Because there is also a difference in size in the current plans, it was decided to add one relatively small, one medium sized and one large project to this second scenario. The locations of the new projects were chosen because there is currently space available at these locations, and because most of the current plans are located on south of the Binckhorst. It is important to note that the location of these new buildings influences the results of the MCA. If other locations were chosen, this might lead to different results. An overview of the current and added plans can be found in Table 4.8. Figure 4.2 shows a map with the corresponding locations of these projects.

Table 4.8: Overview of land-use development plans

	Name	**Address**	**Project**
1	B-Proud	Binckhorstlaan 117	870 houses 8000 m^2 education 1600 m^2 office space 1000 m^2 shops 1200 m^2 + 500 m^2 recreation 650 m^2 + 1500 m^2 health care
2	Binck City Park	Binckhorstlaan 135	1100 houses
3	Binck Blocks	Binckhorstlaan 215	289 houses
4	Binckpark	Verlengde Zonweg	10 houses
5	Juno Park	Binckhorstlaan-Jupiterkade-Trekvliet	650 houses 1 primary school (1100 m^2) 4000 m^2 education
6	Binck kade	Binckhorstlaan 401	113 houses
7	Binck plaats	Binckhorstlaan 401	46 houses
8	Frank is een Binck	Saturnusstraat 50	200 houses
9	One milky way	Saturnusstraat 16	200 houses
10	Stella en Luna	Maanplein 110	250 houses
11	Universe	Maanplein 32	21000 m^2 office space
12	Hoekblok Maanplein	Maanplein	164 houses
A	*Small hypothetical building*	*Plutostraat*	*200 houses*
B	*Large hypothetical building*	*Mercuriusweg*	*800 houses* *5000 m^2 office space* *500 m^2 recreation* *500 m^2 health care*
C	*Medium hypothetical building*	*Wegastraat*	*500 houses* *1000 m^2 office space* *300 m^2 shops*

4.3.3. Network plans

In addition to the land use development scenarios, two different network plans are evaluated. The first network that is evaluated is based on the current plans for a tram connection between Den Haag CS and Voorburg. The second network only contains the current train network. Both networks will be explained below.

Public transport scenario 1: Tram

The first network that has been analysed is based on the current plans of the municipality for realising high-quality public transport between Den Haag CS and Voorburg. The plans include both bus rapid transit and light rail (Lek & Postma, 2018). As was found in literature, public transport having a higher speed and more comfort will attract more cyclists (Brand et al., 2017). Therefore, it has been decided for this study to investigate a light rail (tram) system. It is assumed that this future tram will make use of nearly the same route as

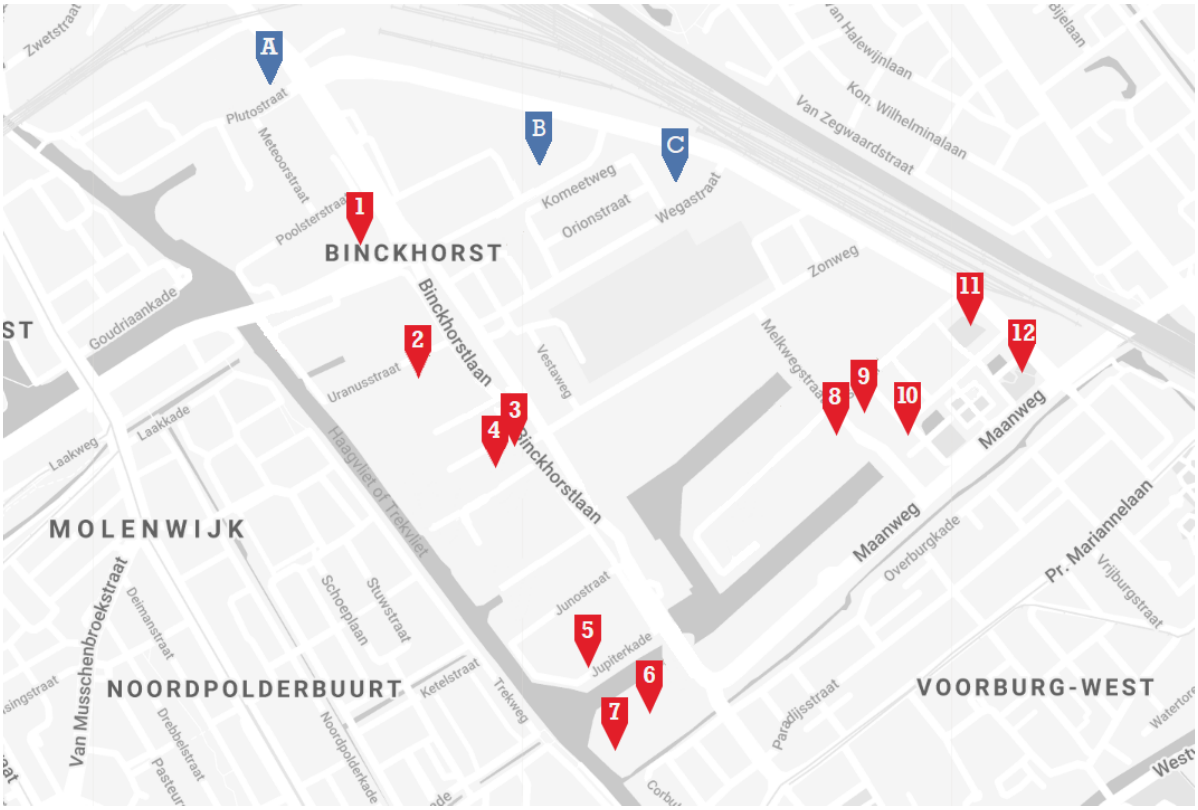

Figure 4.2: Map of development plans for the Binckhorst (WeThinkBinck, 2020)

the busses do in the current network. In was chosen to only locate only one stop in the Binckhorst, in order to achieve a high speed. This stop will be built at the intersection of the Binckhorstlaan and the Zonweg, centrally located in the neighbourhood and close to most of the new buildings (Lek & Postma, 2018).

Public transport scenario 2: Train and bicycle only

The second network plan that was investigated, only includes train. This means that both busses and trams are not taken into account in this situation. Since the Binckhorst is a relatively small area with multiple train stations around, it should be accessible by bicycle from the train stations, according to the bicycle catchment areas (Claessens, 2019, Rijsman et al., 2019). For that reason, this situation was interesting to analyse.

4.4. Multi-criteria analysis in GIS

In order to complete the spatial multi-criteria analysis, the case study area was divided into a grid, with each cell representing a possible location for a bicycle docking station. A grid of 50 by 50 meters was used for this analysis. A larger grid would lead to less accuracy. For instance, if the location potential would have been calculated for a grid of 200 by 200 meters, it means that every location inside this 200 by 200 meters square, will be assigned the same score which makes the results inaccurate. However, if the grid is too small, the results may also be not representative. This will happen because in the extreme land use scenario, the new buildings are included by a single point instead of multiple points, covering the actual size of the building. This is because it is very time consuming to add such a number of addresses manually in GIS and the precise location will still be still uncertain. If a grid becomes smaller, the influence of this uncertainty is larger.

To be able to compare all criteria scores, a classification was made for all criteria, resulting in a score between 0 and 4. In this classification, 0 means that a location scores poorly on this specific criterion, and a score of 4 means that the location scores high on the criterion. By calculating the weighted average of all criterion scores, the total score can be calculated (as was explained in Section 2.1.5).

The first criterion was the distance to the cycling network. For all criteria that consider the distance, the euclidean distances were calculated. The following classification was considered for the distance to the cycling network:

Classification of distance to the cycling network:

- 4: 0 - 25 m
- 3: 25 - 50 m
- 2: 50 - 75 m
- 1: 75 - 100 m
- 0: 100+ m

The second factor that was included in the SMCA was the distance to public transport stations and stops. For public transport, the distance classification was a bit more complex. A classification was used that includes that locations on both a short and a long distance will have less potential. First of all it is assumed that a bicycle docking location will be required at each of the three train stations. Subsequently, the next shared bicycle station does not have to be placed very close to these docking stations, because the shorter the distance, the less likely that travellers will travel by bicycle. However, the longer the distance becomes, the more attractive bicycles will be. This assumption holds until the distance becomes too long that it will be too far for cycling. At that point, the classification decreases.

Classification of distance to public transport:

- 0: 0 - 400m
- 1: 400 - 800m
- 2: 800 - 1200m
- 3: 1200 - 1600m
- 4: 1600 - 2000m
- 3: 2000 - 2400m
- 2: 2400 - 2800m
- 1: 2800 - 3400m
- 0: 3400+ m

Lastly, the distance to buildings and their size was included in the MCA. These two different aspects of buildings were taken into account separately. First, again the distances were classified. It was assumed that a distance of 400 meters is acceptable to walk to a shared bicycle station (Clark & Curl, 2016). Since a shorter distance will be more attractive, the first 200 meters will get the highest score. Buildings on a distance more than 400 m will also included, but will be assigned a lower score because they will be less attractive for a bicycle docking station.

Classification of distance to buildings:

- 4: 0 - 200
- 3: 200 - 400
- 2: 400 - 600
- 1: 600 - 800
- 0: 800 +

The second aspect of the buildings that was considered, was their size. This is expressed in number of trips that are generated in each building (CROW, 2018). In order to define a classification for the number of trips, first the total number of trips per grid cell was calculated. Since there is no defined minimum for the number of trips that ensures the potential of a location for a bicycle docking station, quartiles were used for this classification. This means that all grid cells were divided over four categories, where each of the categories includes 25% of the grid cells. Cells where no trips are generated will be assigned to the classification 0. That resulted in the following classification:

Classification of number of trips:

- 0: 0
- 1: 0 - 99 (25%)
- 2: 99 - 335 (25%)
- 3: 335 - 1012 (25%)
- 4: 1012 - 24971 (25%)

As described before, a distinction in importance has been made between the different public transport stations (CS, HS, Voorburg and the tram stop) an between the different types of buildings, by means of weights.

4.4.1. Resulting heat maps

By use of these classifications, each grid cell has a score between 0 and 4 for each of the criteria. By calculating the weighted average for the criteria for each grid cell, the total scores were obtained. This results in the following heat maps (these can also be found in Appendix C):

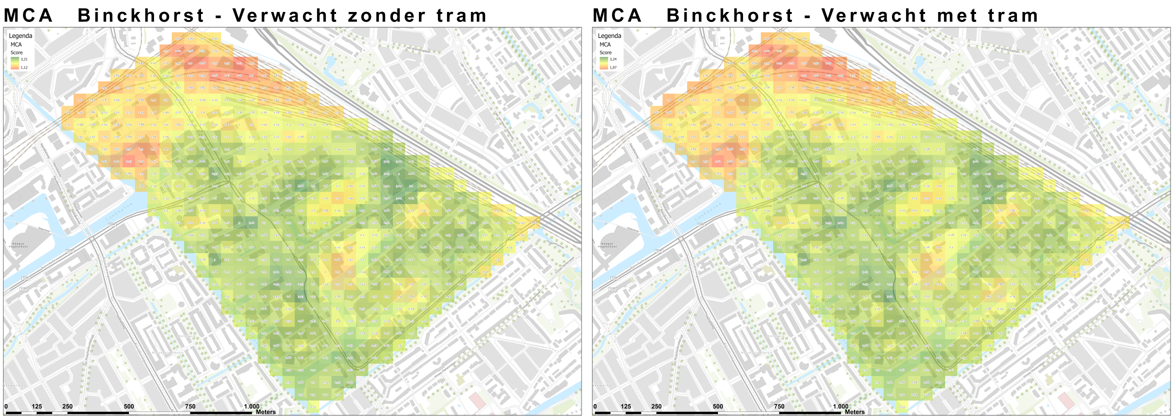

Figure 4.3: Heat maps for the expected land use scenario

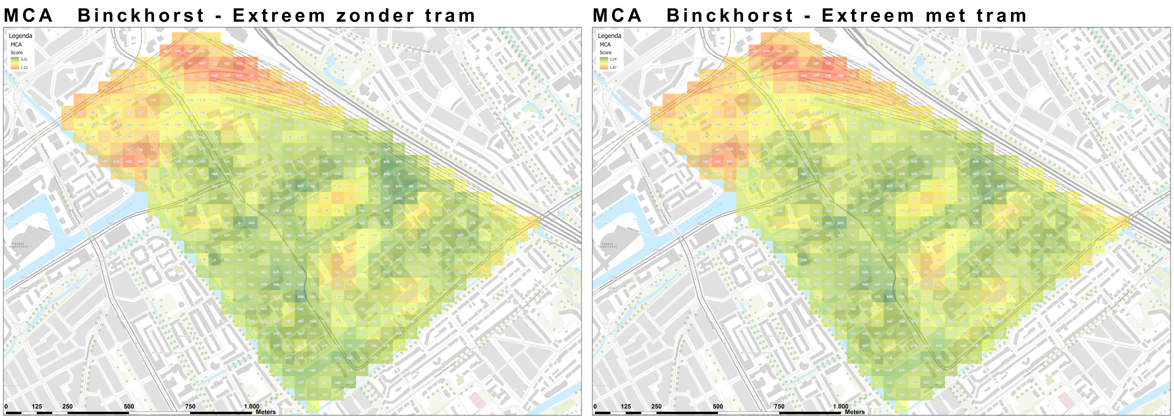

Figure 4.4: Heat maps for the extreme land use scenario

First of all, it can be seen that relatively low scores were achieved on the north side of the Binckhorst, i.e. the potential for bicycle station is the lowest the north. This can be explained by the fact that the train stations Den Haag CS and Den Haag HS are located north of the Binckhorst, and both stations are assumed to have a considerable influence on the bicycle potential. Because these stations are at a distance of 1200 meters or

Figure 4.5: Buildings Binckhorst in GIS

less, they are assigned low scores. There are also (especially in the expected land-use scenario) only a few buildings on the north side of the Binckhorst. As a result, there are no high scores achieved for the buildings and trips. This influence of buildings is also visible in other parts of the case study area. It can be noticed at the Sint Barbara cemetery and the Binckhaven, where also lower scores are achieved because of the lack of buildings.

There are only few differences visible between the four combinations of land use and public transport. In the situation with tram, a higher maximum score is achieved, which is 3.24. In the scenario without the tram, the maximum score is 3.21. This highest score can be found close to the potential tram stop. It can also be seen that the scores are increasing in the extreme land-use scenario, at the three locations where new construction has been added. This was caused by the fact that these locations generate more trips and the distance to buildings logically decreases.

4.5. Potential integrated bicycle-transit networks

The purpose of the SMCA was to select potential locations for the docking stations of the shared bicycles. These docking station locations are selected as follows: The location with the highest score will be the first to be assigned a shared bicycle docking station. Then a buffer of 300 meters was created around it, where no second bike sharing station may be placed inside to avoid two bicycle station too close to each other. Next, the location with the highest score was searched for again and the second bicycle sharing station has been placed here. A buffer of 300 meters will be created around this again. By repeating this method, all bike station locations were chosen, ensuring that the distance between two stations will never be less than 300 meters. This density was assumed since it ensures that users can easily find a bicycle when they want to use it and can easily return it where they want (García-Palomares et al., 2012).

	Expected land-use	Extreme land-use
Inhabitants	10580	13730
Number of bicycles per inhabitant	0,005	0,005
Total number of bicycles in the system	53	69
Number of bicycles per station	12	12
Number of bicycle docking stations	**4**	**6**

Table 4.9: Calculation of number of bicycle docking stations

The number of shared bike stations to be built (and thus the number of iterations of the above described method) is determined by the number of inhabitants of the area. García-Palomares et al. (2012) shows that different bicycle sharing systems maintain different quantities for the number of bicycles per inhabitant. This varies approximately from 1 bicycle per 1000 inhabitants to 10 bicycles per 1000 inhabitants. For this study, the average of these was assumed: 5 bicycles per 1000 inhabitants. These shared bicycles are then divided over a number of bicycle docks. On the one hand, more shared bicycle locations means that there are more options for picking up or returning the bicycle, however fewer bicycles per station also increases the chance that there is no bicycle available at the chosen bicycle station. Comparable bicycle sharing systems consider an average of 12 bicycles per station (García-Palomares et al., 2012, Midgley, 2011). This number is therefore also assumed for this study. That results in up to 4 bicycle docking stations in the expected scenario and 6 in the extreme scenario (see Table 4.9).

Since the differences between the four land-use and public transport scenarios are very small, the above described location selection steps result in the same bicycle docking locations in each scenario. The figures 4.6 and 4.7 illustrate the expected land-use scenario with the potential tram, but the results for the other scenarios are the same.

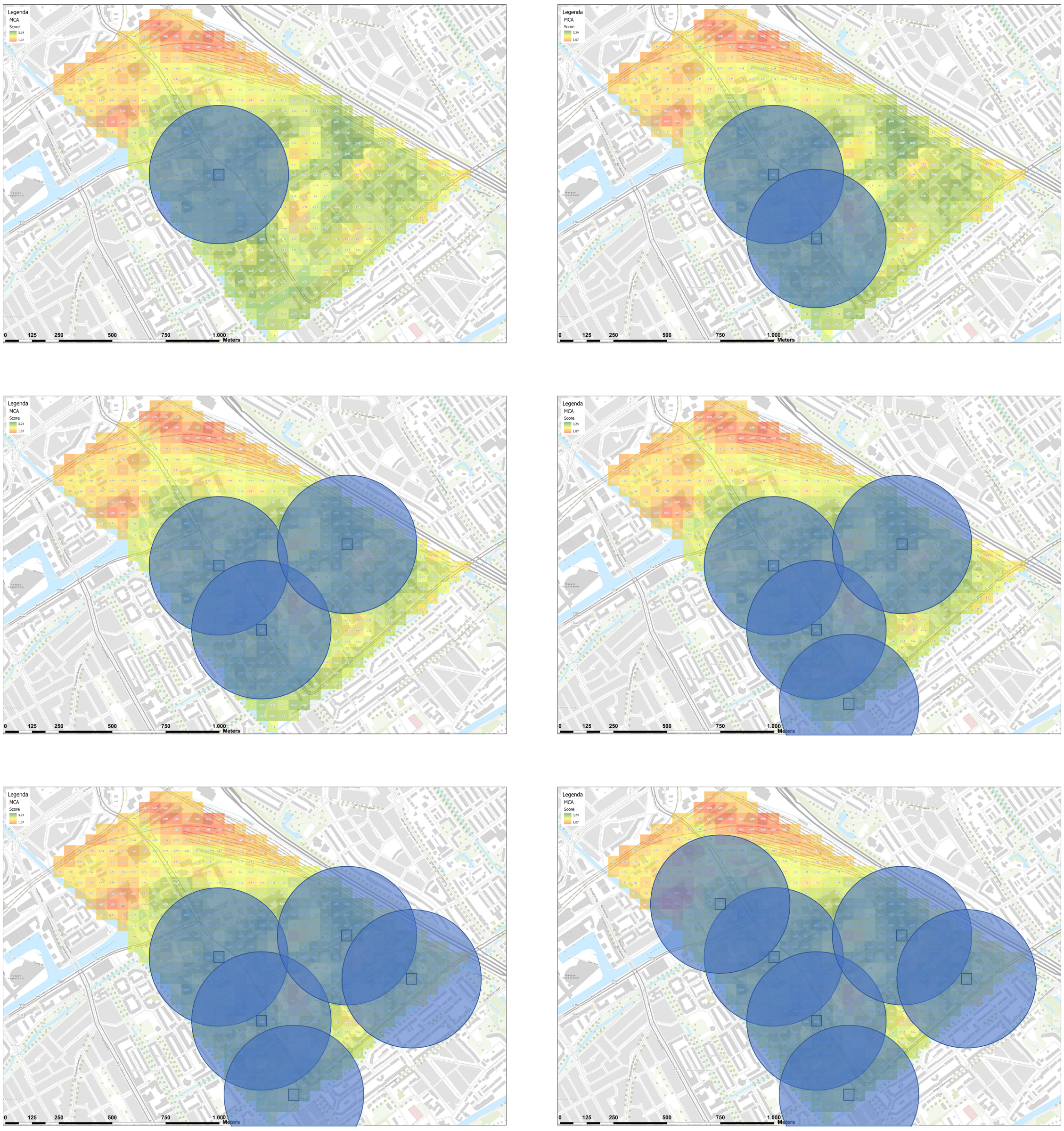

Figure 4.6: Iterations of the bicycle docking station selection

Bicycle docking locations and potential tram line

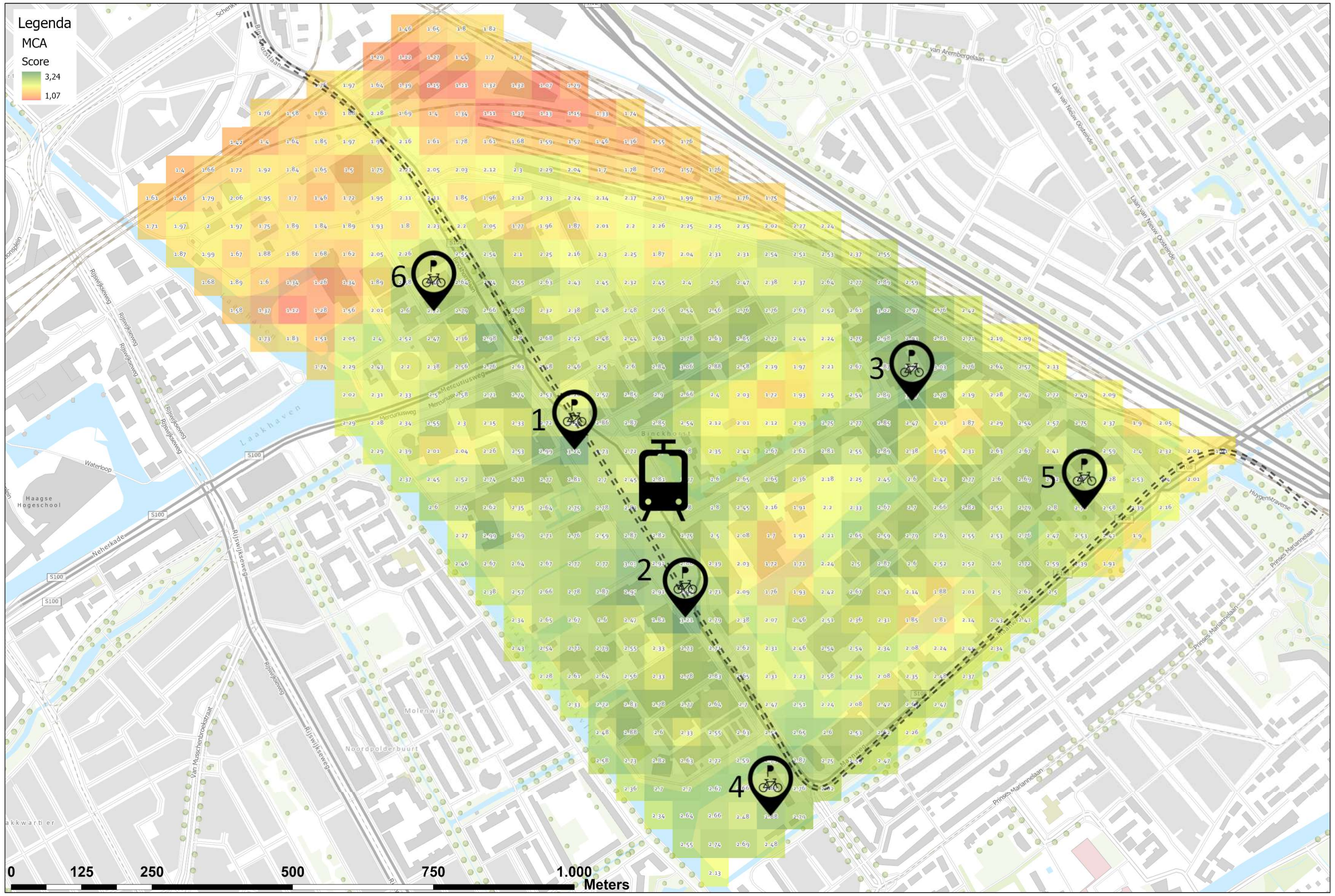

Figure 4.7: Final locations of the docking stations

5

Assessment of different network designs

Before the different networks could be compared, a selection was made of the assessment criteria. There are various indicators of accessibility considered in literature. However, not all indicators are suitable for the purpose of this study and some indicators require information that is not available. Therefore, in this chapter a selection is made of the indicators that are important in this study and that have been used to compare the networks.

5.1. Assessment framework

The purpose of this research was to investigate the potential of a bicycle-transit network to keep the city accessible. An important goal of public transport and shared mobility is to contribute to the accessibility and to ensure congestion reduction (Bakker & Zwaneveld, 2009). However, accessibility is a broad concept. Different indicators can be used to measure accessibility.

Geurs & Van Wee (2004) makes a distinction between four different approaches of measuring accessibility (Kansen & Jorritsma, 2018):

1. The first approach focuses on infrastructure. This involves both the physical infrastructure (e.g. the number of kilometres of roads or rail) as the infrastructure use (e.g. the length of the traffic jam, the average speed on the road network).
2. The second approach focuses on activities. This means that the number of activities that can be reached within a specific travel time or travel distance will be considered. This not only includes the available roads, but also the proximity of people, companies, jobs, shops and other facilities.
3. The third approach involves time and space. This approach focuses on individuals and their possibilities or limitations in time and space to participate in activities at a specific location, within a given travel time or budget. In order to use this approach, a lot of individual traveller data is required.
4. The last approach focuses on transport-related utility. This utility can be expressed as generalised transport and travel costs. This is a measure of all the costs and efforts (time and effort, expressed in money) associated to a specific trip. This approach is widely used in economic studies such as cost-benefit analyses.

In this research, the focus is not on the infrastructure, but on the bicycle-transit system. Therefore, the first approach is suitable for this study. The second approach partly overlaps with the location potential that was determined by the multi-criteria analysis, and has already been included in this study. The third approach requires a lot of detailed information about travellers, which is not available. In addition, such a level of detail is not necessary to provide an answer to the research question in this study. The fourth approach is the most applicable to this research, since it makes it possible to also include different qualitative context factors. Therefore, the generalised travel costs have been used here to calculate travellers' resistance to various alternatives.

This approach, in which accessibility is described as the effort travellers have to make to get to their desired destination, is also mentioned by Bakker & Warffemius (2017). This definition captures the resistance of the traveller by the following aspects: travel expenses, travel time, (un)reliability and convenience and travel comfort.

The first two indicators, travel time and travel expenses, are easily measurable and have therefore been included quantitatively in this study. The last two, (un)reliability and comfort, are less easy to quantify. These are therefore included qualitatively in the assessment.

Eijgenraam et al. (2000) discusses an extensive number of indicators to measure accessibility. Due to the scope of this study, not all indicators mentioned in this report are relevant. Indicators that are interesting for this research are the travel times and travel time gains, reliability and number of travellers. However, for instance punctuality, environmental effects and safety are not included.

In conclusion, the indicators that are assessed by use of the flow model are:

- Travel time
- (Generalised) travel costs
- Number of travellers (per mode)

The indicators that were not included quantitatively in the flow model, but that were taken into account in the qualitative assessment, are:

- Un(reliability)
- Convenience and travel comfort
- Investment costs

6 Traffic flow model

To assess the network designs on the indicators that were proposed in Chapter 5, these indicators had to be calculated for each network design. A flow model was used to get insight into the traveller flows over the networks, which were used to calculate the travel times and travel costs. First, the model set up was explained in Section 6.1 and in the next section the results are presented (6.2). Additionally, a sensitivity analysis was performed (Section 6.3) and some policy measures were analysed (Section 6.4). The chapter concludes with the assessment of the network designs in Section 6.5.

6.1. Model set up

To assess the proposed networks on the indicators presented in Chapter 5, the passenger flows over the different networks have been calculated. A flow model has been built to gain insight into these passenger flows. The structure of this flow model is based on the four step model (see Section 2.3). Since the travel times to and from different locations in the Binckhorst vary, the area was divided into twenty different zones. This definition of zones was obtained from Gemeente Den Haag (2018).

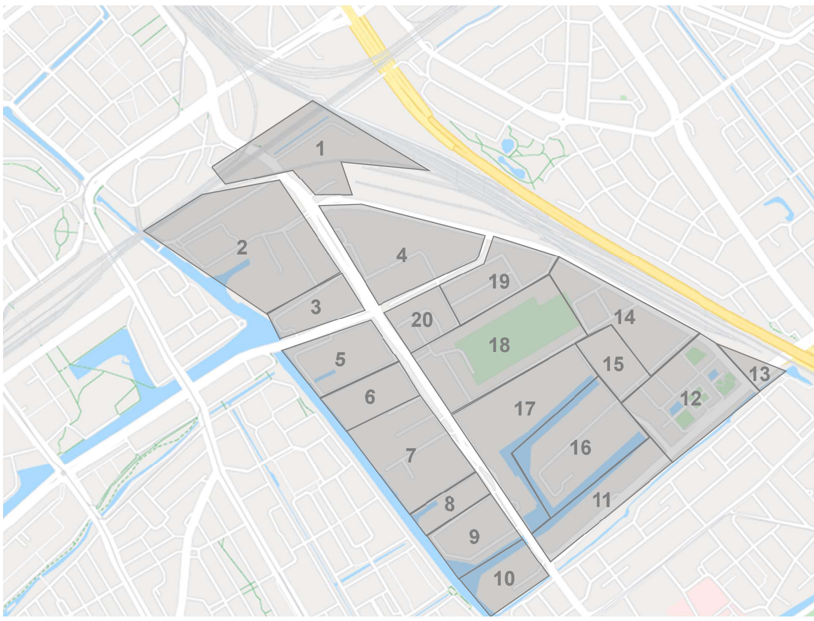

Figure 6.1: Different zones within the Binckhorst (Gemeente Den Haag, 2018)

Table 6.1: Zone numbers and corresponding names

Zone	Zone name
1	Binck 36
2	Trekvlietplein / Poolsterhaven
3	Poolsterhaven - Zuid
4	Spoorboogzone
5	Trekvlietzone - Noord
6	Binckhorsthof & Kasteel
7	Trekvlietzone - Midden
8	Junostraat
9	Junopark
10	Binckeiland
11	Maanhaven
12	Maanplein
13	Haagse Arc
14	Regulusweg
15	Immorand
16	Binckhaven (kop)
17	Industriecluster
18	Begraafplaats
19	Komeetweg / Orionstraat / Wegastraat
20	Polluxstraat

It was assumed that the potential users of the bicycle-transit system, are travellers between the train stations and the Binckhorst. Therefore flows that are considered in this model are the flows between these 20 zones and the three train stations (Den Haag Centraal, Den Haag Hollands Spoor and Voorburg). For each of these zones, the trip generation was calculated before in Chapter 4. However, this is the total trip generation, while for this model only part of the trips is relevant. The next section discusses which trips are relevant, where these trips go to and what modes will be used for these trips. The travel times and travel costs were then calculated using this information. Finally, the networks were assessed using the assessment framework.

6.1.1. Trip generation

The first step in the model set up was the trip generation. For the trip generation, the origins and destinations were defined. The origins were assumed to be the above mentioned zones (Gemeente Den Haag, 2018). These zones were included in GIS. By use of GIS, the centroid of each zone was defined and the total number of trips was calculated. After that, the geographic coordinates of these centroids were retrieved. Also for the three train stations and the six potential bicycle docking locations (see Section 4.5) the geographic coordinates were retrieved. These locations were selected in the SMCA. In addition to the bicycle docking stations inside the Binckhorst, it is assumed that there are docking stations located at each of the three train stations to make trips from the Binckhorst to the stations by shared bicycle possible. The trip generation was calculated before, in the SMCA. This was based on the trip generation per building type (CROW, 2018). This was used to calculate the total of trips per zone. However, this total amount of trips also includes internal trips within the Binckhorst, or trips by car. It was assumed that these travellers are not likely to be potential users of the bicycle-transit system. Therefore only the trips of train travellers were considered, as it was assumed that the bicycle-transit system will be used as access and egress to the train stations. According to Jonkeren, Wust, & de Haas (2019), the share of trips by train in urban areas is 10%. Accordingly, for the calculations in the model, only 10% of the total number of trips is used. It is conceivable that a effectively functioning public transport system can lead to an increase in public transport users. In this model, this would mean that by offering a better connection from Binckhorst to the train stations, namely by implementing an shared bicycle system, the number of train travellers would increase.

6.1.2. Trip distribution

After collecting the origins, destinations and number of trips, the second step was the trip distribution. In this model it was assumed that the travellers have three options to leave the Binckhorst, being the three train stations. In reality, the train station itself will not be the final destination of the travellers, but since the model only includes the access and egress trips, it does not matter where exactly the travellers go. Therefore, the train stations are in this model considered as the destinations. The distribution of travellers between the three stations is as follows: Den Haag Centraal - 16% of the travellers; Den Haag Hollands Spoor - 67% of the travellers; Voorburg - 14% of the travellers; Laan van NOI - 3% of the travellers (D. Ton, personal communication, March 24, 2020). However, given the small share of travellers via Laan van NOI, and because this station is difficult to reach from the Binckhorst due to the limited and illogical access routes, this station was not included in the model. If this station had to be included, it would mean that also at this station, a bicycle docking station had to be built. Given the number of travellers, that is not conceivable. For that reason, this station was not included in the model. In order to obtain a total of 100% of travellers, the other percentages are scaled proportionally. This results in the following distribution of travellers:

Table 6.2: Percentage of travellers per destination

Station	Percentage of travellers
Den Haag Centraal	16,5%
Den Haag Hollands Spoor	69,1%
Voorburg	14,4%

The model includes four different alternative situations. The first situation is the “base situation”, in which no public transport system is offered. In this alternative it is assumed that all travellers have to walk to their destination. In the second alternative there will be two options: walking to the destination or walking to a bicycle docking station and cycle to the destination. The number of bicycle docking stations in this alternative can vary between 1 and 6. The third alternative does not include bicycle docking station, but introduces the potential tram including one stop at the Binckhorstlaan. In the last alternative, both tram and the bicycle stations are included, leading to three possible modes for the travellers.

Travel times

The travel times for the walking trips from all origins to all destinations, the six bicycle locations and the potential tram stop are calculated using Matlab. By use of Matlab, the travel times for different modes between a set of origins and destinations could be retrieved via a Google Maps API. The travel times by bicycle are calculated in the same way, for the trips between the six bicycle docking stations and the three destinations. In reality, the speed of e-bikes will be higher than the speed of conventional bicycles, so this calculation might be not entirely accurate. However, because the trips assumed in this model have short distances, and are within the city, it is expected that the e-bikes will not reach their maximum speed and that there will be therefore only a small difference in travel time.

The last travel time, for the trips by tram, had to be estimated. These travel times could not be obtained from Google Maps since this tram line does not exist yet. It was assumed that the trip between Den Haag CS and the tram stop in Binckhorst will cover a distance of about 2 kilometres. The distance between the tram stop and Voorburg will be a little shorter, approximately 1.5 kilometres. Assuming these travel distances and an average travel speed of 25 km/h (Stroecken, 2019), the travel times by tram were calculated.

Travel costs

The travel costs for both the bicycle and the tram are based on the current rates that are charged for public transport and comparable bicycle sharing systems in The Hague. A basic rate plus a rate per kilometre is charged for the tram (HTM, 2020b). For the bicycles, a fixed amount of 1 euro per 30 minutes is charged (HTM, 2020a). Since none of the travel times by bicycle exceeds 30 minutes, all bicycle trips have the same price.

Bicycle station choice

When implementing a bicycle sharing system, it would be possible to to start with only a few bicycles and stations, and later expand this to the above-mentioned numbers (4 and 6). That is why the model is able to vary with 1 to 6 shared bike stations. In the situations where 2 or more bicycle docking stations are implemented, travellers by bicycle have to decide at which bicycle docking station they will pick up their bicycle. The number of bicycle docking stations varies from 1 to 6 (García-Palomares et al., 2012). The docking stations will always be implemented in the same order. In this model it is assumed that travellers will always choose the bicycle station that results in the shortest total travel time (walking time to the docking station and cycling time to the destination). As the bicycle costs are the same for all trips, travellers make their choice only on the basis of the travel time. The model does not include the chance that there will no longer be a bicycle available at a particular docking station, since the departure time of day has also not been observed in this model.

6.1.3. Modal split

After all traveller flows between the different origins and destinations and all travel times and travel costs have been calculated for the possible options, the last step of this model is to assign the travellers to the different modes. To determine this model split, an RUM MNL model is used (Chorus, 2018). For all possible options, the (negative) utility was calculated. The utility function for the three possible modes are as follows:

$$V_{walk} = \beta_{time} \cdot x_{travel\ time} \tag{6.1}$$

$$V_{bike} = \beta_{time} \cdot x_{travel\ time} + \beta_{cost} \cdot x_{travel\ costs} + \beta_{transfer\ time} \tag{6.2}$$

$$V_{tram} = \beta_{time} \cdot x_{travel\ time} + \beta_{cost} \cdot x_{travel\ costs} + \beta_{transfer\ time} \tag{6.3}$$

For the walking trips, there are no travel costs, meaning that the (negative) utility of these trips is only determined by the travel time. For the trips that are made by bike or by tram, the total utility is the sum of V_{walk} and V_{bike} or V_{tram}. Moreover, for these trips a $\beta_{transfertime}$ is added to take into account the (un)locking time and parking time for the bicycle or the waiting time for the tram. The value of $\beta_{transfertime}$ equals the additional negative utility of two minutes travel time.

To calculate the utilities, β_{time} and β_{cost} had to be determined. In previous research, different values for either β_{time} or β_{cost} were estimated. Table 6.3 shows three possible sets of parameters. The values in bold are obtained from literature. The other values are calculated by use of the Value of Time (VoT), see eq. 6.4. It was assumed to use the value of time of train travellers, as for the travellers observed in this model, the train will be the main mode of their trips. This value is assumed to be €12,65 euro per hour (Rijkswaterstaat, 2020b). Different values were presented for the year 2020 and 2030, and for both of these years a high and a low value was given. For this study, the low VoT of 2030 was assumed as this value was in between 2020 high and 2030 low and this study also focuses on the situation between 2020 and 2030.

$$Value\ of\ Time = \frac{\beta_{time}}{\beta_{cost}} \tag{6.4}$$

Table 6.3: Parameter sets for utility function

	Set A	Set B	Set C
β_{time}	-0,0898	**-0,075**	**-0,0824**
β_{cost}	**-0,426**	-0,3557	-0,3908
$\beta_{transfer\ time}$	-0,1796	-0,15	-0,1648
Value of Time	**€12,65**	**€12,65**	**€12,65**

For the first parameter set, set A, β_{cost} was found in Bronsvoort et al. (2020). For set B and C, β_{time} was the value that was found in literature. The β_{time} of set B was presented in Tjiong et al. (2018) and the β_{time} in set

C was presented in Mackie et al. (2003). In this last study, the β_{time} for commuters was calculated. Set A was assumed to be most suitable and was therefore used in this model, as these values are retrieved from a recent study that was performed in The Netherlands. Since all parameters sets are very similar, the parameter set was assumed to be reliable.

After calculating the modal split, all individual travel flows are known. By use of the *Value of Time*, the generalised travel costs for each trip were calculated. These costs include the direct costs for the tram or the bicycle and the travel time, expressed as travel costs. Also, the average travel times percentage of travellers per mode were obtained from the model. Since the generalised travel costs for all trips are known, the total generalised travel costs for the complete network was determined.

6.2. Results

There were three different network designs investigated by this model, being bike & walk, tram & walk and bike, tram & walk. These three network designs were compared to the walk-only alternative to evaluate the contribution of these bicycle-transit networks to the accessibility of the Binckhorst. For the networks including bicycles, the number of docking stations was varied between 1 and 6.

When observing the results, an important limitation of the flow model should be considered. In the three presented alternatives, travellers only have two or three mode choices: walking, cycling and/or travelling by tram. The flow model does not take into account that travellers can also use their own bicycles or take the bus. Therefore the model results in a relatively large share of travellers walking to their destination, while in reality this share will probably be smaller. In addition, the share of cyclists is not equal to the number of shared bicycle users. It is likely that some of these travellers would have travelled by their own bicycle if that option was available.

To assess the different bicycle-transit networks, three indicators were presented in the assessment framework in Chapter 5. The indicators that were quantitatively included in the flow model were:

- Travel time
- (Generalised) travel costs
- Number of travellers (per mode)

These indicators were summarised in the total generalised travel costs per alternative. This included the ticket/travel fares for tram and bike plus the travel time expressed as travel costs, for all travellers added together. The lower these total generalised travel costs, the less resistance travellers experience over the network in terms of money. In other words; the lower the generalised travel costs, the higher the accessibility. First the results of the total generalised travel cost gains were discussed to evaluate of the performance of the three alternative networks. Consequently, these results were explained in more detail by highlighting the different indicators separately.

Total gain in generalised travel costs

The three alternative networks including bicycles, tram or both, were compared to the situation of walk only. The total generalised travel costs over these networks was divided by the total generalised travel costs of the walk only alternative, to calculate the gain in generalised travel costs that was obtained in each of the alternatives. This comparison was made for both the expected land-use scenario and the extreme land-use scenario. This resulted in the gains presented in Figure 6.2. This figure shows the results of the gain in generalised travel costs compared to walk for each alternative, following from the calculations in the model. In this calculation the number of bicycle docking stations was ranged from 1 to 6. Logically, the results for the tram alternative did not change since in this alternative there were no bicycle docking stations at all.

First of all, the differences between the expected and the extreme land-use scenario appeared to be small. For the tram alternative there was no difference at all between the expected and the extreme land-use scenario, and for the bike and bike + tram alternative there was a small difference, but a comparable increase in gain was visible. An interesting result is that the gain in the extreme land-use scenario is lower than in the expected land-use scenario. This does not mean that in the extreme scenario there are fewer travellers using the shared bicycles, however the share of travellers by bicycle is smaller. This is because in the extreme land-use scenario,

	Expected		
	Bike	Tram	Bike + Tram
1	9%	6%	11%
2	10%	6%	13%
3	14%	6%	16%
4	15%	6%	16%
5	16%	6%	17%
6	19%	6%	20%

	Extreme		
	Bike	Tram	Bike+Tram
1	7%	6%	11%
2	9%	6%	12%
3	12%	6%	15%
4	12%	6%	15%
5	13%	6%	16%
6	15%	6%	19%

Figure 6.2: Percentage gain in generalised travel costs, compared to walk only

buildings (and therefore travellers) are added in zones 2, 4 and 19 only. These three zones are located in the north of the Binckhorst, while the bicycle stations (except for station 6) were added at a location that did not result any travel time gains for these additional travellers. As a result, the majority of these travellers did not use the bicycle and therefore the average travel time per traveller increased, and consequently the generalised travel costs were higher. In comparison with the walk only alternative, the total gain was therefore 1 to 4 percentage points lower.

Secondly, it was observed that the tram alternative resulted in the lowest gain in both land-use scenarios. Furthermore, these results show that the difference between the bike alternative and the bike and tram alternative, was only two or three percentage points. Before it can be concluded that the tram alternative is not profitable, a few things need to be explained. Firstly, it was assumed that the potential tram connects Den Haag Centraal with the Binckhorst and continues to Voorburg. This means that there was no tram connection between Den Haag HS and the Binckhorst. Therefore, in the tram alternative, only travel time gains (compared to walk only) were obtained for travellers to CS and Voorburg. However, the largest share of travellers (69,1%) had HS as its destination. Since only 30% of the travellers benefits from the potential tram, it was expected that this alternative was not able to obtain the same gain as the alternatives that include bicycles. On the other hand; because nothing changed for the trips having HS as destination, it also did not result in a loss in generalised travel time cost, compared to the walk-only alternative.

Moreover, as can be clearly seen in Figure 6.3, the bicycle docking stations that generated the highest gains were 1, 2, 3 and 6. When adding station 4 and 5, the marginal gain was only 1 percentage point or less (see Figure 6.3 for a graph of the gain in the expected land use scenario). As expected, the gain did not decrease when adding an additional bicycle station. This is reasonable, because travel times did only get shorter or remain the same, but did never increase. However, this low marginal increase was not only due to the fact that these stations are added as 4th or 5th, but was also depending on their location and the amount of travel time that could have been saved by using these stations.

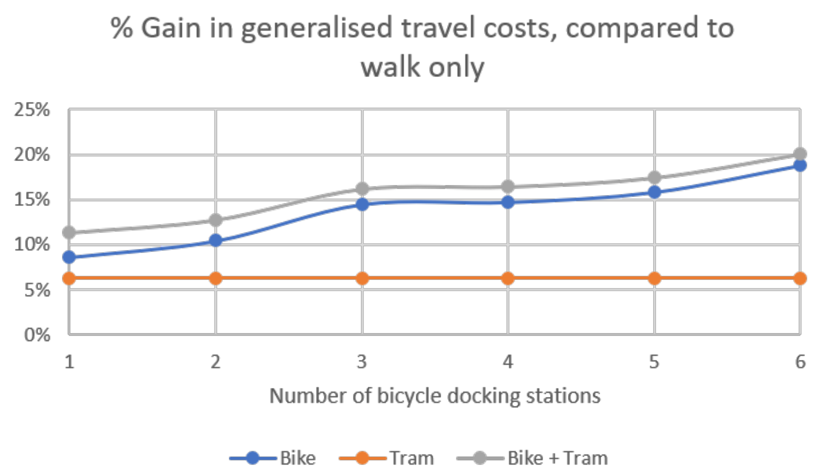

Figure 6.3: Percentage of gain in generalised travel costs (expected scenario)

As shown in Figure 4.7 (Section 4.5), docking stations 4 and 5 were both located near the border of the Binckhorst. This means that they only attracted travellers from a few zones who make a profit by choosing this bicycle docking station. Since only a few travellers used it, and thus experienced travel time gains, the increase in total generalised travel cost gain was limited. As shown in Figure 6.4, in the situation where six bicycle docking stations were included only 8% and 10% of the cycle-trips used the bicycle docking stations 4 and 5 respectively. Observing the share of travellers by bike, it can be seen that only 6% of the travellers used bicycle station 4. The share of travellers for station 5 was slightly higher, that was 13%. However, since this bicycle station results in a low gain in generalised travel costs it can be concluded that these travellers experienced only small travel time savings. It was therefore concluded that a location that has the highest potential for a bicycle docking station, according to the SMCA, does not always result in the highest contribution to the accessibility. The optimal combination of bike sharing stations is therefore not necessarily the same as the locations that were assigned the highest score in the SMCA.

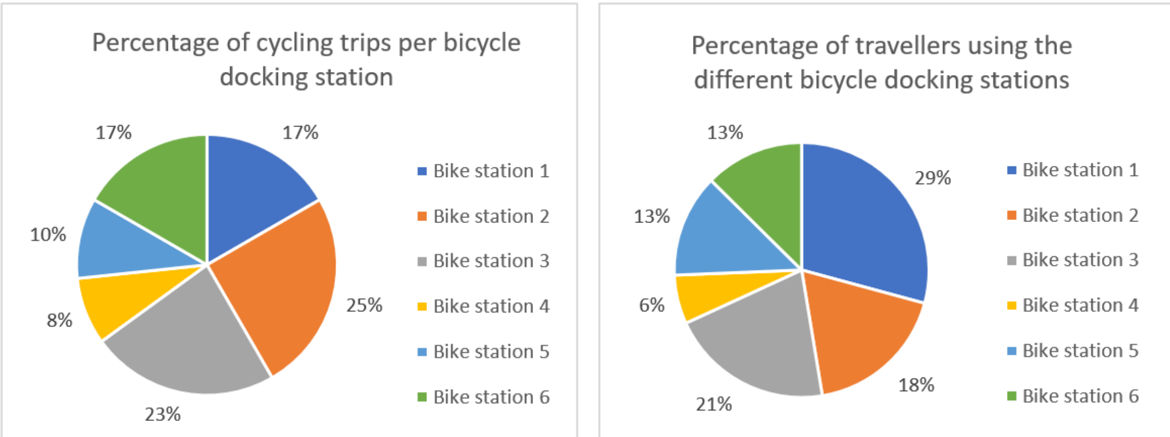

Figure 6.4: Pie charts showing the use of the different bicycle stations

While in total a gain was observed for all destinations for all alternatives, when diving more into details of the results per origin, it appeared that adding bicycle station or adding the tram for some zones resulted in an increase in generalised travel costs and therefore a loss compared to the walk only reference alternative. Sometimes this was caused by higher travel times for the bike or tram option than for walking. The reason that these faster modes still led to longer travel times, was due to the fact that travellers from specific zones first had to walk in the opposite direction than their destination, to go to the bicycle docking station or the tram stop before they can use these modes. Because of this detour, the total travel time became higher. Even though these new modes resulted in a higher travel time, there were still some travellers choosing this mode because of the used MNL model, in which it is assumed that not all travel preferences are known. In this study, only travel time and travel costs are taken into account, but the MNL model also takes into account that there might by other preferences that influence the mode choice. By adding this uncertainty in the form of an error term, there will always be travellers who choose the longer option. There were also situations in which the new modes did achieve a travel time gain, but these travel time gains were not sufficient to outweigh the travel costs that were associated with these modes. This only occurred for zones that are located relatively close to the destination and therefore have a short travel time in the walk alternative. Therefore, the zones that experience a loss in total generalised travel costs compared to walking vary per destination. Logically, since the detour became smaller when a bicycle station was added on a location near these zones, this loss became smaller when more bicycle stations were included. An example of the complete calculation per origin and destination can be found in Appendix D.

Gain per destination

When the gain was analysed per alternative and per destination, it became visible that for the destinations Den Haag CS and Voorburg the tram alternative resulted in higher gain than the bike + tram alternative, for the situations containing only a few bicycle stations (see Figure 6.5). This means that when only two bicycle stations were implemented, this was disadvantageous for Den Haag CS and Voorburg. This was due to the fact that the travel time by tram is shorter than by bicycle, so the average travel time will increased when travellers when more travellers used the bicycle instead of the tram. The assumed MNL model that was used to determine the modal split, caused that some of the travellers chose the bicycle, because this was faster than walking but cheaper than the tram. That was why some of the travellers (both from walk and tram) will shift to cycling when this became an option. However, Den Haag HS is a frequent destination for travellers from the Binckhorst. When the weighted average of the total gain was calculated, it appeared to be higher for the bike + tram alternative than for the tram alternative. This can be explained by the fact that Den Haag HS obtains no gain at all in the tram alternative, which highly reduces the total weighted average over the three destinations for the tram alternative. Therefore it can be concluded that for the accessibility of the total area, adding bicycles is beneficial.

	Expected											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	13,00%	8,70%	3,17%	9%	28,57%	-	11,00%	6%	25,56%	8,70%	7,67%	11%
2	14,94%	10,27%	6,06%	10%	28,57%	-	11,00%	6%	26,09%	10,27%	9,33%	13%
3	19,25%	14,16%	10,59%	14%	28,57%	-	11,00%	6%	27,50%	14,16%	12,80%	16%
4	19,25%	14,30%	11,63%	15%	28,57%	-	11,00%	6%	27,79%	14,30%	13,60%	16%
5	20,50%	15,23%	13,47%	16%	28,57%	-	11,00%	6%	28,38%	15,23%	15,33%	17%
6	24,37%	17,78%	17,53%	19%	28,57%	-	11,00%	6%	31,31%	17,78%	17,97%	20%

Figure 6.5: Percentage of gain in generalised travel costs, per destination, expected scenario

Travel time and costs

The gain that was observed was caused by the decrease in travel time and the corresponding decrease in generalised travel costs. In Figure 6.6 it is shown what the gain in travel time and corresponding travel costs was, compared to the walk only situation. On the x-axis, the number of bicycle docking stations is ranged. A comparable slope can be observed as for the gain (Figure 6.3), resulting in the highest decrease for the first three bicycle docking stations. Figure 6.6 shows that even in the tram alternative, that resulted in the lowest total gain, a travel time gain of more than 3 minutes was achieved compared to walking. In terms of generalised travel costs, a profit of about 50 cents was achieved in the tram alternative. For the alternatives including bicycles, these gains increased to almost 10 minutes on average and about €1,30 per traveller.

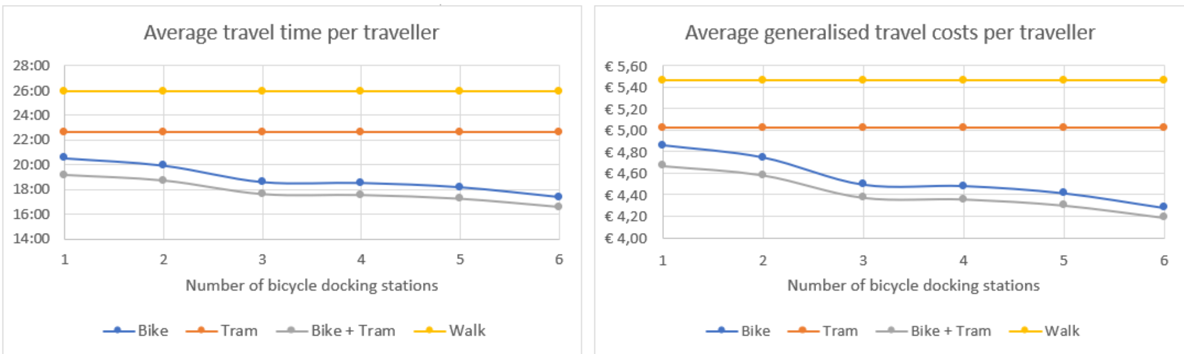

Figure 6.6: Average travel times and costs (expected scenario)

Percentage of travellers per mode

In Figure 6.7, the percentage of travellers per mode for the three alternatives can be found. It can be seen that share of travellers that walk to their destination, was significantly higher in the tram alternative than in the bike alternative. In the tram alternative, 81% percent of the travellers chose to walk, while in the bike alternative only 38% to 47% (depending on the number of bicycle stations) preferred to walk. When both bicycle and tram were available, the percentage of bicycle users was also higher than tram. It can be observed that when more bicycle stations where added in the bike + tram alternative, the share of cyclists increased since there became more cyclists that benefit from travel time savings when travelling by bike. These additional bicycle users were taken away from both the tram and walking, which is more clearly visible in the right graph in Figure 6.7. When more bicycle stations were added and consequently the share of travellers by bike increased, the walking share decreased by 6 percentage points while the share of tram users decreased by only 2 percentage points.

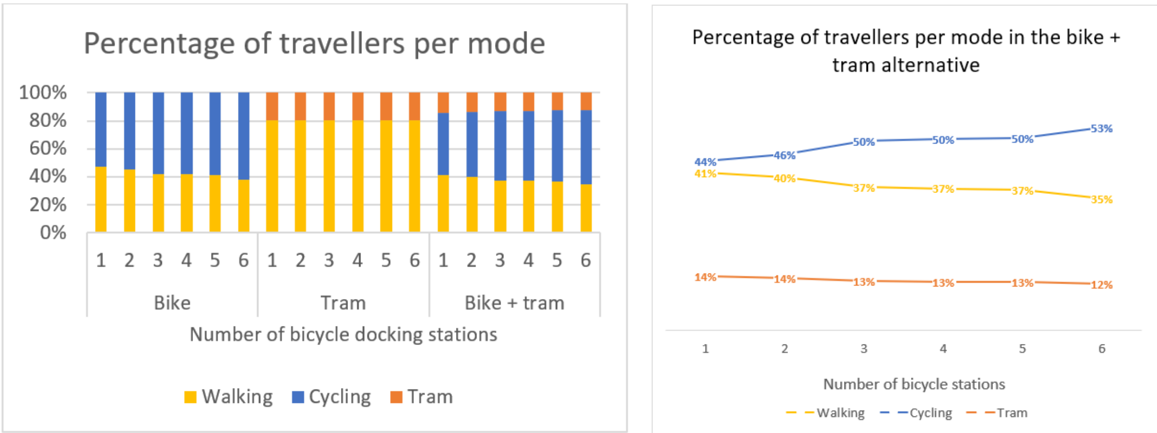

Figure 6.7: Left: Percentage of travellers per mode, per alternative (expected scenario)
Right: Percentage of travellers per mode in the bike + tram alternative

Bicycle docking station choice

When observing the bicycle docking station choice for the travellers that took the shared bike, it stood out that for some origins (zones) the chosen bicycle docking station was differing per destination (train station). For instance, when travelling from zone 4, for each of the destinations another bicycle docking station will result in the shortest travel time (see Figure 6.8). This means that travellers do not always pick up their bicycle at the closest bicycle docking station. This was caused by the assumption that travellers always use the docking station that results in the shortest total travel time. However, in reality, people might prefer a shorter walk, even when this results in some additional travel time. In some situations, travellers even walked to a bicycle station in the opposite direction than their destination, to pick up a bicycle at a docking station that results in the shortest total travel time. For example: a traveller goes from zone 20 to Den Haag CS. To minimise the total travel time, the traveller picked up the bicycle at docking station 2, while this station is located further away from the destination.

It should be mentioned that the difference in travel time for two routes (via bicycle docking stations) sometimes was only several seconds. In reality, it is likely that travellers would use both of these docking stations. However, in this model it was assumed that all travellers will take the shortest route regardless of the difference in travel time. It should also be considered that the travel times were calculated by Google Maps, which means that there might be some inaccuracy in the exact travel times.

Lastly, it was observed that bicycle station 4 was for none of the zones the best choice to all destinations. Even for zone 10 and 11, where bicycle station 4 was used to travel to Den Haag HS and Voorburg, it was shorter to travel via docking station 2 when going to Den Haag CS (see Figure 6.8). This was remarkable, because the walk to docking station 2 was considerably longer than to station 4. For a comprehensive overview of the travel times for all O-D pairs and docking station options, see Appendix D).

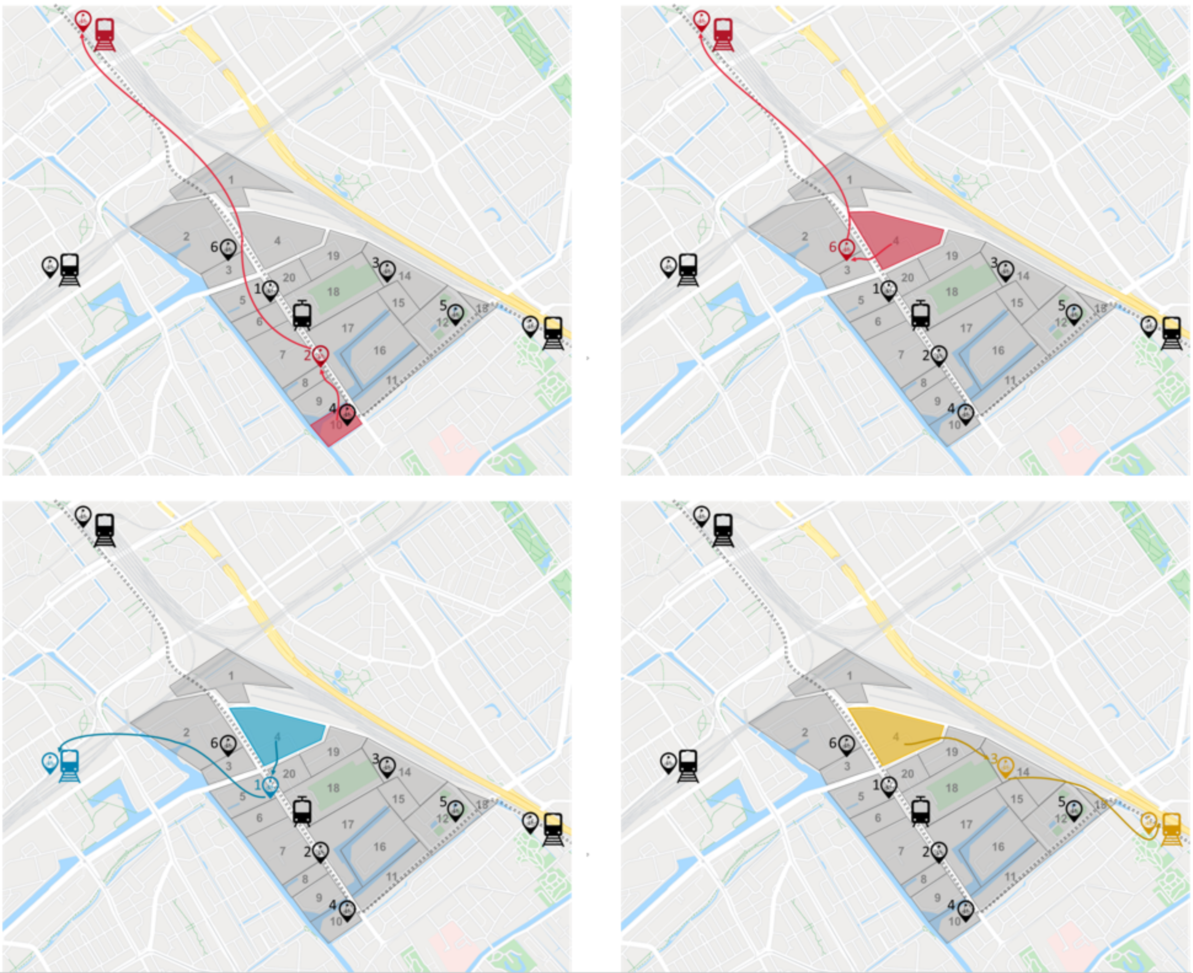

Figure 6.8: Example of the chosen bicycle docking stations for some O-D pairs, to achieve the shortest travel time

Table 6.4: Bicycle docking station choices for all O-D pairs

	Zones																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CS	6	6	6	6	1	1	2	2	2	2	2	5	5	3	3	3	2	2	3	2
HS	6	6	6	1	1	1	2	2	2	4	4	5	5	3	3	3	1	1	3	1
VB	6	6	6	3	1	1	2	2	4	4	4	5	5	3	3	3	3	2	3	2

6.3. Sensitivity analysis

A sensitivity analysis has been carried out to get insight into the extent to which the model results are influenced by the assumed parameter values. In the sensitivity analysis, different values for the parameters have been tested in the model to see how they affect the results. The parameters tested in the sensitivity analysis are:

- β_{cost} and β_{time}
- *Value of Time*
- $\beta_{transfertime}$

6.3.1. Beta time and beta cost

First, β_{cost} is increased and decreased by 10% to evaluate the sensitivity of the model on the assumed values for these β's. By assuming a fixed VoT, β_{time} was calculated. The value for β_{cost} that was obtained by the decrease of 10% approximates the parameter sets B and C (see Table 6.3). This makes it possible to consequently evaluate what the influence on the results would have been if one of the other parameter sets had been chosen.

When decreasing β_{cost} by 10%, it will become a larger negative value. Since β_{time} changes in proportion to the VoT, this also becomes a larger negative value. This decrease in β's results in a small modal shift of about 1 percentage point of additional bicycle users and about 1 percentage point of additional tram users. Because there is a small increase in travellers choosing a more profitable mode, the average travel times and generalised travel costs slightly decrease. The influence on the total gain is an slight increase of about 1 percentage point.

When increasing β_{cost} by 10%, the β's became a smaller negative value. As expected, the opposite results were observed: a modal shift of about 1 percentage point fewer bicycle and tram users. Since there are slightly more travellers choosing the less profitable mode (walking), the average travel times and generalised costs will increase and the total gain decreases by 1 percentage point.

It can be concluded that the model is not sensitive for a 10% increase or decrease of the β's. However, it should be explained why a modal shift could be observed and how the direction of this modal shift is associated with the increase or decrease of the β's.

This modal shift can be explained by looking at the assumed probability equation of the MNL model. The mode shares were determined by:

$$P(Y=i) = \frac{e^{V_i}}{\sum_J e^{V_j}} \tag{6.5}$$

When decreasing the values for the β's (i.e. more negative), the utility of the mode choice alternatives will also further decrease. The exponential choice probability curve determines that for values of the utility approaching 0, the probability of choosing that alternative is 0.5. That means both modes will have an equal chance to be chosen. However, when the utility becomes larger negative, the probability of choosing the alternative that results in the highest utility will eventually converge to 1. In other words, for decreasing β's, the utilities decrease, and the alternative that results in the highest utility will inherently be experienced more advantageous and the alternative that results in the smallest utility will be experienced even more disadvantageous. By only changing the magnitude and not the ratio between the utilities, a different probability distribution can thus be expected. This is shown in Figure 6.9.

The amount of gain or loss in probability for choosing a mode depends on the ratio between the utilities of the mode choices. The higher this ratio, the steeper the increase in probability per unit increase in utility, therefore reaching the maximum probability of 1 earlier. By investigating the most extreme case in terms of utility distribution between modes, an estimate may be made for the expected sensitivity of the model with respect to a changing β. For this extreme case, a significant increase in probability for choosing a mode can be expected. In the most extreme trip scenario that occurs within this model, one alternative produces about twice as much utility than the other alternative. For that situation, the modal split changes 5 percentage points. Therefore, this is the maximum change in modal split of a trip in this model. Consequently, as most utilities of the mode choices are more equal, those situations will result in a smaller modal shift. The graph below shows the probability of choosing a mode while using a common utility ratio between the two modes within this model. As the magnitude of the utility of different alternatives in this model varies approximately between 0.5 and 5, this indicates that only 2% increase in probability results from an increase or decrease of the values for β of about 10%. Taking into account the extreme case and this more common case, the expected sensitivity is between 1% and 5% probability change per 10% change in β.

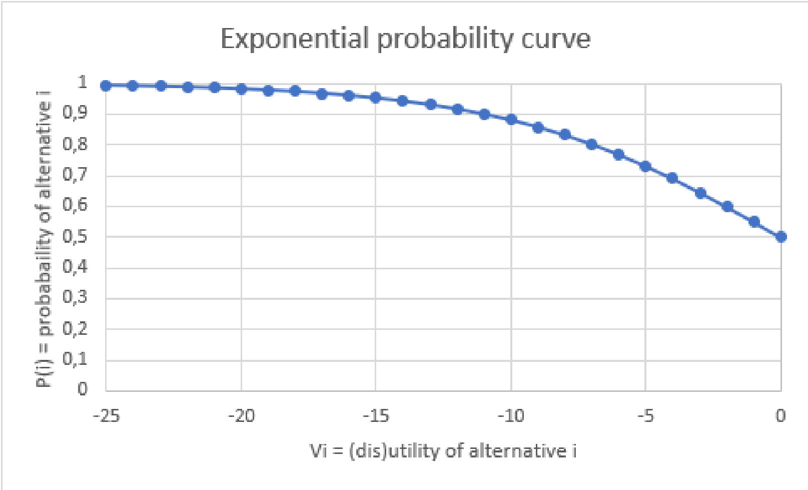

Figure 6.9: Exponential probability curve for mode choices

6.3.2. Value of Time

Secondly, it was observed to what extent the model was sensitive for the assumed Value of Time. To evaluate, the VoT was increased and decreased by 10%. By this changes, the test VoT's approached the minimum VoT's that were presented for 2020 and 2030 (Rijkswaterstaat, 2020b).

As expected, the increased VoT resulted in a mode shift in favour of the faster, more expensive modes. However, this was an increase of only 1 percentage point. This resulted in a decrease in average travel times ranging from 10 to 20 seconds per traveller, but a higher generalised travel cost. This was an increase ranging from 30 to 40 cents. Even while the travel times were shorter, the generalised travel costs increased due to the higher VoT and the fact that more people used the more expensive alternative. This resulted in an increase in total gain of 1 percentage point.

For the decreased VoT, the opposite results were observed. There was a small shift of travellers towards walking. The average travel times increased by 10 to 20 seconds while the generalised travel costs became lower. In total, the gains in generalised travel costs compared to walk decreased by 2 percentage points. It was concluded that the sensitivity of the model was only 1% change in generalised travel cost gain for a 10% change in VoT. Accordingly, the results would have changed only 2 percentage points when another VoT (as presented by Rijkswaterstaat (2020b)) was used.

6.3.3. Transfer time penalty

The model also considered a transfer time penalty that accounted for the additional travel time caused by unlocking and parking the bicycle or waiting for the tram. The sensitivity of the model was evaluated for a transfer time penalty of 0 (i.e. no penalty) and a penalty of 4 minutes instead of 2 minutes. As was expected, the increased additional travel time penalty resulted in a decrease in the total generalised travel costs gain. However, this was a decrease of only 1 percentage point. It was interesting to conclude that this increased transfer time penalty resulted in a modal shift from bike towards walking of 4 percentage points and from tram towards walking of only 1 percentage point. This was caused by the fact that for the bicycle, the negative utility was more comparable to walking, while the negative utility for tram in most cases was only half the negative utility of walking. This makes the tram less sensitive for an additional travel time penalty.

Logically, when assuming a travel time penalty of 0, an increase in bicycle and tram use was observed. The average travel times decreased by approximately 30 seconds per traveller, and also the generalised travel costs slightly decreased. Again, the tram use increased by 1 percentage point and the bicycle use increased by 4 percentage points.

6.4. Policy measures

In this section, the results of some policy measures that were tested with use of the model are discussed. These policy measures were analysed to explore the influence of the measures on the mode choices and the accessibility. These policy measures were based on the perspectives of the different stakeholders: the traveller, the operator and the authority.

6.4.1. Traveller's perspective: No bicycle costs

From a traveller's perspective, the optimal bicycle-transit system consists of bicycles that are free to use. This could include a system in which the bicycle can be used free of charge for travellers with a train subscription or when employers in the Binckhorst offer their employees a subscription to the bicycle. To explore the effects of free bicycles, the bicycle costs in the model were set to 0. This resulted in a large increase in total travel time gain of 10 to 15 percentage points. The average generalised travel costs decreased by 50 to 80 cents per traveller, and the average travel time decreased by 30 seconds up to one minute. A modal shift of 10% from walking towards cycling was observed.

6.4.2. Operator's perspective: Increased bicycle costs

From the operator's point of view, the bicycle-transit system should be profitable and therefore it should be explored what travellers are willing to pay and at what point the price resulted in a decrease of the number of users. In this situation it was evaluated what the effect was on the modal split when the prices of the bicycle are equal to the prices of the current *OV-fiets* that are offered at all NS stations. For an *OV-fiets*, travellers have to pay € 3,85 per 24 hours (NS, 2020).

This increased bicycle price resulted in a negative gain in generalised travel costs, i.e. a loss. This is a results of the fact that part of the travellers chose the bicycle, while this resulted in a larger negative utility than walking. In other words, the travel time savings do not outweigh the extra travel costs. However, due to the probability calculations of the MNL model, some travellers will still opt for this mode. As a consequence, for most of the zones, higher generalised travel costs are experienced than in the situation where all travellers have to walk. In the bicycle alternative, only 30% of the travellers had used the bicycle. In the bike + tram alternative this was even less, ranging from 22% to 28%. In this alternative, 17% used the tram, which is more than before. Some travellers will shift from cycling to tram because this is an cheaper and even faster option.

6.4.3. Authority's perspective: Change in bicycle locations

From the perspective of the authority, it was interesting to evaluate the results for another configuration of bicycle docking stations. As was concluded earlier, the first three bicycle stations and the last station resulted in the highest decrease in generalised travel cost and travel times. Consequently, the results were explored for a new order of adding the bicycle docking stations by adding the 6th docking station after the third. The new order was: 1, 2, 3, *6*, 4, 5.

Figures 6.10 and 6.11 respectively show the generalised travel cost gains and the average travel times in the new configuration, compared to the reference scenario (Bike-0, Tram-0 and Bike+Tram-0). For the first three docking stations, as expected no differences were observed. However, it can be seen in both graphs that the increase in gain and decrease in travel time became steeper. In other words, a higher accessibility can be achieved by implementing fewer bicycle docking stations. This is a consequence of the fact that more travellers shifted to cycling instead of walking, which decreases the average travel time. For the new docking station 5 and 6, no significant changes were observed.

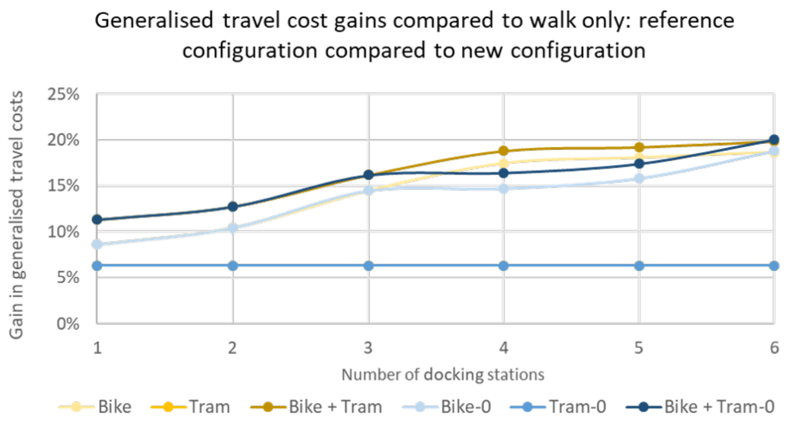

Figure 6.10: Gain in generalised travel costs for new docking configuration

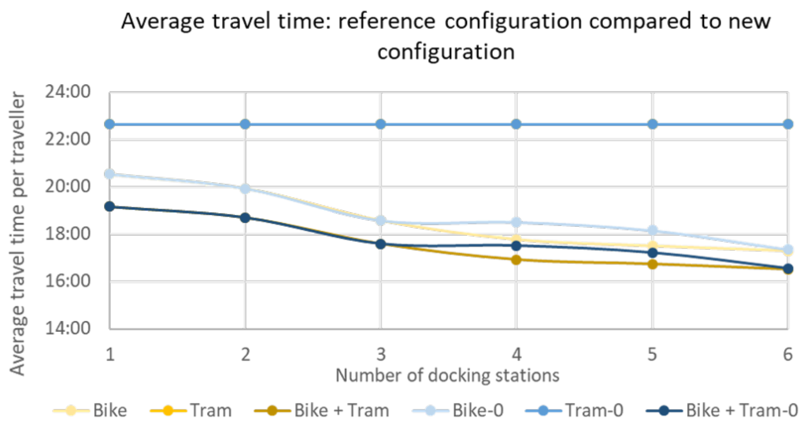

Figure 6.11: Average travel times for new docking configuration

6.5. Assessment of different network designs

Based on the results of the model, the sensitivity and different policy measures, several conclusions were drawn and the network designs were assessed by use of the indicators of the assessment framework.

In terms of travel times and travel costs, which can also be summarised as the generalised travel cost gains, the bike + tram alternative scored only slightly better than the bike alternative. The average travel costs were only 10 to 20 cent lower, and the travel times were approximately one minute decreased (depending on the number of bicycle docking stations). This indicates that implementing the tram in this case did not result in much gain.

However, due to the fact that a tram has additional advantages in terms of comfort and travel convenience, this alternative should not be excluded before further research has been performed. Under certain circumstances, the tram has advantages compared to cycling that are not considered in this model. For example for travellers who have difficulty walking or cycling, which is 6% of the population (van Oort, 2019). Also when carrying heavy luggage or when the weather is bad, travellers may prefer the tram over cycling. In addition, the tram stop in the Binckhorst is only one stop within a much larger tram network, so the costs and benefits of this tram line should be examined in a broader perspective. Since the tram did not connect Den Haag HS while this was the most common destination, the alternative did not lead to much travel time gains in total. However, it was observed that for the two other destinations, the tram saved a lot of travel time, considerably more than the bicycles. On top of that, when comparing the travel time of tram by the travel time of walk, an average saving of approximately 3 minutes per traveller was found.

However, an advantage of a shared bicycle system in comparison to the tram, is that the investment and operational costs are significantly lower. The total investment costs of a small-scale bicycle sharing system including docking stations is approximately €1,200 to €1,800 per bicycle (Rijkswaterstaat, 2020a). Usually, operating costs of €1,200 per bicycle per year are assumed. Considering back-to-many bicycle sharing systems, particularly redistribution leads to high cost. The advantage of this system is that the bicycles can be rented several times a day, leading to higher incomes (Cannegieter et al., 2018). The investment and operational costs of a tram are considerably higher. As an indication: the construction of the infrastructure costs about €35 million per kilometre, the area within the Binckhorst is about 3.5 kilometres.

Based on this study, it was concluded that bicycle stations 1, 2, 3 and 6 will achieve the most travel time and cost gains. Adding two extra bicycle stations, number 4 and 5, did not provide much additional profit. Although logically more bicycle stations will always result in travel time gains for at least some travellers, distributing the same number of bicycles over more shared bicycle stations also increases the chance that bicycles will no longer be available at a specific station. This reduces the reliability of the system. In addition, more bicycle stations also leads to higher redistribution costs. The operator of the bicycle sharing system has to ensure that the bicycles are well distributed between all docking stations.

7

Evaluation of the design approach

In this chapter, the developed design approach for a bicycle-transit system is evaluated. The advantages and limitations of the approach are discussed and it is mentioned what could be improved and what should be considered when applying this approach to another case study. In general it can be concluded that the three main steps of this approach were able to achieve the required information to design an integrated bicycle-transit network. However, there are still some improvements possible for each of these steps, or some adjustments that are necessary if this approach will be applied to another case study.

7.1. Evaluation of the spatial multi-criteria analysis

The first step of the design approach was the bicycle docking location selection. From a literature study (see Chapter 3), it became clear that the three main factors that were relevant in this location selection were the cycling network, the public transport network and the built environment. However, the exact interpretation of these criteria would differ per case study, as it depends on the characteristics of the case study area and the intended users of the system. The area that was analysed in this research did not contain any hills, however this might influence the potential of some locations. It should therefore be included in the SMCA when the area contains height differences. Furthermore, when the area contains only a limited number of cycle paths or when there is a lot of variation in the safety level of different roads, these factors are also relevant to include. On the other hand, some factors may no longer be relevant in another case study. This could be the case for different types of buildings that are not available in another area. The same applies to public transport: if other modes are available in the research area, this can be adjusted in the analysis. Additionally, when a university or other education is located in the case study area, this might influence the potential users. In this analysis, education was included as a building type but it was assigned not much weight since in this case only a primary school was considered. However, since university students will probably make more use of shared bicycles than primary school children (Jonkeren, Kager, et al., 2019, Shelat et al., 2018), higher weights should be assigned to these type of educational buildings.

The weights of the criteria in this study were determined by use of stakeholder input. A small sample of stakeholders was asked to assign weights to a set of criteria. The average of their responses was calculated to obtain one final set of weights. To get more insight into the different perspectives of different stakeholder groups, more stakeholders should fill in the form to determine the weight of the criteria. This will result in more reliable weights per stakeholder group. Additionally, it can be examined how these different perspectives influence the bicycle locations, by including the weights per stakeholder group separately. Since all stakeholder groups have different objectives (van Nes, 2015, van Nes & Bovy, 2000), it was expected that the assigned weights will differ per stakeholder as well.

After the SMCA was conducted, the bicycle locations had to be selected. Although the way these locations were chosen in this study, already leads to a profitable network, a few improvements to the approach are still possible. It can be learned from this research that the locations that were found to have the highest bicycle location potential, were not necessarily the locations that resulted in the highest accessibility for the total area. An important aspect is the distribution of bicycle stations over the area and the combination of the travel time gains that can be achieved and the number of travels that will benefit from the station. For the Binckhorst, this was observed when adding bicycle station 4 and 5 compared to bicycle station 6. Therefore, it can be concluded that only the SMCA is not sufficient to determine the optimal bicycle locations. To achieve a final design, an extra step should be taken after conducting the spatial multi-criteria analysis, as has been done in this case by calculating the passenger flows over the system.

Another improvement for the docking location selection, could be calculating the new location potential after a shared bicycle station was added. In this research, the location selection was done manually by choosing the highest score and adding a buffer of 300 metres around it, in which it was not possible to locate another bicycle station. However, the scores of the location outside this buffer were not calculated again. Therefore, the influence of existing bicycle stations on the location potential of the surrounding area, was not included in this calculation. This could result in lower scores for locations near the already located bicycle docking stations.

The multi-criteria analysis did not include any constraints about the costs of different locations and the availability of the land. By including this in the analysis, unavailable locations will be assigned a lower score and will have therefore less potential. Including this will improve the usefulness of the SMCA.

7.2. Evaluation of the assessment framework

The assessment framework was a step that offered guidance and clarity during the setting up of the flow model and the analysis of the results. With the help of the assessment framework it has been determined on the basis of which indicators the different network designs are compared with each other. These assessment indicators can be adjusted depending on the purpose of the system that is analysed in a case study. It should be considered that to be able to include different indicators, the required information should be available. For instance, when more information will be available, the investment and operational costs of different systems and designs can be discussed in more detail. Although it is not really an improvement for this framework, it would be valuable for the case study to analyse the investment costs in more detail. Since the results of the assessment are based on the assessment criteria, it can be imagined that, when different criteria had been assumed, another network design would have been preferred. Therefore, the result of the network assessment could be influenced by choosing different criteria. For example, if a criteria was included that is related to the coverage of bicycle docking stations through the area, this could lead to an optimal network that includes more bicycle docking stations.

7.3. Evaluation of the flow model

The assessment framework was also used for the set-up of the flow model. By taking the assessment framework into account, it was determined which information had to be retrieved by the calculations of the flow model. The flow model was a good way to gain insight into the passenger flows corresponding to the different network designs. In addition, this model provided insight into travel times and associated travel costs for each alternative. However, certain aspects of the model could still be improved.

The flow model as was used in this research, does not yet include all possible modes. For instance, the bus was not taken into account because of its limited capacity, and there was no distinction made between private bicycles and shared bicycles. Therefore, the flow model could be improved by including other modes, such as a bus, private bicycles, or other shared modes. This is of course depending on the situation to which this approach will be applied. This would make the model results more reliable, because the available alternatives in the model will become closer to the actual alternatives. In addition, all alternative modes that are included in the model could be compared with the other alternatives, making the opportunities of the model a lot more extensive.

Moreover, depending on the modes that are analysed and the characteristics of the potential travellers, the utility function can be adapted or extended with, among other things, alternative specific constants or beta's that take into account the influence on the mode choice caused by for example the weather, the age of the travellers, the amount of luggage they carry or their travel motive. This might influence the mode choice and therefore the corresponding demand for shared bicycles and tram. In this research, a fixed demand was assumed. However, it can be expected that the implementation of a shared bicycle system could result in a modal shift toward public transport use. This modal shift from car to public transport, is one of the initial motivations for introducing such a system.

In addition to improving the flow model, it can also be considered to gain insight into the traveller behaviour and the performance of different network designs in a different way. For instance, by conducting a stated preference experiment in which various possible network designs including associated travel time gains were presented (Arentze & Molin, 2013, Bos et al., 2004, Molin & Timmermans, 2010). In such an experiment, a bicycle sharing system including different combinations of bicycle docking locations and a possible tram line could be compared. For each of these choices the travel time and travel cost should be presented. The results of this experiments show the modal split, and thus the corresponding demand for a bicycle sharing system and a tram line. On top of that, the travel time gains could be calculated. The advantage of this stated preference experiment, is that the mode choices are not based on assumptions in the model and the utility function, but are indicated by the respondents and might therefore be more realistic. A general benefit of a stated preference experiment is that it allows the analysis of non-existent alternatives and it can include a complete range of attribute values (Kroesen, 2018). Before this can be applied to the approach, further research is required to determine the experiment design.

7.4. Evaluation of the applicability of the approach

The above mentioned adjustments could lead to a more reliable selection of bicycle docking locations and an improved final design. This is beneficial for both travellers and the operator. It is favourable for travellers if the bicycles are placed at the locations of which it is most likely that they will go there by use of a shared bicycle. An improved final design results in the most profit, and it is beneficial for the operator if a profitable system is chosen. It is also useful for the operator to gain insight into the extra profit or loss as a result of changes to the system. The flow model offers the possibility to compare these different options. The integrated approach is also valuable for the authority. The approach provides insight into all the different modes in an area, making it possible to evaluate all travel options together. This is helpful for the authority, because it is in their interest that a complete range of transport options is offered, ensuring that the entire area is accessible to all travellers.

This design approach could be a valuable addition to the decision making process regarding area development. Currently, only in large land use development projects, both the spatial development and infrastructure and mobility solutions are investigated. In area development, the existing infrastructure is often assumed as a starting point. However, by investigating different mobility solutions as one of the first steps in area development, mobility could be much better incorporated in land use plans. Therefore, in every project, someone should be responsible for mobility (M. Markus, personal communication, June 10, 2020).

For example, if a shared bicycle system is considered, this affects the distances that travellers are willing to travel. Because of the larger catchment area of cycling compared to walking, there will be an overlap in catchment areas of different stations. Travellers can choose between different stations, and have therefore more flexible travel options (M. te Brömmelstroet, personal communication, June 11, 2020). This is important to take into account during area development.

According to Markus (personal communication, June 10, 2020), the potential for a bicycle sharing system consists of a bicycle corridor, where travellers can leave the bicycle at the station. For that reason, a shared bicycle system will mainly be successful for areas where public transport is further away, where no intercity train station is nearby. Examples of these types of areas are, for example, Nieuw-Vennep or Hart van de Waalsprong, where urban development is taking place outside the city.

A problem that is encountered during decision-making is caused by the hierarchical structure of the government. The municipality that is responsible for the spatial development project, can only make decisions about the local network, but not about the regional network. In addition, for instance NS is responsible for the construction of a bicycle docking station at a train station (M. Markus, personal communication, June 10, 2020).

This approach can be used for exploring the location and context, which is the responsibility of the area developer. The next layer is for the contractor, who is responsible for investigating how and where to build the docking stations. For instance, the docking stations can be built in a building or in public space. The last layer is for the mobility operator. Their responsibility is to investigate what type of mobility exactly has to be offered, which is depending on the target group.

Therefore, this approach could contribute to the decision making process for designing an integrated bicycle-transit network, because it includes comprehensible steps that can be adapted individually according to the characteristics and goals of the case study. This approach facilitates the design of bicycle-transit systems, and provides a clear foundation for the final design. This could contribute to a faster implementation of such a system, which is desirable for stimulating cycling.

8 Discussion

During this research, different assumptions and choices had to be made in each step of the design approach. First, the scope had to be determined by choosing what would be included in this study. In addition, various assumptions had to be made within the scope, for example when there was insufficient information available or in order to facilitate the research. The results and conclusions that followed from this study depended on these choices and assumptions. Therefore, this section critically discusses the limitations of this research.

In the multi-criteria analysis, different land-use scenarios were considered. The purpose of investigating an expected and extreme land-use scenario, was to take into account some of the uncertainty about the land-use development in the spatial multi-criteria analysis. While it became clear that the results were not that sensitive for the additional land use in the extreme scenario, it should also be concluded that these results were highly dependent on the chosen locations to add some additional buildings. Also their size, function and corresponding trip generation did influence the results. When different locations were selected for these additional buildings, the results would logically shifted towards a higher potential for these new locations. Consequently, this might influence the potential bicycle locations. However, for this case study the extreme land-use scenario was assumed at these locations since at these locations there was space available for new buildings. Since there was no considerable difference observed between the expected and the extreme land-use scenarios, is was assumed that the uncertainty related to the land-use development, does not significantly influence the results.

The weights that were used for criteria in the multi-criteria analysis, were conducted from a small selection of stakeholders that were asked to give their opinion. The small size of this sample makes these weights less reliable. This sample should be expanded to obtain a more reliable set of weights.

It should also be mentioned that in the SMCA, all buildings and corresponding trips were included for determining the location potential of the bicycle docking stations. A differentiation between the importance of different types of buildings was indicated by use of weights. It was determined that offices should be assigned a heavier weight than for example shops. It was expected that commuters that are travelling to their offices, are more likely to use a shared bicycle than inhabitant of the Binckhorst going to a shop. However, it was not specific taken into account that for instance many of those shopping trips, are often trips within Binckhorst. Therefore it is possible that these trips are included twice; as a departing trip from home and an arriving trip at the shop. For these kind of trips, it is expected that they will be made with a private bicycle because the traveller started his trip at home. Therefore, these trips should not have been included in the analysis of potential shared bicycle locations. However, since all trips were included when choosing the location of the shared bikes, the selected locations may not be entirely correct.

Furthermore, this study only gave an indication of possible shared bicycle locations. Before implementing a shared bicycle system, it has to be investigated whether space is actually available at these locations.

For the third part of this research, the traveller flow model, it has been assumed that the shared bicycles will mainly be used for access and egress. Therefore, the trips that were included in this model was the share of train users. That means that for instance trips by car and the trips that are performed within Binckhorst, are excluded. When including trips within the Binckhorst and assuming that these travellers might also use the bicycles, the demand for a shared-bicycle system could increase.

In the model it was also assumed that travellers always choose the bicycle docking station that results in the shortest total travel time. However, in practice, people might prefer another route, for instance the route that contains the shortest walking distance. For the cycling part of the route, cyclists might prefer another route for instance because they find another route more convenient. In this model, only one route between an origin and destination was assumed, that was calculated by Google Maps. In addition, the travel times that were calculated by use of Google Maps for cycling, are based on the cycling speed of conventional bicycles instead of electric bicycles. Therefore, the assumed travel times for cycling might be somewhat longer than they should be. However, since the cycling distances are quite short and are within the city, the e-bikes are not likely to reach their maximum speed, meaning that there will be not much difference in travel times between conventional bicycles and electric bicycles.

The model does not include the fact that a well-functioning public transport system could lead to more public transport passengers. This model assumes a fixed number of travellers. Further research should be conducted to explore the potential increase of transit travellers that can be caused by an increased transit connection, such as a high quality tram or shared bicycles.

The flow model should be improved by including all modes, to be able to get insight in the actual mode shares. Since in this model not all modes are included, the share of travellers that walk to their destination is assumed to be not representative. When the bus and the private bike should have been added, some of the travellers will shift to these modes and a more realistic modal split would be observed.

Additionally, the area of the Binckhorst that was considered in this study, was too small to let travellers make the combination of cycling, tram and train. The travel times are too short to let travellers transfer twice. On top of that, since the bicycles have to be picked up at a bicycle station that also requires some walking time. Therefore, by use of this research it can not be concluded what the influence of shared bicycles on the tram network design will be.

It might be possible that a bicycle sharing system becomes more successful when it will be implemented in a larger area, for instance within The Hague. The assumed system in this study could only be used for trips between the Binckhorst and the surrounding train stations, which possibly leads to less users. It would be interesting to apply the developed method to a larger case study. During this research it also appeared that the chosen case study was not only quite small for a bicycle sharing system in general, but especially for e-bikes, due to the short distances and the fact that for most of the trips, the maximum speed will not be achieved.

When comparing this study with previous research, especially the design approach can be seen as an additional value. While various aspects of bicycle-transit has been researched, the design of an integrated network is quite unexposed. Therefore, by combining the results from other studies related to bicycle-transit, this research aimed at filling this knowledge gap.

Although many studies indicate that 1 - 3 kilometres between the origin of a traveller and the station can be seen as the optimal distance for a bicycle-transit system, this study shows that a longer distance may be even better, as this could result in greater travel time savings. However, logically the distance will be shorter for conventional bikes than for e-bikes.

The combination of a spatial multi-criteria analysis with the modelling of transport flows is something that is not often done yet. The research of García-Palomares et al. (2012) also made use of a spatial multi-criteria analysis to determine the bicycle-locations, however, this study assumed that the public transport network was fixed. In their study, two optimisation techniques were compared: maximum coverage and minimum impedance. The study showed that the first optimisation method will be the most efficient. This is comparable to the results of this study, because it means that the service area of a bicycle docking station is more important than the distance to one origin. They also mention that a larger number of docking stations logically leads to an increase in both covered demand and the accessibility, but also confirm that a very large number of stations can cause an excessive increase in the cost of the system without resulting in substantial profit.

9 Conclusions and recommendations

To ensure that cities remain accessible despite the growing number of inhabitants, challenges are arising about how to use existing infrastructure as efficiently as possible. More inhabitants in a city also means more transport movements. At the same time, space in cities is becoming scarcer, making parking spaces for cars more expensive. Moreover, car use is also increasingly discouraged from a sustainability point of view. Therefore it is important to search for alternative modes that offer comparable travel convenience as the car. Currently, no single mode can compete with the car, but a possible alternative for car usage may be a bicycle-transit system. The advantage of rail transit is the high speed and therefore large spatial reach, while the bicycle provides the door-to-door accessibility. Mainly for the egress part of a trip, shared bicycles could be a solution for the fact that travellers not always have a bicycle available. In recent years, more and more research has been carried out into sustainable modes of transport and bicycle sharing systems, but the combination of public transport and shared bicycles remains untouched. According to Shelat et al. (2018), an integrated design for bicycle infrastructure and public transport is needed. Therefore, the aim of this research was to develop an approach for designing integrated bicycle-transit systems, and to apply this newly developed approach to a case study. This approach does not only contribute to filling the scientific gap, but also facilitates designing these systems, making it easier to implement. A well-functioning system makes cycling more attractive and can therefore contribute to the stimulation of travelling by bicycle. The following research question was formulated:

Which approach should be used to design an integrated bicycle-transit network and how should this design look like?

In this last chapter, the conclusions of this research are discussed by answering the research sub-questions one by one, to then answer the main research question. To be more specific, in Section 9.1, the answers on the subsections are discussed. Thereafter, the conclusions about the approach are discussed in Subsection 9.1.1 and the conclusions about the final design are discussed in Subsection 9.1.2. Lastly, the recommendations for further research are discussed in Section 9.2 and the recommendations for practice are discussed in Section 9.3.

9.1. Conclusions

In order to formulate an answer on the main research question, four sub-questions were formulated. In the following section, first the sub-question will be answered and after that the main research question will be answered.

1. *What are the main findings from previous research into bicycle-transit?*
   As there was research about a wide range of bicycle-transit related topics available, this question was divided into three separate questions. Research into the user characteristics showed that students and commuters are most likely to use shared bicycles. Studies about the catchment areas mention that these can be increased significantly, by cycling instead of walking. The focus of the literature study was on factors that influence the design of a bicycle-transit network. From a first literature review it

became clear that there were three main factors that should be considered when looking for suitable locations for a shared bicycle docking station. In short, the location potential was found to be related to the cycling environment, the origins and destinations of the trips of the prospective users, and the connection of the bicycle sharing system to the public transit network. The following sub-questions a, b and c have been formulated to investigate these three factors in more detail.

(a) *Which factors determine an area's suitability for a shared bicycle network?*
Different factors were found to be relevant according to literature. For instance, quality and quantity of the cycling network, the safety level for cycling and the availability of safe and sheltered parking spots. Furthermore, hills and weather conditions might influence the suitability of an area for a shared bicycle system. Additionally, the cycling culture in a country influences the chance that travellers will use the shared bicycles. Also the distance to public transport is important. Regarding the built environment, the population density, as well as the number of students and universities, the number of commuters and offices and the distance to other attractive locations influences the suitability. For each investigation for a new shared bicycle system design, it is necessary to examine which factors can influence the cycling environment in that specific area.

(b) *What characterises the activity pattern of the prospective users and where do the activities take place?*
The aim of this question was to find out which buildings and locations are attractive for locating a bicycle docking station, since this correlates to the number of trips that are generated. The approach is as follows: First of all, it has to be determined what the target group of the assumed bicycle-transit system will be. Most studies indicate that the users of shared bicycles are most likely students or commuters (Jonkeren, Wust, & de Haas, 2019, Shelat et al., 2018). Hence, mostly offices and educational buildings are attractive locations. Using stakeholder input, it was determined near which locations they assumed that bicycle stations should be located. The attractiveness of a location was calculated using the distance to buildings and the trip generation of these buildings. In this study, it was assumed that the distance and trip generation of offices was most important, because this area only contained one primary school. Although it was found that most travellers already have their own bicycle at the access part of their trip and thus shared bicycle are mostly used for egress (Brand et al., 2017, Kager et al., 2016), the stakeholders indicated that they prefer a bicycle docking station near residential buildings. Information from the Kadaster (2019) and CROW (2018) was used to get an overview of the buildings and the corresponding trips that were generated within the case study area. The number of trips that were generated at different locations was used to calculate where the activities take place.

(c) *What is the effect of bicycles as access and egress mode on the catchment area of transit stops and how does this influence the transit network design?*
The stakeholders indicated that the connection between the shared bicycle-system and the public transport was assumed to be very important. The case study area in this study seemed to be too small for the travellers to use the bicycle as egress for the tram, because the travel distances of the tram were too short. Therefore the network design for tram is not influenced in this case study. A fixed tram network design was assumed, although both a situation with tram and a situation without tram were analysed. For a larger area, it might be interesting to evaluate how the network design of a tram should be adjusted, when bicycles are used as egress for the tram.

The main findings from this sub-question were the following: shared bicycles are mostly used by commuters and students, so this should be considered when choosing the potential docking station locations. The bicycles will be used mainly for the egress side of a trip. Additionally, the quality and quantity of the cycling network influence the attractiveness of a shared bicycle system. Although, in most case studies the quality and quantity of the cycle paths will be equal within an area. Finally, a connection to the public transport should be ensured. It can be concluded that bicycle docking stations should be implemented at train stations. The highest potential will be achieved for locations near offices, education and residential buildings. Depending on the size of the study area and the corresponding travel times, an additional bicycle docking station could be located near a tram stop. It should be mentioned that the final set of criteria will have to be adapted for each case study.

2. *How do these previous findings influence the design of an integrated bicycle-transit network?*
The findings from literature to determine the criteria for the bicycle docking locations, were combined

with the input of the stakeholders that determined the corresponding weights. This resulted in heat maps that indicated the potential of placing a bicycle station for different locations. By means of these heat maps, a location selection was performed. In addition to three bicycle docking stations at the train stations, six bicycle docking locations inside the area were selected. Based on the number of inhabitants in both the expected land-use scenario and the extreme land-use scenario, the required number of docking stations was determined by using an average number of bicycles per inhabitant and per docking station. This turned out to be four bicycle stations in the expected scenario and six in the extreme scenario. Both these scenarios were analysed with and without the potential tram stop. The optimal locations were then determined based on the location potential. The location that achieved the highest score was selected for the first bicycle docking station. Then, a buffer of 300 metres was created around this docking station to ensure sufficient distance between two bicycle docking stations. Then, a second location was determined using the highest scores, and so on. This was repeated until six docking station locations were selected. It was found that these optimal bicycle locations did not differ between these four scenarios. While the location potential did change a little for some locations, the highest scores were the same in each scenario. From this research it can be concluded that on the scale of this case study, the land-use development and available public transport both do not influence the bicycle-locations.

This resulted in four alternative network designs. First of all, there was the null-alternative where no public or shared transit was offered and all travellers had to walk from the train stations to the Binckhorst. This scenario was used as a reference to analyse the influence of the other modes. The second alternative was bike and walk, where the number of bicycle stations could be ranged from one to six. It may be realistic to start the system with 1 bicycle station and expand it later on. The third alternative was the tram and walk scenario, in which no bicycles were assumed, only a tram connection between CS and Voorburg via the Binckhorstlaan. The last alternative was the walk, bike and tram alternative in which all modes are available and again the number of bicycle docking stations was ranged.

3. *How should an integrated bicycle-transit network be designed according to the previous findings?*
For this study, it was assumed that increasing the accessibility of the Binckhorst was the goal of the bicycle-transit system. To assess which of these network alternatives contributes most to the accessibility of the Binckhorst, an assessment framework was constructed in which the indicators for accessibility were defined. A selection was made of indicators that were found in literature. These indicators were chosen since they were suitable to the information that was available and because the combination of these indicators was suitable to evaluate different network designs. Logically, this framework could be adjusted when the alternatives had to be compared on the basis of a different aspect. The following indicators were analysed using the flow model in this research:

   - Travel time
   - Travel costs
   - Number of travellers (per mode)

   The following indicators should also be considered, however in this research it was not possible to include these in the calculation because they were out of scope of this research and due to the lack of information:

   - (Un)reliability
   - Convenience and travel comfort
   - Investment costs

   By taking these indicators into consideration, a flow model was set up that was based on a four-step model. This model gave insight in the origins and destinations of the trips, the mode choices for these trips and the corresponding travel times and costs. The modal split was calculated by means of a RUM MNL model. The travel times, travel costs and mode shares were then used for the indicators to compare the different network alternatives. The model showed that the travel time in the bike + tram alternative, was approximately one minute shorter compared to the bike alternative and the corresponding travel cost were on average only 10 to 20 cents lower per traveller. The tram alternative without bicycles resulted in the lowest improvements. The relatively small travel time and cost savings for tram can be explained as follows: The average travel times for tram were relatively high due to the fact that the tram does not go to Den Haag HS, where most of the travellers go to. Tram and walk were the only modes that were included, meaning that all travellers to HS had to walk which resulted in longer travel times. Significant travel time savings were observed for the other two destinations, but they paled in comparison to the travel time to Den Haag HS.

When analysing the contribution of the different bicycle locations to the total accessibility, it can be concluded that the bicycle station 1, 2, 3 and 6 are of most influence. This means that the locations achieving the highest potential in the SMCA are not directly the locations that achieve the highest decrease in generalised travel costs, when investigating the traffic flows.

In addition, another noticeable result is that travellers departing from one zone used a different bike sharing stations depending on their destination. In other words, they did not always choose the nearest bicycle docking station, but they choose the station that provided the shortest total travel time. The shortest travel times were not always achieved by travelling via the nearest bicycle docking station. This means that the bicycle stations do not necessarily have to be located as close as possible to the origin or destination as long as they provide enough travel time savings.

4. *How can this approach contribute to the decision making process?*
The approach for designing an integrated bicycle-transit network can contribute to determining the location for bicycle docking stations, and to the assessment of different transit networks by investigating the travel times, travel costs and generalised travel costs. Depending on the case study, the criteria in the SMCA and the corresponding weights can be adapted, making it possible to apply this approach to many different case studies. Additionally, the indicators of the assessment framework can be differed, based on available data or required insights. Finally, the flow model can be expanded by including new modes, or improving the utility function to determine the modal split. The modal can also be used to evaluate different travel fares or timetables and their influence on the modal split.

This approach provides a transparent way to select the locations for bicycle docking stations. Travellers will benefit when the optimal locations are chosen. The model is also able to compare different alternative modes and networks. Travellers' preferences can easily be included in the model by changing the β's in the utility function. This makes it possible to investigate which alternative is the most favourable for different types of travellers.

Operators of both transit and shared-bicycle systems, could use this approach as it provides insight into the performance of different systems and network designs. Also, travel fares can be varied in the model. This allows the operator to examine the profit that can be achieved by different systems.

Lastly, the model also contributes to the decision making process for the authority, because it provides insight into all the different transport systems in one model. This is a great advantage compared to separately analysing the tram network and the bicycle sharing system, for example. For the authority, it is of great importance that the different transport systems in a city connect well and strengthen each other instead of competing with each other. By use of this model it can be investigated what the added value of for instance a shared bicycle system will be, and which modal shift will be caused. This provides the authority insight into which systems complement each other and which should not be combined.

However, it should be considered that the model is based on several assumptions. The sensitivity analysis showed that these assumptions were not of great influence on the final results, yet those assumptions should be further substantiated before the model could actually be used to support the decision-making.

Summarising the conclusions of these sub-questions results in the answer on the main question. Since the main research question was twofold, first a conclusion was drawn about the design approach and afterwards the conclusion about the final design for this case study was presented.

9.1.1. Conclusions about the design approach

From this study, it can be concluded that the design approach should consist of a first analysis in which potential locations are chosen, and a second analysis in which possible networks are compared with each other, to obtain insight into the passenger flows. The spatial multi-criteria analysis to select the bicycle location, is not sufficient to draw conclusions about the complete integrated bicycle-transit system. This can be explained by the fact that the highest location potential does not necessarily result in the highest accessibility of a system. Furthermore, the location determination just does not offer insights into travel times, travel costs and travel time gains. As a result, different systems cannot be compared with each other by this method only. For that reason, a second analysis is required, to evaluate the performance of the networks. Prior to this analysis, it is recommended to set up an assessment framework. An assessment framework clearly shows which indicators are used to compare the network and provides guidance during the development of the flow model. Although the different steps within the approach could be improved in some aspects, the approach is able to provide support in the design of a bicycle-transit system. An advantage of the developed approach is that the different steps are easily adaptable to the case study to which the approach is applied. In addition, because of these subsequent steps, the developed approach is transparent and easily understandable.

9.1.2. Conclusions about the final design

The results of the model indicated that the bike + tram alternative achieves the highest reduction in generalised travel costs. Since no investment or operational costs have been included in the model, it was expected that the most elaborated alternative with the multiple travel options resulted in the shortest travel times. From the model it can also be concluded that the bike + tram alternative scores only slightly better than bike only, although this does not directly mean that in can be concluded that the tram has no added value for the accessibility of the Binckhorst. The model does not take into account that in reality, people could also travel by bus or cycle with their own bicycle instead of the shared bicycles. Therefore, it is likely that a considerable share of the travellers who chose to cycle according to the model, would have taken their own bicycle when this was an option. To get insight into the share of shared bike users, more research should be performed. Due to the limitation in available information, and the exclusion of the bus as a mode, the tram seems to score relatively poorly. This is caused by the fact that travellers having Den Haag HS as their destination, which is a large percentage of travellers, have no options other than walking in the tram alternative. This increases the average travel time in this alternative. However, significant travel time savings were achieved for the destinations to which the tram does go. In addition, it should be taken into account that the tram through Binckhorst is part of a larger tram network. In this larger perspective, the tram can therefore yield more gain, even if this gain may be only relatively low for the Binckhorst. It could also be an idea to investigate the options of a tram line to Den Haag HS. In any case, it should be taken into account that HS is a more important station. Lastly, it can be concluded from the model is that the bicycle docking locations 1, 2, 3 and 6 contributed the most to the accessibility of the Binckhorst.

The final design of the bicycle transit-network for the Binckhorst, should thus include four bicycle docking stations at the locations number 1, 2, 3 and 6. The system should also include the tram, because significant travel time savings are achieved for the destinations to which the tram can be used. On top of that, this mode offers comfort to travellers that are not able to walk or travel by bike and because of this tram line will be part of a connection between Den Haag CS and surrounding region, more gains will be achieved outside the investigated area.

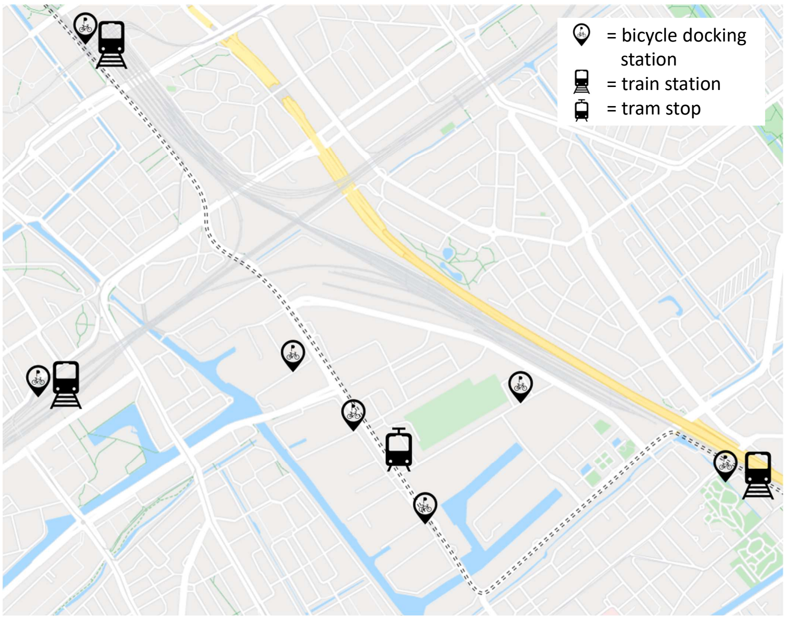

Figure 9.1: Final design of the bicycle-transit network for the Binckhorst

9.2. Recommendations for future research

Given the limited time that was available for this research, the approach has been developed as well as possible. However, there are still some limitations that can be resolved and there are still some improvements possible. Therefore, this chapter discusses some recommendations for further research. Some suggestions about the multi-criteria analysis and flow model in detail are already mentioned in the previous chapters. Some more general recommendations are presented in this section.

- For the bicycle docking stations, the locations were selected that achieve the highest scores in the SMCA, i.e. have the highest location potential. However, after selecting the first location, the scores have not been recalculated. This means that the scores are not affected by the presence of a docking station nearby. It would be interesting to investigate whether the final selected locations will change, when the scores are calculated by means of an iterative process, for instance by use of GIS, that takes the added bicycle docking locations into account. By assigning the locations around the previously selected bicycle docking locations a lower score, the chance that two bicycle stations that are located close to each other are selected, will be reduced. This could lead to a better distribution of the bicycle docking stations. In addition, this selection method does not take into account the total coverage of bicycle docking stations in the area. In a case study area where all the highest scores are achieved around the same location, this may cause that multiple stations are placed relatively close to each other, while it may be more favourable to place one (larger) station in between these docking stations.
- This research has showed that a shared-bicycle system can achieve significant travel time gains and it offers a flexible connection to the train station from different locations. This research also made clear that a tram connection leads to the shortest travel times, but is less flexible since there are fewer tram stops than bicycle docking stations. According to this study, both modes will be widely used. However, since private bicycles and the bus are not included in the traveller flow model, it is not yet possible to conclude with certainty what the share of shared bicycle users and tram users will be for each alternative. When all modes are added in the model, a more realistic modal split may be obtained. When a distinction is made between private bicycle users and shared bicycle users, the demand for a bike sharing system can be determined. Including bus and private bike will also influence the use of tram, and it will also affect the results in the tram-only alternative. Since travellers could use their own bicycle, the travel times to Den Haag HS will probably decrease. As a result, the alternative in general will probably achieve higher gains. Therefore, further research is needed to improve the calculation of the

modal split more accurately. Before a bicycle-transit system should be implemented, further research must be conducted into the actual demand for shared bicycles and the tram. For instance, traveller data collected by current shared bicycle operators could be used to gain insights into the traveller demand.

- To get more insights into the traveller behaviour and mode choices, it can be considered to conduct a stated choice experiment in which different alternative bicycle-transit systems are presented to respondents. By asking respondents to choose between, for example, a faster connection, in which they have to walk longer to the bicycle docking station, or a short walk to the bicycle docking station but a longer total travel time, the user preferences about the walking distance can be investigated. In the same way, preferences could be investigated between cycling or travelling by tram. This provides insight into travellers' mode choices and considerations. A stated choice experiment also offers the possibility to analyse the effects of, for instance, various fare schemes (Arentze & Molin, 2013, Molin & Timmermans, 2010).
- In addition to a more precise estimate of the modal split for the different access and egress modes, it is also interesting to gain more insight into the modal split in a broader context. In this study, only the mode choice for access and egress is evaluated. However, the mode choice for the main mode, for instance car or train, is also likely to be influenced by the existence of new access and egress options. It could therefore be investigated whether the availability of a well-functioning bicycle-transit system as access and egress to train stations, results in more train travellers instead of car users. Since the the aim of the bicycle-transit system was to stimulate more travellers to shift from car to sustainable modes of transport, the model could be improved by including this potential shift.
- Because the case study in this research was relatively small and therefore the travel times were short, it was assumed that travellers did not transfer from the shared bicycle to the tram, but had to choose between these modes. It would be interesting to apply this approach to a larger sized case study, to investigate to what extent the shared bicycles will be used for access and egress to the tram stop(s) and what that would mean for the design of a tram network. Since cycling ensures larger catchment areas, it is possible that catchment areas of different tram stops will be overlapping. That means that travellers will have the flexibility to choose between multiple tram stops, which could result in certain stops being almost no longer used. That could mean that fewer stops will be needed, and that the distance between these stops could increase.
- An important aspect that has not been investigated in this study is the cost of different bicycle-transit systems. A limited cost indication has been presented in this study, but it will be necessary to carefully consider the costs of constructing a tram line or one (or more) bicycle docking stations, when deciding about a final bicycle-transit design. Logically, each bicycle docking station that is added, results in a higher accessibility of the area. However, the profit from each additional docking station must be in balance with the costs involved. More insight will have to be obtained into the costs of the different network designs, before a final design can be chosen.

9.3. Recommendations for practice

It can be concluded that the developed approach is a suitable method for selecting bicycle docking locations and subsequently designing a bicycle-transit network. Therefore, it is recommended to further develop and improve this method so that it can be applied to suitable case studies in the future. In this subsection, some recommendations for BAM Infraconsult, policymakers and bicycle-transit system designers are discussed. These recommendations should be considered when applying this approach in practice. The recommendations are based on the findings of this research and on the reflections of two experts, as was discussed in Chapter 7.

- The developed design approach has proven to be a useful method to create and evaluate different designs. Therefore, it is recommended to use this method during the decision-making process for mobility in combination with area development. This approach is a promising addition to the decision-making process regarding the selection of bicycle docking station locations and subsequently the implementation of a bicycle-transit system, since it provides insights into the possible designs and their effects on the accessibility of an area. This approach makes it possible to compare different network designs including different modes at the same time. This means that this approach suitable to be applied to mobility studies for areas that are under development, where several (public and shared) mobility options have to be compared. To gain more insight into how this approach can be used in the decision making process, it is advisable to interview different decision makers.

- This research has shown that the location that has the highest potential according to the SMCA, does not always result in the best accessibility. This is the case, for example, for bicycle locations on the edge of an area, which have only a small catchment area. It is also possible that a location that achieves a high score, is on the fastest route only for a few travellers. As a result of that, some travellers with their origin or destination close to this docking station, by will still travel via another shared bicycle location as that results in a shorter travel time. Therefore, when designing an integrated bicycle-transit network, it is recommended to not only look at the location potential, but analyse the passenger flows as well in order to assess the effect of each network design.

- Based on this study it is recommended for the case study Binckhorst, to investigate the possibilities to implement the bicycle docking stations on the locations: 1, 2, 3 and 6 (see Figure 9.1). It turned out that this combination of locations will lead to the highest accessibility of Binckhorst. This research has shown that in general, the nearest bicycle station does not always lead to the shortest travel time. To achieve the highest profits, it is important to consider that a shared bicycle station is on the shortest route for many travellers, so that many travellers benefit from it. Therefore, centrally located shared bicycle stations are more advisable than shared bicycle stations on the edge of an area, unless there is a destination that attracts a significant number of travellers. Since the number of travellers who travel via a bicycle docking station therefore provides more travel time savings than the fact that a shared bicycle point is very close to one frequently visited building, it can also be concluded that the number of shared bicycle stations that contribute to the accessibility of an area, will at some point reach an optimum. After the optimum number of docking stations, adding an extra station will only provide travel time savings for a few travellers and therefore it will no longer be cost effec to implement additional docking stations.

- During this research it became clear that the chosen case study area was somewhat small for the implementation of a bicycle-transit system consisting of e-bikes. Therefore, it is recommended to apply shared bicycle systems to larger areas. This study showed that a system of shared e-bikes can achieve comparable travel time savings to a tram connection. While bicycles within the city have lower speeds than a tram, the walking distances are shorter since there are more docking stations than tram stops. It can be imagined that, for an area where the e-bikes can be used at their maximum speed, the advantages compared to a tram system will increase. E-bikes will thus be more beneficial for longer distances and cycling routes outside the city. The higher speeds of e-bikes compared to conventional bikes, will be achieved only to a limited extent within the city. For short distances, the bicycle will also have to compete with walking. It is recommended to apply this system to an area that is being developed nearby an existing city, a few kilometres away from a connection to public transport, where walking could not be an alternative. Examples of possible case studies are Nieuw-Vennep West (Haarlemmermeer) and Hart van de Waalsprong (Nijmegen).

- Regarding the potential travellers, it is especially important to search for areas that attracht students or commuters. These travellers are most likely to make use of shared bicycles, mainly for egress trips. In comparison with walking, bicycles and especially e-bikes, provide a larger catchment area. This means that cyclists can choose between several train stations, while there will be, for instance, only one station within an acceptable walking distance. By effectively connecting public transport to the shared bicycle system, the catchment area of public transport will increase and a flexible last-mile connection can be offered. Therefore, the connection to public transport is very important.

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A

Analytic Hierarchy Process

A.1. Example of the form

Figure A.1, A.2 and A.3 show the form that was filled in by different stakeholders to calculate the weights for the criteria in the SMCA. In the first part they had to divide points between different factors, with the sum of these points being 100. In the second part, they had to pairwise compare the seven different types of building purposes. They had to indicate on a 7-point scale which of the two factors they considered the most important. The value 0 meant that both factors were found to be equally important.

Hoe belangrijk vindt u de afstand van deelfietsstations tot...

(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	
OV (trein en tram)	
Gebouwen	
punten nog te verdelen	100

Hoe belangrijk vindt u de afstand van deelfietsstations tot...

(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	
Den Haag HS (trein)	
Voorburg (trein)	
Eventuele tramhalte in de Binckhorst	
punten nog te verdelen	100

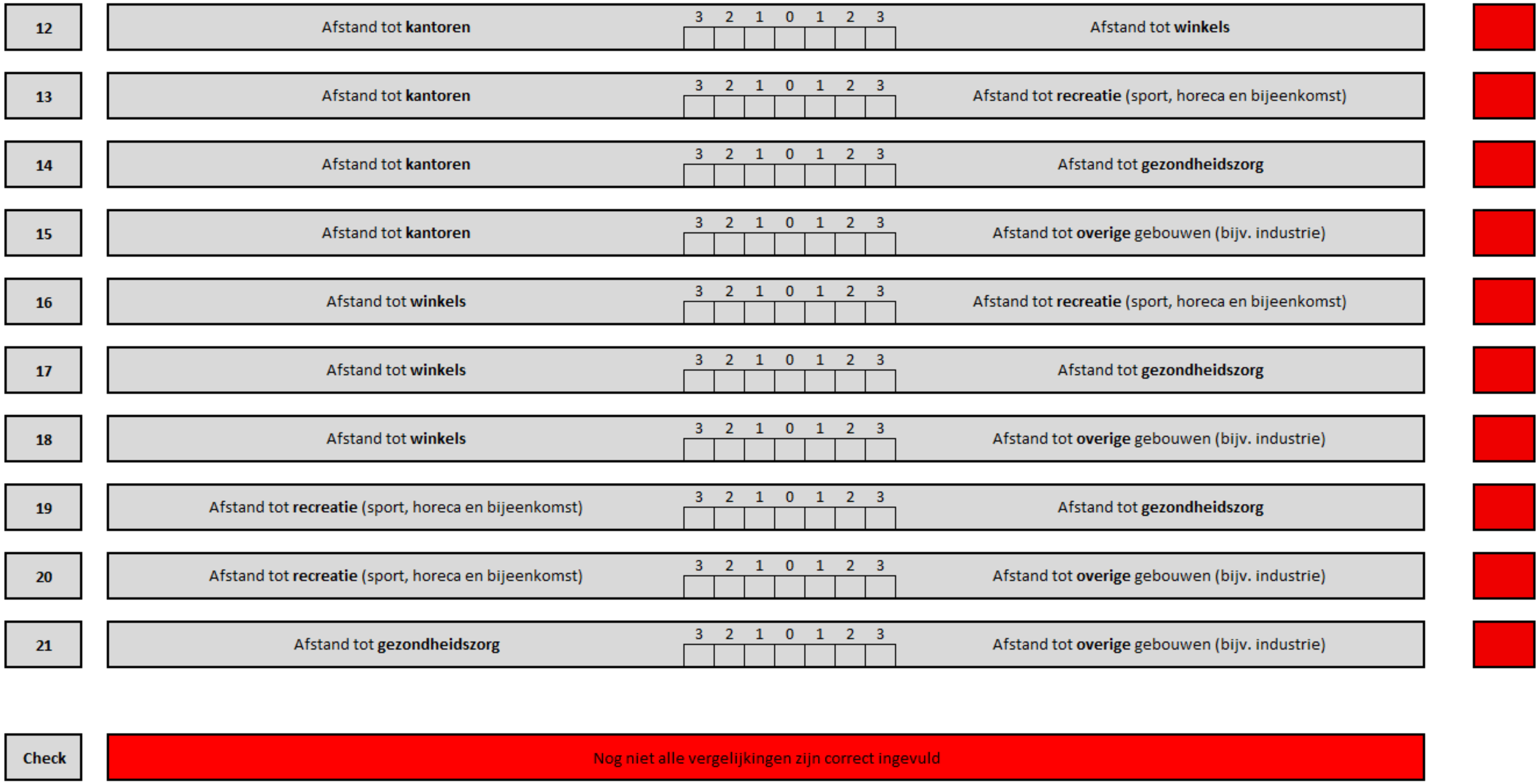
Figure A.1: Weight assignment by dividing 100 points

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties

(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3		
1	Afstand tot **woningen**								Afstand tot **onderwijs** (basisschool)	
2	Afstand tot **woningen**								Afstand tot **kantoren**	
3	Afstand tot **woningen**								Afstand tot **winkels**	
4	Afstand tot **woningen**								Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
5	Afstand tot **woningen**								Afstand tot **gezondheidszorg**	
6	Afstand tot **woningen**								Afstand tot **overige** gebouwen (bijv. industrie)	
7	Afstand tot **onderwijs** (basisschool)								Afstand tot **kantoren**	
8	Afstand tot **onderwijs** (basisschool)								Afstand tot **winkels**	
9	Afstand tot **onderwijs** (basisschool)								Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
10	Afstand tot **onderwijs** (basisschool)								Afstand tot **gezondheidszorg**	
11	Afstand tot **onderwijs** (basisschool)								Afstand tot **overige** gebouwen (bijv. industrie)	

Figure A.2: First set of comparisons



12	Afstand tot **kantoren**	3 2 1 0 1 2 3	Afstand tot **winkels**
13	Afstand tot **kantoren**	3 2 1 0 1 2 3	Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**	3 2 1 0 1 2 3	Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**	3 2 1 0 1 2 3	Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**	3 2 1 0 1 2 3	Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**	3 2 1 0 1 2 3	Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**	3 2 1 0 1 2 3	Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)	3 2 1 0 1 2 3	Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)	3 2 1 0 1 2 3	Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**	3 2 1 0 1 2 3	Afstand tot **overige** gebouwen (bijv. industrie)

Check Nog niet alle vergelijkingen zijn correct ingevuld

Figure A.3: Second set of comparisons

A.2. Calculation of the weights

The following figures (Figure A.4 and A.5) show an example of the calculations that are performed with the completed forms, in order to obtain weights for the different building types. In yellow the value as filled in in the equations can be found. Diagonally opposite, the calculated reciprocal value was shown (according to equation 2.6. The sum of each column is calculated at the bottom of the table. This value was used in the second matrix (Figure A.5) to calculate the normalized relative importance of each of the functions. Finally, all relative weights per building function were averaged to obtain a final set of weights (Equation 2.7). These weights used as percentages in the multi-criteria analysis. Logically, since these were normalized values, the sum of these averages is 1.00 (or 100%).

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	1	1	1	1	2
onderwijs	1/2	1	1	1	0	0	0
kantoren	1	1	1	1	1	0	1
winkels	1	1	1	1	1	0	1
recreatie	1	0	1	1	1	0	0
gezondheidszorg	1	0	0	0	0	1	1
overig	1/2	0	1	1	0	1	1
	6,00	*5,00*	*6,00*	*6,00*	*4,00*	*3,00*	*6,00*

Figure A.4: Calculation of the comparison (yellow) and the reciprocal value (white)

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig	gemiddelde
woningen	0,17	0,40	0,17	0,17	0,25	0,33	0,33	0,26
onderwijs	0,08	0,20	0,17	0,17	0,00	0,00	0,00	0,09
kantoren	0,17	0,20	0,17	0,17	0,25	0,00	0,17	0,16
winkels	0,17	0,20	0,17	0,17	0,25	0,00	0,17	0,16
recreatie	0,17	0,00	0,17	0,17	0,25	0,00	0,00	0,11
gezondheidszorg	0,17	0,00	0,00	0,00	0,00	0,33	0,17	0,10
overig	0,08	0,00	0,17	0,17	0,00	0,33	0,17	0,13
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	1,00

Figure A.5: Calculation of the normalized and final weights per building function

A.3. Completed forms and calculations per stakeholder

The following pages contain the completed forms and corresponding calculations of the weights for each of the stakeholders. Table A.1 provides an overview of the stakeholders that completed the form.

Table A.1: Overview of surveyed stakeholders

Name	**Company/Organisation**	**Stakeholder**
Mirza Hotic	Municipality of The Hague	Authority
Inge Molenaar	Municipality of The Hague	Authority
Charles Huijts	Municipality of The Hague	Authority
Lodewijk Lacroix	Municipality of The Hague	Authority
Casper Prudhomme van Reine	APPM	Spatial developer
Matthijs Boon	Next Urban Mobility	Operator
Sandra Nijenstein	HTM	Operator
Tim Vleeshouwer	Local resident	Traveller
Anne Boijmans	Local resident	Traveller

Authority
Gemeente Den Haag
Mirza Hotic

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	10
OV (trein en tram)	30
Gebouwen	60
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	50
Den Haag HS (trein)	50
Voorburg (trein)	0
Eventuele tramhalte in de Binckhorst	0
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**		X						Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**			X					Afstand tot **kantoren**
3	Afstand tot **woningen**			X					Afstand tot **winkels**
4	Afstand tot **woningen**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**			X					Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**		X						Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)					X			Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)					X			Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**			X					Afstand tot **winkels**
13	Afstand tot **kantoren**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**				X				Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**			X					Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**				X				Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**			X					Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				X				Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				X				Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**			X					Afstand tot **overige** gebouwen (bijv. industrie)

Check Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	1	1	1	1	2
onderwijs	1/2	1	1	1	0	0	0
kantoren	1	1	1	1	1	0	1
winkels	1	1	1	1	1	0	1
recreatie	1	0	1	1	1	0	0
gezondheidszorg	1	0	0	0	0	1	1
overig	1/2	0	1	1	0	1	1
	6,00	*5,00*	*6,00*	*6,00*	*4,00*	*3,00*	*6,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,17	0,40	0,17	0,17	0,25	0,33	0,33
onderwijs	0,08	0,20	0,17	0,17	0,00	0,00	0,00
kantoren	0,17	0,20	0,17	0,17	0,25	0,00	0,17
winkels	0,17	0,20	0,17	0,17	0,25	0,00	0,17
recreatie	0,17	0,00	0,17	0,17	0,25	0,00	0,00
gezondheidszorg	0,17	0,00	0,00	0,00	0,00	0,33	0,17
overig	0,08	0,00	0,17	0,17	0,00	0,33	0,17
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	26%
onderwijs	9%
kantoren	16%
winkels	16%
recreatie	11%
gezondheidszorg	10%
overig	13%
	100%

fietsnetwerk	10%
OV	30%
gebouwen	60%
	100%

Den Haag CS (trein)	50%
Den Haag HS (trein)	50%
Voorburg (trein)	0%
Eventuele tramhalte	0%
	100%

Authority
Gemeente Den Haag
Inge Molenaar

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	20
OV (trein en tram)	20
Gebouwen	60
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	40
Den Haag HS (trein)	50
Voorburg (trein)	10
Eventuele tramhalte in de Binckhorst	0
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**		X						Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**		X						Afstand tot **kantoren**
3	Afstand tot **woningen**		X						Afstand tot **winkels**
4	Afstand tot **woningen**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**			X					Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**		X						Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)						X		Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)					X			Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)					X			Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**		X						Afstand tot **winkels**
13	Afstand tot **kantoren**		X						Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**			X					Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**			X					Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**				X				Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**				X				Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				X				Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				X				Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**				X				Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	2	2	1	1	2
onderwijs	1/2	1	1/2	1	1	0	0
kantoren	1/2	2	1	2	2	1	1
winkels	1/2	1	1/2	1	1	0	0
recreatie	1	1	1/2	1	1	0	0
gezondheidszorg	1	0	1	0	0	1	0
overig	1/2	0	1	0	0	0	1
	5,00	*7,00*	*6,50*	*7,00*	*6,00*	*3,00*	*4,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,20	0,29	0,31	0,29	0,17	0,33	0,50
onderwijs	0,10	0,14	0,08	0,14	0,17	0,00	0,00
kantoren	0,10	0,29	0,15	0,29	0,33	0,33	0,25
winkels	0,10	0,14	0,08	0,14	0,17	0,00	0,00
recreatie	0,20	0,14	0,08	0,14	0,17	0,00	0,00
gezondheidszorg	0,20	0,00	0,15	0,00	0,00	0,33	0,00
overig	0,10	0,00	0,15	0,00	0,00	0,00	0,25
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	30%
onderwijs	9%
kantoren	25%
winkels	9%
recreatie	10%
gezondheidszorg	10%
overig	7%
	100%

fietsnetwerk	20%
OV	20%
gebouwen	60%
	100%

Den Haag CS (trein)	40%
Den Haag HS (trein)	50%
Voorburg (trein)	10%
Eventuele tramhalte	0%
	100%

Authority
Gemeente Den Haag
Charles Huijts

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	10
OV (trein en tram)	70
Gebouwen	20
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	30
Den Haag HS (trein)	30
Voorburg (trein)	15
Eventuele tramhalte in de Binckhorst	25
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**		x						Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**			x					Afstand tot **kantoren**
3	Afstand tot **woningen**		x						Afstand tot **winkels**
4	Afstand tot **woningen**				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**						x		Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**			x					Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**		x						Afstand tot **winkels**
13	Afstand tot **kantoren**			x					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**					x			Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**		x						Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**						x		Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**			x					Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)						x		Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)		x						Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**	x							Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	1	2	0	1/2	1
onderwijs	1/2	1	1/2	1/2	1/2	1/2	1
kantoren	1	2	1	2	1	1	2
winkels	1/2	2	1/2	1	0	1/2	1
recreatie	0	2	1	0	1	1/2	2
gezondheidszorg	2	2	1	2	2	1	3
overig	1	1	1/2	1	1/2	1/3	1
	6,00	*12,00*	*5,50*	*8,50*	*5,00*	*4,33*	*11,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,17	0,17	0,18	0,24	0,00	0,12	0,09
onderwijs	0,08	0,08	0,09	0,06	0,10	0,12	0,09
kantoren	0,17	0,17	0,18	0,24	0,20	0,23	0,18
winkels	0,08	0,17	0,09	0,12	0,00	0,12	0,09
recreatie	0,00	0,17	0,18	0,00	0,20	0,12	0,18
gezondheidszorg	0,33	0,17	0,18	0,24	0,40	0,23	0,27
overig	0,17	0,08	0,09	0,12	0,10	0,08	0,09
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	14%
onderwijs	9%
kantoren	19%
winkels	9%
recreatie	12%
gezondheidszorg	26%
overig	10%
	100%

fietsnetwerk	10%
OV	70%
gebouwen	20%
	100%

Den Haag CS (trein)	30%
Den Haag HS (trein)	30%
Voorburg (trein)	15%
Eventuele tramhalte	25%
	100%

Authority
Gemeente Den Haag
Lodewijk Lacroix

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	30
OV (trein en tram)	60
Gebouwen	10
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	40
Den Haag HS (trein)	30
Voorburg (trein)	20
Eventuele tramhalte in de Binckhorst	10
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**		x						Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**				x				Afstand tot **kantoren**
3	Afstand tot **woningen**						x		Afstand tot **winkels**
4	Afstand tot **woningen**						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**						x		Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**			x					Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**				x				Afstand tot **winkels**
13	Afstand tot **kantoren**				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**		x						Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**		x						Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**					x			Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**			x					Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**				x				Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)		x						Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)			x					Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**					x			Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	0	1/2	1/2	1/2	1
onderwijs	1/2	1	1/2	1/2	1/2	1/2	1/2
kantoren	0	2	1	0	0	2	2
winkels	2	2	0	1	1	1	0
recreatie	2	2	0	1	1	2	1
gezondheidszorg	2	2	1/2	1	1/2	1	1
overig	1	2	1/2	0	1	1	1
	8,50	*13,00*	*2,50*	*4,00*	*4,50*	*8,00*	*6,50*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,12	0,15	0,00	0,13	0,11	0,06	0,15
onderwijs	0,06	0,08	0,20	0,13	0,11	0,06	0,08
kantoren	0,00	0,15	0,40	0,00	0,00	0,25	0,31
winkels	0,24	0,15	0,00	0,25	0,22	0,13	0,00
recreatie	0,24	0,15	0,00	0,25	0,22	0,25	0,15
gezondheidszorg	0,24	0,15	0,20	0,25	0,11	0,13	0,15
overig	0,12	0,15	0,20	0,00	0,22	0,13	0,15
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	10%
onderwijs	10%
kantoren	16%
winkels	14%
recreatie	18%
gezondheidszorg	18%
overig	14%
	100%

fietsnetwerk	30%
OV	60%
gebouwen	10%
	100%

Den Haag CS (trein)	40%
Den Haag HS (trein)	30%
Voorburg (trein)	20%
Eventuele tramhalte	10%
	100%

Developer
APPM
Casper Prudhomme
van Reine

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	30
OV (trein en tram)	60
Gebouwen	10
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	80
Den Haag HS (trein)	10
Voorburg (trein)	10
Eventuele tramhalte in de Binckhorst	0
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**		x						Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**							x	Afstand tot **kantoren**
3	Afstand tot **woningen**		x						Afstand tot **winkels**
4	Afstand tot **woningen**					x			Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**	x							Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**	x							Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)							x	Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)							x	Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**	x							Afstand tot **winkels**
13	Afstand tot **kantoren**	x							Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**	x							Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**	x							Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**					x			Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**			x					Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**					x			Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)			x					Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				x				Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**					x			Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	1/3	2	1	3	3
onderwijs	1/2	1	1/3	1/3	1/2	0	1
kantoren	3	3	1	3	3	3	3
winkels	1/2	3	1/3	1	1	1	1
recreatie	1	2	1/3	1	1	1	0
gezondheidszorg	1/3	0	1/3	1	1	1	1
overig	1/3	1	1/3	1	0	1	1
	6,67	*12,00*	*3,00*	*9,33*	*7,50*	*10,00*	*10,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,15	0,17	0,11	0,21	0,13	0,30	0,30
onderwijs	0,08	0,08	0,11	0,04	0,07	0,00	0,10
kantoren	0,45	0,25	0,33	0,32	0,40	0,30	0,30
winkels	0,08	0,25	0,11	0,11	0,13	0,10	0,10
recreatie	0,15	0,17	0,11	0,11	0,13	0,10	0,00
gezondheidszorg	0,05	0,00	0,11	0,11	0,13	0,10	0,10
overig	0,05	0,08	0,11	0,11	0,00	0,10	0,10
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	20%
onderwijs	7%
kantoren	34%
winkels	13%
recreatie	11%
gezondheidszorg	9%
overig	8%
	100%

fietsnetwerk	30%
OV	60%
gebouwen	10%
	100%

Den Haag CS (trein)	80%
Den Haag HS (trein)	10%
Voorburg (trein)	10%
Eventuele tramhalte	0%
	100%

Operator
Next Urban Mobility
Matthijs Boon

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	5
OV (trein en tram)	20
Gebouwen	75
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	25
Den Haag HS (trein)	25
Voorburg (trein)	25
Eventuele tramhalte in de Binckhorst	25
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**	x							Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**		x						Afstand tot **kantoren**
3	Afstand tot **woningen**	x							Afstand tot **winkels**
4	Afstand tot **woningen**	x							Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**	x							Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**	x							Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)						x		Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**		x						Afstand tot **winkels**
13	Afstand tot **kantoren**		x						Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**		x						Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**		x						Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**				x				Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**				x				Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				x				Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)						x		Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**						x		Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	3	2	3	3	3	3
onderwijs	1/3	1	1/2	0	0	0	0
kantoren	1/2	2	1	2	2	2	2
winkels	1/3	0	1/2	1	0	0	0
recreatie	1/3	0	1/2	0	1	0	1/2
gezondheidszorg	1/3	0	1/2	0	0	1	1/2
overig	1/3	0	1/2	0	2	2	1
	3,17	*6,00*	*5,50*	*6,00*	*8,00*	*8,00*	*7,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,32	0,50	0,36	0,50	0,38	0,38	0,43
onderwijs	0,11	0,17	0,09	0,00	0,00	0,00	0,00
kantoren	0,16	0,33	0,18	0,33	0,25	0,25	0,29
winkels	0,11	0,00	0,09	0,17	0,00	0,00	0,00
recreatie	0,11	0,00	0,09	0,00	0,13	0,00	0,07
gezondheidszorg	0,11	0,00	0,09	0,00	0,00	0,13	0,07
overig	0,11	0,00	0,09	0,00	0,25	0,25	0,14
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	41%
onderwijs	5%
kantoren	26%
winkels	5%
recreatie	6%
gezondheidszorg	6%
overig	12%
	100%

fietsnetwerk	5%
OV	20%
gebouwen	75%
	100%

Den Haag CS (trein)	25%
Den Haag HS (trein)	25%
Voorburg (trein)	25%
Eventuele tramhalte	25%
	100%

Operator
HTM
Sandra Nijënstein

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	30
OV (trein en tram)	20
Gebouwen	50
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	45
Den Haag HS (trein)	30
Voorburg (trein)	15
Eventuele tramhalte in de Binckhorst	10
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**						x		Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**						x		Afstand tot **kantoren**
3	Afstand tot **woningen**					x			Afstand tot **winkels**
4	Afstand tot **woningen**						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**					x			Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**				x				Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)			x					Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)		x						Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)		x						Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**		x						Afstand tot **winkels**
13	Afstand tot **kantoren**			x					Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**	x							Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**		x						Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**				x				Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**		x						Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**			x					Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)		x						Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)		x						Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**				x				Afstand tot **overige** gebouwen (bijv. industrie)

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	1/2	1/2	1	1/2	1	0
onderwijs	2	1	0	1	0	2	2
kantoren	2	0	1	2	1	3	2
winkels	1	1	1/2	1	0	2	1
recreatie	2	0	1	0	1	2	2
gezondheidszorg	1	1/2	1/3	1/2	1/2	1	0
overig	0	1/2	1/2	1	1/2	0	1
	9,00	*3,50*	*3,83*	*6,50*	*3,50*	*11,00*	*8,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,11	0,14	0,13	0,15	0,14	0,09	0,00
onderwijs	0,22	0,29	0,00	0,15	0,00	0,18	0,25
kantoren	0,22	0,00	0,26	0,31	0,29	0,27	0,25
winkels	0,11	0,29	0,13	0,15	0,00	0,18	0,13
recreatie	0,22	0,00	0,26	0,00	0,29	0,18	0,25
gezondheidszorg	0,11	0,14	0,09	0,08	0,14	0,09	0,00
overig	0,00	0,14	0,13	0,15	0,14	0,00	0,13
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	11%
onderwijs	16%
kantoren	23%
winkels	14%
recreatie	17%
gezondheidszorg	9%
overig	10%
	100%

fietsnetwerk	30%
OV	20%
gebouwen	50%
	100%

Den Haag CS (trein)	45%
Den Haag HS (trein)	30%
Voorburg (trein)	15%
Eventuele tramhalte	10%
	100%

Traveller
Tim Vleeshouwer

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	10
OV (trein en tram)	60
Gebouwen	30
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot…
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	40
Den Haag HS (trein)	40
Voorburg (trein)	10
Eventuele tramhalte in de Binckhorst	10
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3	
1	Afstand tot **woningen**						x		Afstand tot **onderwijs** (basisschool)
2	Afstand tot **woningen**							x	Afstand tot **kantoren**
3	Afstand tot **woningen**						x		Afstand tot **winkels**
4	Afstand tot **woningen**						x		Afstand tot **recreatie** (sport, horeca en bijeenkomst)
5	Afstand tot **woningen**						x		Afstand tot **gezondheidszorg**
6	Afstand tot **woningen**						x		Afstand tot **overige** gebouwen (bijv. industrie)
7	Afstand tot **onderwijs** (basisschool)							x	Afstand tot **kantoren**
8	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **winkels**
9	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **recreatie** (sport, horeca en bijeenkomst)
10	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **gezondheidszorg**
11	Afstand tot **onderwijs** (basisschool)					x			Afstand tot **overige** gebouwen (bijv. industrie)
12	Afstand tot **kantoren**	x							Afstand tot **winkels**
13	Afstand tot **kantoren**	x							Afstand tot **recreatie** (sport, horeca en bijeenkomst)
14	Afstand tot **kantoren**	x							Afstand tot **gezondheidszorg**
15	Afstand tot **kantoren**	x							Afstand tot **overige** gebouwen (bijv. industrie)
16	Afstand tot **winkels**		x						Afstand tot **recreatie** (sport, horeca en bijeenkomst)
17	Afstand tot **winkels**		x						Afstand tot **gezondheidszorg**
18	Afstand tot **winkels**			x					Afstand tot **overige** gebouwen (bijv. industrie)
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				x				Afstand tot **gezondheidszorg**
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				x				Afstand tot **overige** gebouwen (bijv. industrie)
21	Afstand tot **gezondheidszorg**				x				Afstand tot **overige** gebouwen (bijv. industrie)

Check Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	1/2	1/3	1/2	1/2	1/2	1/2
onderwijs	2	1	1/3	1	1	1	1
kantoren	3	3	1	3	3	3	3
winkels	2	1	1/3	1	2	2	1
recreatie	2	1	1/3	1/2	1	0	0
gezondheidszorg	2	1	1/3	1/2	0	1	0
overig	2	1	1/3	1	0	0	1
	14,00	*8,50*	*3,00*	*7,50*	*7,50*	*7,50*	*6,50*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,07	0,06	0,11	0,07	0,07	0,07	0,08
onderwijs	0,14	0,12	0,11	0,13	0,13	0,13	0,15
kantoren	0,21	0,35	0,33	0,40	0,40	0,40	0,46
winkels	0,14	0,12	0,11	0,13	0,27	0,27	0,15
recreatie	0,14	0,12	0,11	0,07	0,13	0,00	0,00
gezondheidszorg	0,14	0,12	0,11	0,07	0,00	0,13	0,00
overig	0,14	0,12	0,11	0,13	0,00	0,00	0,15
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	7%
onderwijs	13%
kantoren	37%
winkels	17%
recreatie	8%
gezondheidszorg	8%
overig	9%
	100%

fietsnetwerk	10%
OV	60%
gebouwen	30%
	100%

Den Haag CS (trein)	40%
Den Haag HS (trein)	40%
Voorburg (trein)	10%
Eventuele tramhalte	10%
	100%

Traveller
Anne Boijmans

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de drie categorieën)

Fietsnetwerk	30
OV (trein en tram)	50
Gebouwen	20
punten nog te verdelen	0

Hoe belangrijk vindt u de afstand van deelfietsstations tot...
(verdeel 100 punten over de vier OV stations)

Den Haag CS (trein)	30
Den Haag HS (trein)	40
Voorburg (trein)	20
Eventuele tramhalte in de Binckhorst	10
punten nog te verdelen	0

Vergelijkingen afstand van deelfietsstation tot verschillende gebouwfuncties
(plaats een 'x' aan de kant van de bebouwing waarvan u verwacht dat die het meest van belang is, 0 = beide zijn gelijk)

		3	2	1	0	1	2	3		
1	Afstand tot **woningen**		X						Afstand tot **onderwijs** (basisschool)	
2	Afstand tot **woningen**						X		Afstand tot **kantoren**	
3	Afstand tot **woningen**		X						Afstand tot **winkels**	
4	Afstand tot **woningen**		X						Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
5	Afstand tot **woningen**					X			Afstand tot **gezondheidszorg**	
6	Afstand tot **woningen**		X						Afstand tot **overige** gebouwen (bijv. industrie)	
7	Afstand tot **onderwijs** (basisschool)						X		Afstand tot **kantoren**	
8	Afstand tot **onderwijs** (basisschool)					X			Afstand tot **winkels**	
9	Afstand tot **onderwijs** (basisschool)				X				Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
10	Afstand tot **onderwijs** (basisschool)						X		Afstand tot **gezondheidszorg**	
11	Afstand tot **onderwijs** (basisschool)			X					Afstand tot **overige** gebouwen (bijv. industrie)	
12	Afstand tot **kantoren**	X							Afstand tot **winkels**	
13	Afstand tot **kantoren**			X					Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
14	Afstand tot **kantoren**				X				Afstand tot **gezondheidszorg**	
15	Afstand tot **kantoren**	X							Afstand tot **overige** gebouwen (bijv. industrie)	
16	Afstand tot **winkels**				X				Afstand tot **recreatie** (sport, horeca en bijeenkomst)	
17	Afstand tot **winkels**					X			Afstand tot **gezondheidszorg**	
18	Afstand tot **winkels**				X				Afstand tot **overige** gebouwen (bijv. industrie)	
19	Afstand tot **recreatie** (sport, horeca en bijeenkomst)						X		Afstand tot **gezondheidszorg**	
20	Afstand tot **recreatie** (sport, horeca en bijeenkomst)				X				Afstand tot **overige** gebouwen (bijv. industrie)	
21	Afstand tot **gezondheidszorg**		X						Afstand tot **overige** gebouwen (bijv. industrie)	

Check	Alle vergelijkingen zijn correct ingevuld

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	1	2	1/2	2	2	1	2
onderwijs	1/2	1	1/2	1	0	1/2	1
kantoren	2	2	1	3	1	0	3
winkels	1/2	1	1/3	1	0	1	0
recreatie	1/2	0	1	0	1	1/2	0
gezondheidszorg	1	2	0	1	2	1	2
overig	1/2	1	1/3	0	0	1/2	1
	6,00	*9,00*	*3,67*	*8,00*	*6,00*	*4,50*	*9,00*

	woningen	onderwijs	kantoren	winkels	recreatie	gezondheidszorg	overig
woningen	0,17	0,22	0,14	0,25	0,33	0,22	0,22
onderwijs	0,08	0,11	0,14	0,13	0,00	0,11	0,11
kantoren	0,33	0,22	0,27	0,38	0,17	0,00	0,33
winkels	0,08	0,11	0,09	0,13	0,00	0,22	0,00
recreatie	0,08	0,00	0,27	0,00	0,17	0,11	0,00
gezondheidszorg	0,17	0,22	0,00	0,13	0,33	0,22	0,22
overig	0,08	0,11	0,09	0,00	0,00	0,11	0,11
	1,00	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*

woningen	22%
onderwijs	10%
kantoren	24%
winkels	9%
recreatie	9%
gezondheidszorg	18%
overig	7%
	100%

fietsnetwerk	30%
OV	50%
gebouwen	20%
	100%

Den Haag CS (trein)	30%
Den Haag HS (trein)	40%
Voorburg (trein)	20%
Eventuele tramhalte	10%
	100%

B

Traffic generation indicators

This appendix includes the information that was presented by CROW (2018). This contains the indicators for traffic generation for different types of buildings. This information was used in the multi-criteria analysis to determine the traffic in the Binckhorst.

B.1. Degree of urbanisation

Before the correct indicators can be read from the tables, it is important to determine the number of addresses per km^2. Binckhorst can be classified as extremely urbanised.

Klasse	Omgevingsadressendichtheid (adressen per km^2)
zeer sterk stedelijk	> 2500
sterk stedelijk	1500-2500
matig stedelijk	1000-1500
weinig stedelijk	500-1000
niet stedelijk	< 500

Figure B.1: Degree of urbanisation of Dutch municipalities

B.2. Car use

	autobezit per huishouden	auto-gebruik
		totaal
zeer sterk stedelijk	0,69	26%
sterk stedelijk	1,09	33%
matig stedelijk	1,15	35%
weinig stedelijk	1,22	36%
niet stedelijk	1,27	37%

Figure B.2: Car ownership and car use by degree of urbanisation

CROW (2018) has made a distinction between different degrees of urbanisation and between distances from the city center. For this research, the indicators for the categories extremely urbanised were used (*zeer sterk stedelijk*) and center edge (*schil centrum*), according to the number of addresses per km^2 (B.1) and the location of the Binckhorst.

	Autogebruik naar motief								
	Van en naar het werk	Zakelijk bezoek inwerk-sfeer	Diensten/ persoon-lijke ver-zorging	Winkelen/ bood-schap-pen-doen	Onder-wijs/ cursus volgen	Visite/ logeren	Sociaal recreatief overig	Toeren/ wande-len	Ander motief
Zeer sterk stedelijk	41%	62%	30%	20%	4%	29%	21%	7%	29%
Sterk stede-lijk	54%	75%	39%	31%	4%	33%	29%	8%	35%
Matig stede-lijk	57%	79%	40%	34%	4%	34%	30%	9%	35%
Weinig stede-lijk	60%	80%	44%	39%	4%	35%	30%	10%	37%
Niet stedelijk	63#	80%	45%	41%	4%	35%	31%	10%	37%

Figure B.3: Car use by motive

B.3. Traffic generation per building type

The following tables show the trip generation for different types of buildings. These values represent the number of trips generated per 24 hours on an average weekday. For most building types, these numbers are equal to the trip generation per 100 m^2 gross floor area (GFA), but for residential buildings these values are expressed per house, apartment or room.

B.3.1. Residential buildings

Since different types of houses will be built in the Binckhorst, it was decided to average the indicators for all different types of houses that are shown below.

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stede-lijk	5,9	6,7	6,4	7,2	7,3	8,1	7,8	8,6
Sterk stedelijk	6,4	7,2	7,3	8,1	7,8	8,6	7,8	8,6
Matig stedelijk	7,3	8,1	7,6	8,4	7,8	8,6	7,8	8,6
Weinig stedelijk	7,5	8,3	7,7	8,5	7,8	8,6	7,8	8,6
Niet stedelijk	7,5	8,3	7,7	8,5	7,8	8,6	7,8	8,6

Figure B.4: Owner-occupied detached house

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	5,0	5,8	5,9	6,7	6,9	7,7	7,4	8,2
Sterk stedelijk	5,9	6,7	6,9	7,7	7,4	8,2	7,4	8,2
Matig stedelijk	6,9	7,7	7,2	8,0	7,4	8,2	7,4	8,2
Weinig stedelijk	7,2	8,0	7,3	8,1	7,4	8,2	7,4	8,2
Niet stedelijk	7,2	8,0	7,3	8,1	7,4	8,2	7,4	8,2

Figure B.5: Owner-occupied semi-detached house

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	4,5	5,3	5,4	6,2	6,4	7,2	7,0	7,8
Sterk stedelijk	5,4	6,2	6,4	7,2	6,7	7,5	7,0	7,8
Matig stedelijk	6,4	7,2	6,5	7,3	6,7	7,5	7,0	7,8
Weinig stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8
Niet stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8

Figure B.6: Owner-occupied terraced/corner house

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	4,5	5,3	5,4	6,2	6,4	7,2	7,0	7,8
Sterk stedelijk	5,4	6,2	6,4	7,2	6,7	7,5	7,0	7,8
Matig stedelijk	6,4	7,2	6,5	7,3	6,7	7,5	7,0	7,8
Weinig stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8
Niet stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8

Figure B.7: Owner-occupied apartment, expensive

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	2,9	3,7	3,7	4,5	4,7	5,5	5,6	6,4
Sterk stedelijk	3,7	4,5	4,7	5,5	5,2	6,0	5,6	6,4
Matig stedelijk	4,7	5,5	5,0	5,8	5,2	6,0	5,6	6,4
Weinig stedelijk	5,4	6,2	5,5	6,3	5,6	6,4	5,6	6,4
Niet stedelijk	5,4	6,2	5,5	6,3	5,6	6,4	5,6	6,4

Figure B.8: Owner-occupied apartment, averagely priced

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	1,2	2,0	2,8	3,6	3,9	4,7	5,2	6,0
Sterk stedelijk	2,8	3,6	3,9	4,7	4,5	5,3	5,2	6,0
Matig stedelijk	3,9	4,7	4,2	5,0	4,5	5,3	5,2	6,0
Weinig stedelijk	4,8	5,6	5,0	5,8	5,2	6,0	5,2	6,0
Niet stedelijk	4,8	5,6	5,0	5,8	5,2	6,0	5,2	6,0

Figure B.9: Owner-occupied apartment, low-priced

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	4,5	5,3	5,4	6,2	6,4	7,2	7,0	7,8
Sterk stedelijk	5,4	6,2	6,4	7,2	6,7	7,5	7,0	7,8
Matig stedelijk	6,4	7,2	6,5	7,3	6,7	7,5	7,0	7,8
Weinig stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8
Niet stedelijk	6,8	7,6	6,9	7,7	7,0	7,8	7,0	7,8

Figure B.10: Rental, private housing

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	1,2	2,0	2,8	3,6	3,9	4,7	5,2	6,0
Sterk stedelijk	2,8	3,6	3,9	4,7	4,5	5,3	5,2	6,0
Matig stedelijk	3,9	4,7	4,2	5,0	4,5	5,3	5,2	6,0
Weinig stedelijk	4,8	5,6	5,0	5,8	5,2	6,0	5,2	6,0
Niet stedelijk	4,8	5,6	5,0	5,8	5,2	6,0	5,2	6,0

Figure B.11: Rental, social housing

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	2,9	3,7	3,7	4,5	4,7	5,5	5,6	6,4
Sterk stedelijk	3,7	4,5	4,7	5,5	5,2	6,0	5,6	6,4
Matig stedelijk	4,7	5,5	5,0	5,8	5,2	6,0	5,6	6,4
Weinig stedelijk	5,4	6,2	5,5	6,3	5,6	6,4	5,6	6,4
Niet stedelijk	5,4	6,2	5,5	6,3	5,6	6,4	5,6	6,4

Figure B.12: Rental apartment, expensive

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	0,8	1,6	1,8	2,6	2,8	3,6	3,7	4,5
Sterk stedelijk	1,8	2,6	2,8	3,6	3,2	4,0	3,7	4,5
Matig stedelijk	2,8	3,6	3,0	3,8	3,2	4,0	3,7	4,5
Weinig stedelijk	3,7	4,5	3,7	4,5	3,7	4,5	3,7	4,5
Niet stedelijk	3,7	4,5	3,7	4,5	3,7	4,5	3,7	4,5

Figure B.13: Rental apartment, medium/cheap (incl. social rent)

	Verkeersgeneratie (per kamer)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	1,5	1,5	1,5	1,8	1,8	2,1	1,8	2,4
Sterk stedelijk	1,5	1,5	1,5	1,8	1,8	2,1	1,8	2,4
Matig stedelijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4
Weinig stedelijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4
Niet stedelijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4

Figure B.14: Room rental, independent (non-students)

	Verkeersgeneratie (per kamer)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	0,8	1,2	0,8	1,2	0,8	1,2	0,8	1,2
Sterk stedelijk	0,8	1,2	0,8	1,2	0,8	1,2	0,8	1,2
Matig stedelijk	0,8	1,2	0,8	1,2	0,8	1,2	0,8	1,2
Weinig stedelijk	0,8	1,2	0,8	1,2	0,8	1,2	0,8	1,2
Niet stedelijk	0,8	1,2	0,8	1,2	0,8	1,2	0,8	1,2

Figure B.15: Room rental, students, non-independent

	Verkeersgeneratie (per woning)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	0,4	1,2	0,4	1,2	2,0	2,7	2,2	3,0
Sterk stedelijk	0,4	1,2	2,0	2,7	2,1	2,8	2,2	3,0
Matig stedelijk	2,0	2,7	2,0	2,7	2,1	2,8	2,2	3,0
Weinig stedelijk	2,0	2,7	2,1	2,8	2,2	3,0	2,2	3,0
Niet stedelijk	2,0	2,7	2,1	2,8	2,2	3,0	2,2	3,0

Figure B.16: Service apartment

	Verkeersgeneratie (per kamer)							
	Centrum		Schil centrum		Rest bebouwde kom			
Zeer sterk stedelijk	1,5	1,5	1,5	1,8	1,8	2,1	1,8	2,4
Sterk stedelijk	1,5	1,5	1,5	1,8	1,8	2,1	1,8	2,4
Matig stede-lijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4
Weinig stede-lijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4
Niet stedelijk	1,5	1,8	1,8	2,1	1,8	2,4	1,8	2,4

Figure B.17: Small single house (tiny house)

B.3.2. Offices

	Verkeersgeneratie (per 100 m^2 bvo)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stede-lijk	2,1	3,8	3,0	4,7	3,2	4,9	7,9	9,6
Sterk stedelijk	3,2	4,9	4,4	6,2	4,7	6,5	7,9	9,6
Matig stedelijk	4,3	6,1	5,9	7,7	6,3	8,1	7,9	9,6
Niet stedelijk	5,5	7,2	7,4	9,2	7,9	9,6	7,9	9,6
Weinig stedelijk	5,5	7,2	7,4	9,2	7,9	9,6	7,9	9,6

Figure B.18: Offices

B.3.3. Shops

For shops, many types were distinguished. In this analysis, the indicators for shops in a district center were used as there will be built different types of shops.

	Verkeersgeneratie (per 100 m^2 bvo)							
	centrum		schil centrum		rest bebouwde kom		buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
zeer sterk stedelijk	n.v.t.	n.v.t.	32,2	49,5	40,6	57,9	n.v.t.	n.v.t.
sterk stedelijk	n.v.t.	n.v.t.	36,6	53,9	45,9	63,2	n.v.t.	n.v.t.
matig stedelijk	n.v.t.	n.v.t.	36,7	54,0	46,0	63,3	n.v.t.	n.v.t.
weinig stedelijk	n.v.t.	n.v.t.	39,9	57,2	49,9	67,2	n.v.t.	n.v.t.
niet stedelijk	n.v.t.	n.v.t.	41,0	58,3	51,2	68,5	n.v.t.	n.v.t.

Figure B.19: District center

B.3.4. Recreation

All buildings with a sports, accommodation or meeting function have been merged into the category “recreation”. The average of the indicators for a sports hall and lodging (***) is used. For meeting rooms, no traffic generation indicators were presented.

	Verkeersgeneratie (per 100 m^2 bvo)							
	Centrum		Schil centrum		Rest bebouwde kom		Buiten gebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	4,2	6,0	6,3	8,1	8,5	10,3	11,2	12,9
Sterk stedelijk	4,2	6,0	6,3	8,1	8,6	10,3	11,2	12,9
Matig stedelijk	4,5	6,3	6,7	8,5	9,1	10,8	11,2	12,9
Weinig stedelijk	4,5	6,3	6,8	8,6	9,2	10,9	11,2	12,9
Niet stedelijk	4,5	6,3	6,8	8,6	9,2	10,9	11,2	12,9

Figure B.20: Sports hall

	Verkeersgeneratie (per 10 kamers)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	4,3	7,2	7,5	10,3	12,2	15,1	18,0	20,9
Sterk stedelijk	4,3	7,2	7,5	10,3	12,2	15,1	18,0	20,9
Matig stedelijk	4,6	7,5	7,9	10,8	12,9	15,8	18,0	20,9
Weinig stedelijk	4,9	7,7	8,3	11,2	13,5	16,4	18,0	20,9
Niet stedelijk	4,9	7,8	8,3	11,2	13,5	16,4	18,0	20,9

Figure B.21: Lodging (***)

B.3.5. Health care

For health care it was decided to use the values for a health care centre. This indicator was expressed as number of trips per treatment room, so it should be converted to number of trips per 100 m^2.

	Centrum		Schil centrum		Rest bebouwde kom		Buiten gebied	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	8,2	12,4	10,2	14,4	12,3	16,5	18,5	22,6
Sterk stedelijk	10,8	15,1	13,4	17,6	16,0	20,2	18,5	22,6
Matig stedelijk	10,8	15,1	13,4	17,6	16,1	20,2	18,5	22,6
Weinig stedelijk	12,2	16,5	15,1	19,2	18,0	22,1	18,5	22,6
Niet stedelijk	12,5	16,8	15,5	19,6	18,5	22,6	18,5	22,6

Figure B.22: Health care centre

B.3.6. Other

In this analysis, all objects having the purpose "other" or "industrial" were merged. The values for industrial purposes were used for this category.

	Verkeersgeneratie (per 100 m^2 bvo)							
	Centrum		Schil centrum		Rest bebouwde kom		Buitengebied bezoekers	
	min.	max.	min.	max.	min.	max.	min.	max.
Zeer sterk stedelijk	5,2	7,0	6,4	8,1	7,5	9,2	9,1	10,9
Sterk stedelijk	5,8	7,5	7,0	8,8	8,3	10,1	9,1	10,9
Matig stedelijk	6,3	8,0	7,7	9,4	9,1	10,9	9,1	10,9
Weinig stedelijk	6,3	8,0	7,7	9,4	9,1	10,9	9,1	10,9
Niet stedelijk	6,3	8,0	7,7	9,4	9,1	10,9	9,1	10,9

Figure B.23: Labor-intensive / visitor-extensive company (industry, laboratory, workshop)

C

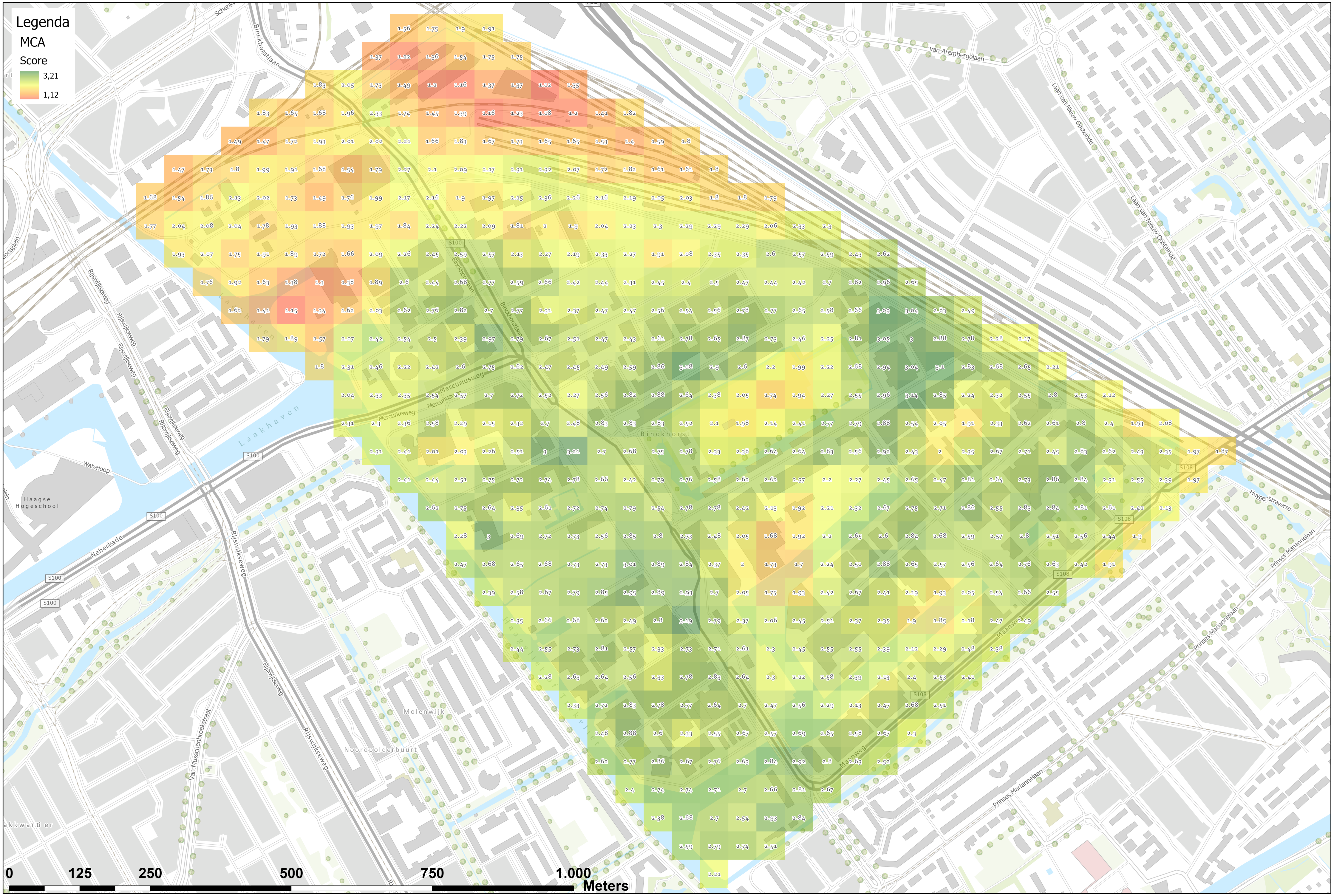
Heat maps spatial multi-criteria analysis

This appendix shows the final heat maps that resulted from the spatial multi-criteria analysis. The heat maps are presented in the following order:

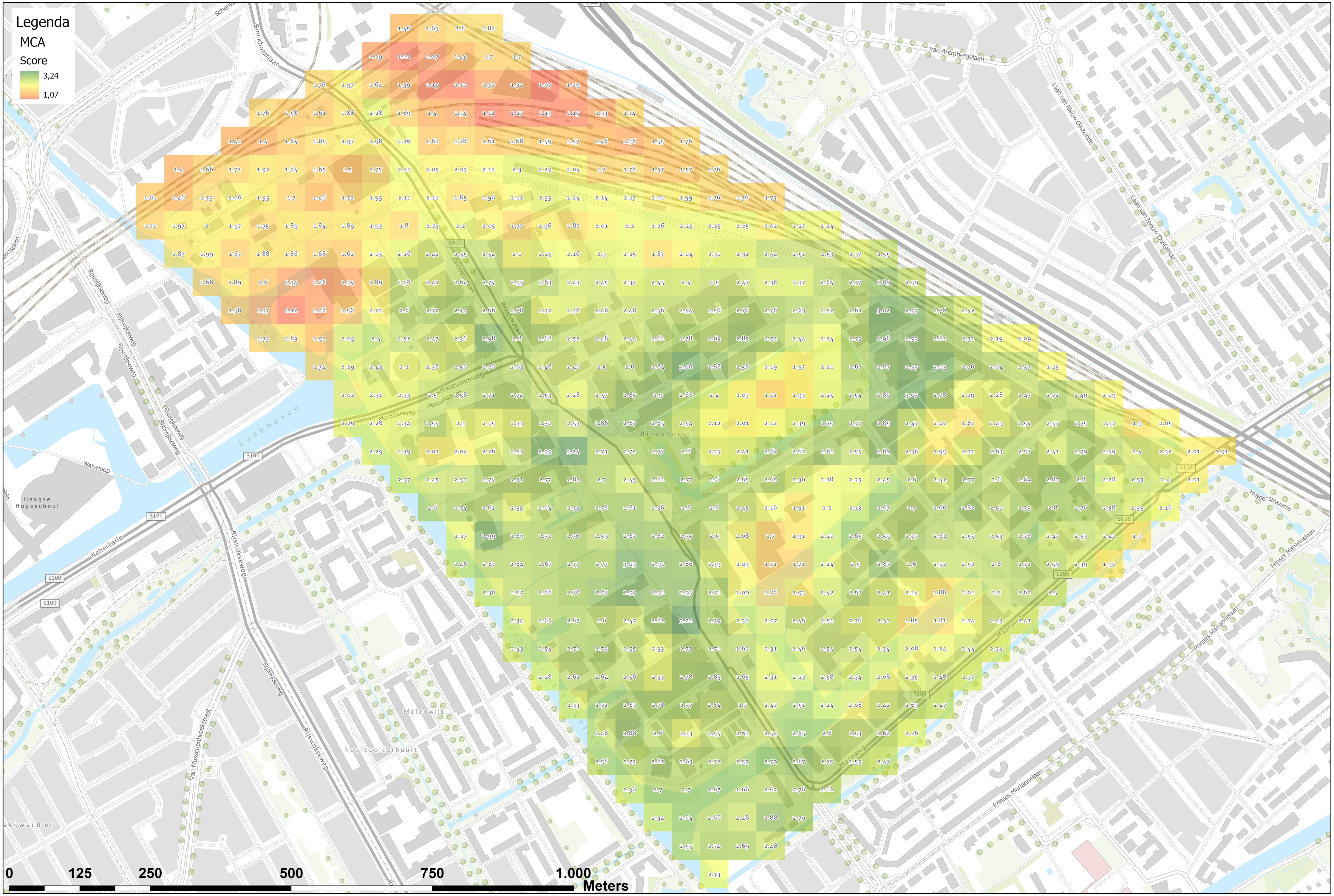
- Expected land-use without potential tram
- Expected land-use with potential tram
- Extreme land-use without potential tram
- Extreme land-use with potential tram

The maps show which locations achieve the highest potential (green) and which locations achieve the lowest potential (red). When comparing the expected and extreme land-use scenario, there is a small difference in the north, around the locations where hypothetical buildings have been added in the extreme scenario. The potential has increased slightly around these additional buildings. The difference between the scenarios with tram and without tram, is that in the scenario with the tram, all scores are slightly increased. Overall, it can be concluded that the difference between all scenarios is very small and therefore has no influence on the selected shared bicycle locations.

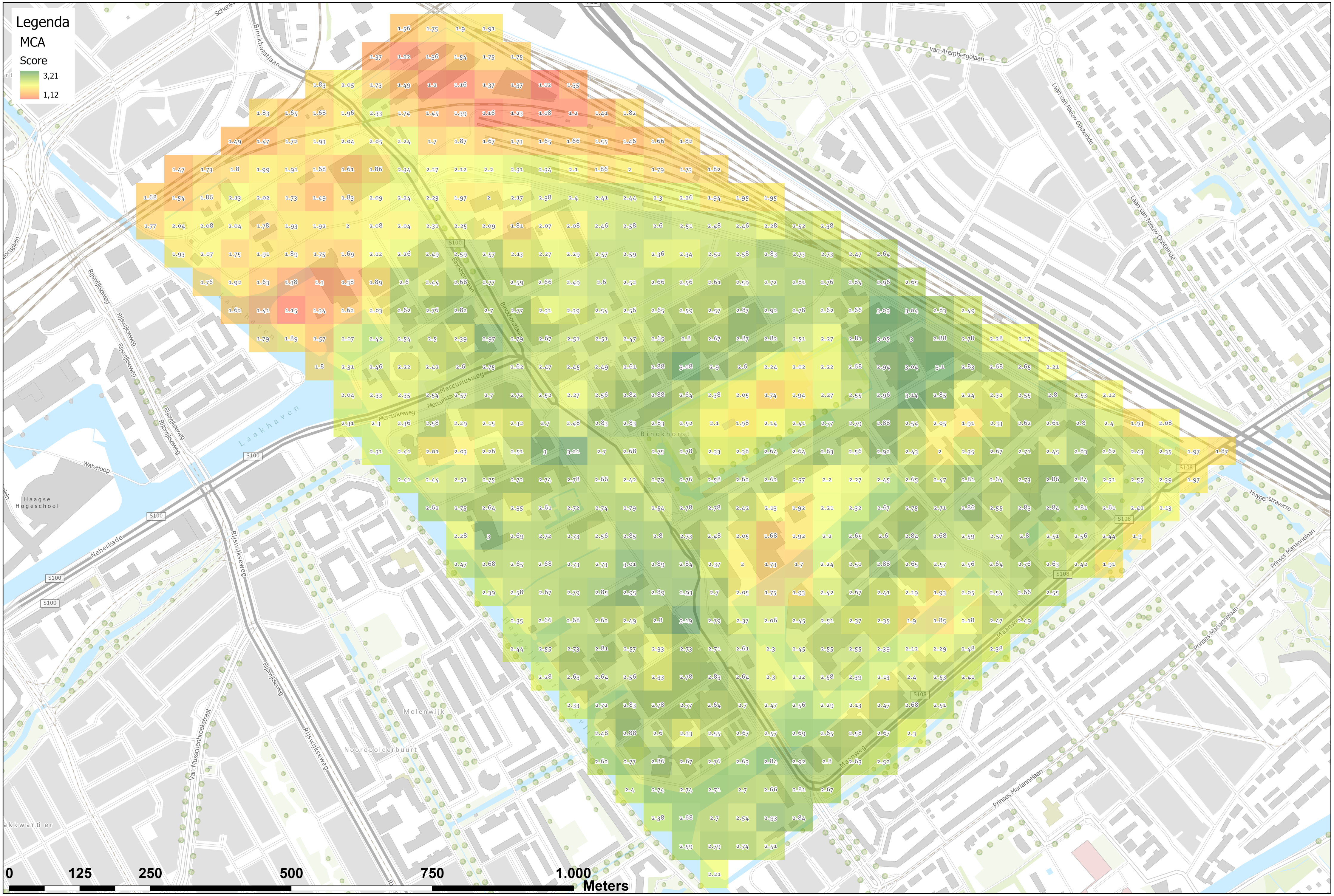
MCA Binckhorst - Verwacht zonder tram



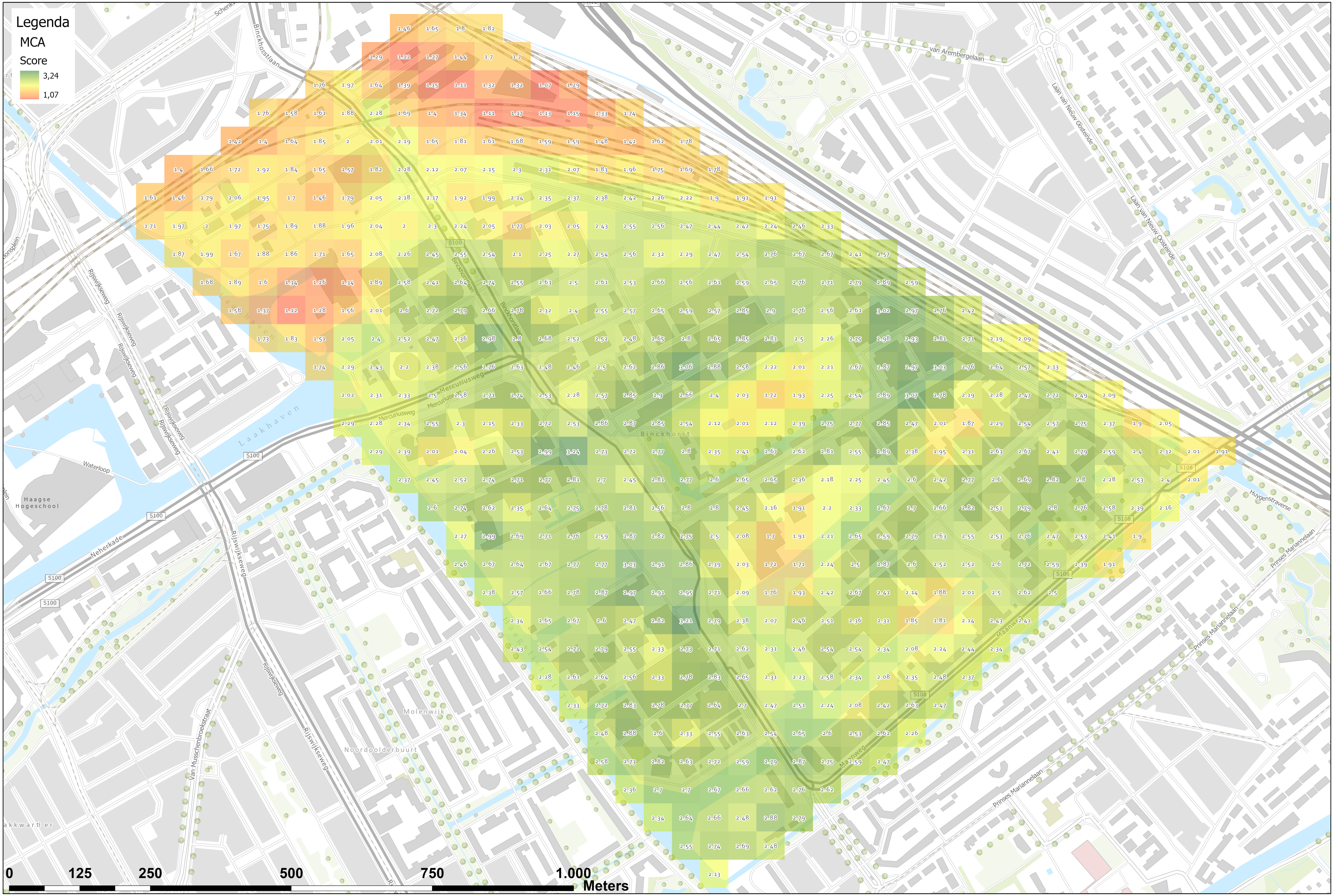
MCA Binckhorst - Verwacht met tram



MCA Binckhorst - Extreem zonder tram



MCA Binckhorst - Extreem met tram



D Flow model calculations

Appendix D contains (examples of) the calculations in the traveller flow model. The example calculations of the travel times and travel costs are based on the situation with expected land-use and six bicycle docking stations. For the results, the values are shown varying from 1 to 6 bicycle docking stations, for both the expected and extreme land-use scenario. The following pages contain in this order:

- The coordinates of the centroids, transit stops and docking stations and an overview of the area including the zones
- The input data, including the Value of Time and taste parameters (β's), travel distances, times and costs for each mode and each O-D pair, as well as the distribution of travellers over the destinations
- The bicycle docking choices for each O-D, varying from 2 to 6 docking stations
- The travel times, costs, corresponding utility and mode choice for each alternative, in the expected land use scenario with 6 bicycle docking stations:
  - Alternative 1: Walk only
  - Alternative 2: Bike + walk
  - Alternative 3: Tram + walk
  - Alternative 4: Tram or bike + walk
- The results of the comparison of the alternatives, for the expected and extreme land-use scenario. These are the results of the indicators that were assumed in the assessment framework.

O/D	X/longitude	Y/latitude
zone 1	4,33418065376	52,07367459920
zone 2	4,33162211096	52,07130566490
zone 3	4,33454321101	52,06957418960
zone 4	4,33789884576	52,07116888580
zone 5	4,33532311911	52,06824474070
zone 6	4,33676353789	52,06710012020
zone 7	4,33865481656	52,06559705210
zone 8	4,34040072262	52,06427240230
zone 9	4,34132677630	52,06342458220
zone 10	4,34264423829	52,06232539340
zone 11	4,34681608265	52,06451692050
zone 12	4,35050941606	52,06733607420
zone 13	4,35321224569	52,06819620000
zone 14	4,34746358939	52,06938006490
zone 15	4,34708849157	52,06809733280
zone 16	4,34567955852	52,06582852610
zone 17	4,34315599516	52,06646114650
zone 18	4,34206944361	52,06856322000
zone 19	4,34206058020	52,07041884100
zone 20	4,33873463072	52,06930673110
CS: Den Haag CS	4,32499980927	52,08027648926
HS: Den Haag HS	4,32250022888	52,06972122192
VB: Voorburg	4,35944461823	52,06666564941
Tram_stop	4,34068322182	52,06712811402
Bike_1	4,33775067351	52,06805915798
Bike_2	4,34101581573	52,06539348455
Bike_3	4,34672355652	52,06907372090
Bike_4	4,34353709221	52,06213510104
Bike_5	4,35147643089	52,06739522778
Bike_6	4,33442294598	52,07010584742

Variable	
Calculated using Matlab	
Assumption	
Calculation	

VoT
€ 12,65

B_time	-0,0898
B_cost	-0,4260
B_transfer	-0,1796

Mode	Walk									
Unit	Seconds									
Origin	CS	HS	VB	Tram_stop	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5	Bike_6
Destination										
1	1158	865	1764	832	867	961	1045	1261	1351	476
2	1335	717	1712	755	746	851	979	1172	1284	226
3	1444	1126	1821	855	846	950	1079	1272	1384	20
4	1532	1212	1438	463	541	624	692	935	997	548
5	1626	1085	1668	476	213	486	803	840	1169	647
6	1959	1418	1533	324	144	315	631	668	997	980
7	1895	1548	1448	239	273	167	546	520	912	928
8	2052	1713	1373	373	438	163	686	346	871	1074
9	2143	1804	1276	465	530	255	778	249	769	1166
10	2269	1946	1190	565	658	383	882	29	696	1292
11	2363	2040	879	659	768	496	575	287	386	1386
12	2285	1965	676	633	876	832	405	687	67	1312
13	2236	1916	523	727	970	926	382	756	244	1287
14	2042	1722	859	388	631	587	43	892	420	1069
15	2181	1866	953	358	602	558	147	715	353	1202
16	2401	2086	1022	579	823	779	368	771	411	1423
17	1907	1592	1165	85	328	284	262	589	629	929
18	1779	1464	1415	167	450	406	513	711	879	806
19	1827	1507	1190	394	650	606	457	917	762	843
20	1749	1434	1396	240	488	444	587	755	969	775

Mode	Walk									
Unit	mm:ss									
Origin	CS	HS	VB	Tram_stop	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5	Bike_6
Destination	mm:ss									
1	19:18	14:25	29:24	13:52	14:27	16:01	17:25	21:01	22:31	07:56
2	22:15	11:57	28:32	12:35	12:26	14:11	16:19	19:32	21:24	03:46
3	24:04	18:46	30:21	14:15	14:06	15:50	17:59	21:12	23:04	00:20
4	25:32	20:12	23:58	07:43	09:01	10:24	11:32	15:35	16:37	09:08
5	27:06	18:05	27:48	07:56	03:33	08:06	13:23	14:00	19:29	10:47
6	32:39	23:38	25:33	05:24	02:24	05:15	10:31	11:08	16:37	16:20
7	31:35	25:48	24:08	03:59	04:33	02:47	09:06	08:40	15:12	15:28
8	34:12	28:33	22:53	06:13	07:18	02:43	11:26	05:46	14:31	17:54
9	35:43	30:04	21:16	07:45	08:50	04:15	12:58	04:09	12:49	19:26
10	37:49	32:26	19:50	09:25	10:58	06:23	14:42	00:29	11:36	21:32
11	39:23	34:00	14:39	10:59	12:48	08:16	09:35	04:47	06:26	23:06
12	38:05	32:45	11:16	10:33	14:36	13:52	06:45	11:27	01:07	21:52
13	37:16	31:56	08:43	12:07	16:10	15:26	06:22	12:36	04:04	21:27
14	34:02	28:42	14:19	06:28	10:31	09:47	00:43	14:52	07:00	17:49
15	36:21	31:06	15:53	05:58	10:02	09:18	02:27	11:55	05:53	20:02
16	40:01	34:46	17:02	09:39	13:43	12:59	06:08	12:51	06:51	23:43
17	31:47	26:32	19:25	01:25	05:28	04:44	04:22	09:49	10:29	15:29
18	29:39	24:24	23:35	02:47	07:30	06:46	08:33	11:51	14:39	13:26
19	30:27	25:07	19:50	06:34	10:50	10:06	07:37	15:17	12:42	14:03
20	29:09	23:54	23:16	04:00	08:08	07:24	09:47	12:35	16:09	12:55

Mode	Tram	
Unit	km/min/€	
Origin	CS	VB
Destination		
Tram_stop		
Distance	2	1,5
Time	04:48	03:36
Costs	€ 1,32	€ 1,23

km/h	25

basistarief	€ 0,98
kilometerprijs	€ 0,169

Mode	Bike		
Unit	seconds		
Origin	CS	HS	VB
Destination			
Bike_1	708	493	475
Bike_2	736	558	410
Bike_3	797	657	322
Bike_4	1173	763	353
Bike_5	852	793	297
Bike_6	601	542	551

Mode	Bike		
Unit	mm:ss		
Origin	CS	HS	VB
Destination			
Bike_1	11:48	08:13	07:55
Bike_2	12:16	09:18	06:50
Bike_3	13:17	10:57	05:22
Bike_4	19:33	12:43	05:53
Bike_5	14:12	13:13	04:57
Bike_6	10:01	09:02	09:11

Mode	Bike	€ 1,00	
Unit	€		
Origin	CS	HS	VB
Destination			
Bike_1	€ 1,00	€ 1,00	€ 1,00
Bike_2	€ 1,00	€ 1,00	€ 1,00
Bike_3	€ 1,00	€ 1,00	€ 1,00
Bike_4	€ 1,00	€ 1,00	€ 1,00
Bike_5	€ 1,00	€ 1,00	€ 1,00
Bike_6	€ 1,00	€ 1,00	€ 1,00

	Travellers		
	%		
Origin	CS	HS	VB
	16%	67%	14%

2 BIKE STATIONS	CS					HS					VB				
	Bike_1	Bike_2	Choice			Bike_1	Bike_2	Choice			Bike_1	Bike_2	Choice		
Cycle time to station	708	736				493	558				475	410			
Walking time				walk	bike										
1	1575	1697	Bike_1	867	708	1360	1519	Bike_1	867	493	1342	1371	Bike_1	867	475
2	1454	1587	Bike_1	746	708	1239	1409	Bike_1	746	493	1221	1261	Bike_1	746	475
3	1554	1686	Bike_1	846	708	1339	1508	Bike_1	846	493	1321	1360	Bike_1	846	475
4	1249	1360	Bike_1	541	708	1034	1182	Bike_1	541	493	1016	1034	Bike_1	541	475
5	921	1222	Bike_1	213	708	706	1044	Bike_1	213	493	688	896	Bike_1	213	475
6	852	1051	Bike_1	144	708	637	873	Bike_1	144	493	619	725	Bike_1	144	475
7	981	903	Bike_2	167	736	766	725	Bike_2	167	558	748	577	Bike_2	167	410
8	1146	899	Bike_2	163	736	931	721	Bike_2	163	558	913	573	Bike_2	163	410
9	1238	991	Bike_2	255	736	1023	813	Bike_2	255	558	1005	665	Bike_2	255	410
10	1366	1119	Bike_2	383	736	1151	941	Bike_2	383	558	1133	793	Bike_2	383	410
11	1476	1232	Bike_2	496	736	1261	1054	Bike_2	496	558	1243	906	Bike_2	496	410
12	1584	1568	Bike_2	832	736	1369	1390	Bike_1	876	493	1351	1242	Bike_2	832	410
13	1678	1662	Bike_2	926	736	1463	1484	Bike_1	970	493	1445	1336	Bike_2	926	410
14	1339	1323	Bike_2	587	736	1124	1145	Bike_1	631	493	1106	997	Bike_2	587	410
15	1310	1294	Bike_2	558	736	1095	1116	Bike_1	602	493	1077	968	Bike_2	558	410
16	1531	1515	Bike_2	779	736	1316	1337	Bike_1	823	493	1298	1189	Bike_2	779	410
17	1036	1020	Bike_2	284	736	821	842	Bike_1	328	493	803	694	Bike_2	284	410
18	1158	1142	Bike_2	406	736	943	964	Bike_1	450	493	925	816	Bike_2	406	410
19	1358	1342	Bike_2	606	736	1143	1164	Bike_1	650	493	1125	1016	Bike_2	606	410
20	1196	1180	Bike_2	444	736	981	1002	Bike_1	488	493	963	854	Bike_2	444	410

3 BIKE STATIONS	CS						HS						VB					
	Bike_1	Bike_2	Bike_3	Choice			Bike_1	Bike_2	Bike_3	Choice			Bike_1	Bike_2	Bike_3	Choice		
Cycle time to station	708	736	797				493	558	657				475	410	322			
Walking time																		
1	1575	1697	1842	Bike_1	867	708	1360	1519	1702	Bike_1	867	493	1342	1371	1367	Bike_1	867	475
2	1454	1587	1776	Bike_1	746	708	1239	1409	1636	Bike_1	746	493	1221	1261	1301	Bike_1	746	475
3	1554	1686	1876	Bike_1	846	708	1339	1508	1736	Bike_1	846	493	1321	1360	1401	Bike_1	846	475
4	1249	1360	1489	Bike_1	541	708	1034	1182	1349	Bike_1	541	493	1016	1034	1014	Bike_3	692	322
5	921	1222	1600	Bike_1	213	708	706	1044	1460	Bike_1	213	493	688	896	1125	Bike_1	213	475
6	852	1051	1428	Bike_1	144	708	637	873	1288	Bike_1	144	493	619	725	953	Bike_1	144	475
7	981	903	1343	Bike_2	167	736	766	725	1203	Bike_2	167	558	748	577	868	Bike_2	167	410
8	1146	899	1483	Bike_2	163	736	931	721	1343	Bike_2	163	558	913	573	1008	Bike_2	163	410
9	1238	991	1575	Bike_2	255	736	1023	813	1435	Bike_2	255	558	1005	665	1100	Bike_2	255	410
10	1366	1119	1679	Bike_2	383	736	1151	941	1539	Bike_2	383	558	1133	793	1204	Bike_2	383	410
11	1476	1232	1372	Bike_2	496	736	1261	1054	1232	Bike_2	496	558	1243	906	897	Bike_3	575	322
12	1584	1568	1202	Bike_3	405	797	1369	1390	1062	Bike_3	405	657	1351	1242	727	Bike_3	405	322
13	1678	1662	1179	Bike_3	382	797	1463	1484	1039	Bike_3	382	657	1445	1336	704	Bike_3	382	322
14	1339	1323	840	Bike_3	43	797	1124	1145	700	Bike_3	43	657	1106	997	365	Bike_3	43	322
15	1310	1294	944	Bike_3	147	797	1095	1116	804	Bike_3	147	657	1077	968	469	Bike_3	147	322
16	1531	1515	1165	Bike_3	368	797	1316	1337	1025	Bike_3	368	657	1298	1189	690	Bike_3	368	322
17	1036	1020	1059	Bike_2	284	736	821	842	919	Bike_1	328	493	803	694	584	Bike_3	262	322
18	1158	1142	1310	Bike_2	406	736	943	964	1170	Bike_1	450	493	925	816	835	Bike_2	406	410
19	1358	1342	1254	Bike_3	457	797	1143	1164	1114	Bike_3	457	657	1125	1016	779	Bike_3	457	322
20	1196	1180	1384	Bike_2	444	736	981	1002	1244	Bike_1	488	493	963	854	909	Bike_2	444	410

4 BIKE STATIONS	CS				Choice		
	Bike_1	Bike_2	Bike_3	Bike_4			
Cycle time to station	708	736	797	1173			
Walking time							
1	1575	1697	1842	2434	Bike_1	867	708
2	1454	1587	1776	2345	Bike_1	746	708
3	1554	1686	1876	2445	Bike_1	846	708
4	1249	1360	1489	2108	Bike_1	541	708
5	921	1222	1600	2013	Bike_1	213	708
6	852	1051	1428	1841	Bike_1	144	708
7	981	903	1343	1693	Bike_2	167	736
8	1146	899	1483	1519	Bike_2	163	736
9	1238	991	1575	1422	Bike_2	255	736
10	1366	1119	1679	1202	Bike_2	383	736
11	1476	1232	1372	1460	Bike_2	496	736
12	1584	1568	1202	1860	Bike_3	405	797
13	1678	1662	1179	1929	Bike_3	382	797
14	1339	1323	840	2065	Bike_3	43	797
15	1310	1294	944	1888	Bike_3	147	797
16	1531	1515	1165	1944	Bike_3	368	797
17	1036	1020	1059	1762	Bike_2	284	736
18	1158	1142	1310	1884	Bike_2	406	736
19	1358	1342	1254	2090	Bike_3	457	797
20	1196	1180	1384	1928	Bike_2	444	736

4 BIKE STATIONS	HS				Choice		
	Bike_1	Bike_2	Bike_3	Bike_4			
Cycle time to station	493	558	657	763			
Walking time							
1	1360	1519	1702	2024	Bike_1	867	493
2	1239	1409	1636	1935	Bike_1	746	493
3	1339	1508	1736	2035	Bike_1	846	493
4	1034	1182	1349	1698	Bike_1	541	493
5	706	1044	1460	1603	Bike_1	213	493
6	637	873	1288	1431	Bike_1	144	493
7	766	725	1203	1283	Bike_2	167	558
8	931	721	1343	1109	Bike_2	163	558
9	1023	813	1435	1012	Bike_2	255	558
10	1151	941	1539	792	Bike_4	29	763
11	1261	1054	1232	1050	Bike_4	287	763
12	1369	1390	1062	1450	Bike_3	405	657
13	1463	1484	1039	1519	Bike_3	382	657
14	1124	1145	700	1655	Bike_3	43	657
15	1095	1116	804	1478	Bike_3	147	657
16	1316	1337	1025	1534	Bike_3	368	657
17	821	842	919	1352	Bike_1	328	493
18	943	964	1170	1474	Bike_1	450	493
19	1143	1164	1114	1680	Bike_3	457	657
20	981	1002	1244	1518	Bike_1	488	493

4 BIKE STATIONS	VB				Choice		
	Bike_1	Bike_2	Bike_3	Bike_4			
Cycle time to station	475	410	322	353			
Walking time							
1	1342	1371	1367	1614	Bike_1	867	475
2	1221	1261	1301	1525	Bike_1	746	475
3	1321	1360	1401	1625	Bike_1	846	475
4	1016	1034	1014	1288	Bike_3	692	322
5	688	896	1125	1193	Bike_1	213	475
6	619	725	953	1021	Bike_1	144	475
7	748	577	868	873	Bike_2	167	410
8	913	573	1008	699	Bike_2	163	410
9	1005	665	1100	602	Bike_4	249	353
10	1133	793	1204	382	Bike_4	29	353
11	1243	906	897	640	Bike_4	287	353
12	1351	1242	727	1040	Bike_3	405	322
13	1445	1336	704	1109	Bike_3	382	322
14	1106	997	365	1245	Bike_3	43	322
15	1077	968	469	1068	Bike_3	147	322
16	1298	1189	690	1124	Bike_3	368	322
17	803	694	584	942	Bike_3	262	322
18	925	816	835	1064	Bike_2	406	410
19	1125	1016	779	1270	Bike_3	457	322
20	963	854	909	1108	Bike_2	444	410

5 BIKE STATIONS	CS					Choice		
	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5			
Cycle time to station	708	736	797	1173	852			
Walking time							walk	bike
1	1575	1697	1842	2434	2203	Bike_1	867	708
2	1454	1587	1776	2345	2136	Bike_1	746	708
3	1554	1686	1876	2445	2236	Bike_1	846	708
4	1249	1360	1489	2108	1849	Bike_1	541	708
5	921	1222	1600	2013	2021	Bike_1	213	708
6	852	1051	1428	1841	1849	Bike_1	144	708
7	981	903	1343	1693	1764	Bike_2	167	736
8	1146	899	1483	1519	1723	Bike_2	163	736
9	1238	991	1575	1422	1621	Bike_2	255	736
10	1366	1119	1679	1202	1548	Bike_2	383	736
11	1476	1232	1372	1460	1238	Bike_2	496	736
12	1584	1568	1202	1860	919	Bike_5	67	852
13	1678	1662	1179	1929	1096	Bike_5	244	852
14	1339	1323	840	2065	1272	Bike_3	43	797
15	1310	1294	944	1888	1205	Bike_3	147	797
16	1531	1515	1165	1944	1263	Bike_3	368	797
17	1036	1020	1059	1762	1481	Bike_2	284	736
18	1158	1142	1310	1884	1731	Bike_2	406	736
19	1358	1342	1254	2090	1614	Bike_3	457	797
20	1196	1180	1384	1928	1821	Bike_2	444	736

5 BIKE STATIONS	HS					Choice		
	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5			
Cycle time to station	493	558	657	763	793			
Walking time							walk	bike
1	1360	1519	1702	2024	2144	Bike_1	867	493
2	1239	1409	1636	1935	2077	Bike_1	746	493
3	1339	1508	1736	2035	2177	Bike_1	846	493
4	1034	1182	1349	1698	1790	Bike_1	541	493
5	706	1044	1460	1603	1962	Bike_1	213	493
6	637	873	1288	1431	1790	Bike_1	144	493
7	766	725	1203	1283	1705	Bike_2	167	558
8	931	721	1343	1109	1664	Bike_2	163	558
9	1023	813	1435	1012	1562	Bike_2	255	558
10	1151	941	1539	792	1489	Bike_4	29	763
11	1261	1054	1232	1050	1179	Bike_4	287	763
12	1369	1390	1062	1450	860	Bike_5	67	793
13	1463	1484	1039	1519	1037	Bike_5	244	793
14	1124	1145	700	1655	1213	Bike_3	43	657
15	1095	1116	804	1478	1146	Bike_3	147	657
16	1316	1337	1025	1534	1204	Bike_3	368	657
17	821	842	919	1352	1422	Bike_1	328	493
18	943	964	1170	1474	1672	Bike_1	450	493
19	1143	1164	1114	1680	1555	Bike_3	457	657
20	981	1002	1244	1518	1762	Bike_1	488	493

5 BIKE STATIONS	VB					Choice		
	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5			
Cycle time to station	475	410	322	353	297			
Walking time							walk	bike
1	1342	1371	1367	1614	1648	Bike_1	867	475
2	1221	1261	1301	1525	1581	Bike_1	746	475
3	1321	1360	1401	1625	1681	Bike_1	846	475
4	1016	1034	1014	1288	1294	Bike_3	692	322
5	688	896	1125	1193	1466	Bike_1	213	475
6	619	725	953	1021	1294	Bike_1	144	475
7	748	577	868	873	1209	Bike_2	167	410
8	913	573	1008	699	1168	Bike_2	163	410
9	1005	665	1100	602	1066	Bike_4	249	353
10	1133	793	1204	382	993	Bike_4	29	353
11	1243	906	897	640	683	Bike_4	287	353
12	1351	1242	727	1040	364	Bike_5	67	297
13	1445	1336	704	1109	541	Bike_5	244	297
14	1106	997	365	1245	717	Bike_3	43	322
15	1077	968	469	1068	650	Bike_3	147	322
16	1298	1189	690	1124	708	Bike_3	368	322
17	803	694	584	942	926	Bike_3	262	322
18	925	816	835	1064	1176	Bike_2	406	410
19	1125	1016	779	1270	1059	Bike_3	457	322
20	963	854	909	1108	1266	Bike_2	444	410

6 BIKE STATIONS	CS									HS									VB								
	Bike_1	Bike_2	Bike_3	Bike_4	Bike_5	Bike_6	Choice			Bike_1	Bike_2	Bike_3	Bike_4	Bike_5	Bike_6	Choice			Bike_1	Bike_2	Bike_3	Bike_4	Bike_5	Bike_6	Choice		
Cycle time to station	708	736	797	1173	852	601		walking time	cycle time	493	558	657	763	793	542		walking time	cycle time	475	410	322	353	297	551		walking time	cycle time
Walking time																											
1	1575	1697	1842	2434	2203	1077	Bike_6	476	601	1360	1519	1702	2024	2144	1018	Bike_6	476	542	1342	1371	1367	1614	1648	1027	Bike_6	476	551
2	1454	1587	1776	2345	2136	827	Bike_6	226	601	1239	1409	1636	1935	2077	768	Bike_6	226	542	1221	1261	1301	1525	1581	777	Bike_6	226	551
3	1554	1686	1876	2445	2236	621	Bike_6	20	601	1339	1508	1736	2035	2177	562	Bike_6	20	542	1321	1360	1401	1625	1681	571	Bike_6	20	551
4	1249	1360	1489	2108	1849	1149	Bike_6	548	601	1034	1182	1349	1698	1790	1090	Bike_1	541	493	1016	1034	1014	1288	1294	1099	Bike_3	692	322
5	921	1222	1600	2013	2021	1248	Bike_1	213	708	706	1044	1460	1603	1962	1189	Bike_1	213	493	688	896	1125	1193	1466	1198	Bike_1	213	475
6	852	1051	1428	1841	1849	1581	Bike_1	144	708	637	873	1288	1431	1790	1522	Bike_1	144	493	619	725	953	1021	1294	1531	Bike_1	144	475
7	981	903	1343	1693	1764	1529	Bike_2	167	736	766	725	1203	1283	1705	1470	Bike_2	167	558	748	577	868	873	1209	1479	Bike_2	167	410
8	1146	899	1483	1519	1723	1675	Bike_2	163	736	931	721	1343	1109	1664	1616	Bike_2	163	558	913	573	1008	699	1168	1625	Bike_2	163	410
9	1238	991	1575	1422	1621	1767	Bike_2	255	736	1023	813	1435	1012	1562	1708	Bike_2	255	558	1005	665	1100	602	1066	1717	Bike_4	249	353
10	1366	1119	1679	1202	1548	1893	Bike_2	383	736	1151	941	1539	792	1489	1834	Bike_4	29	763	1133	793	1204	382	993	1843	Bike_4	29	353
11	1476	1232	1372	1460	1238	1987	Bike_2	496	736	1261	1054	1232	1050	1179	1928	Bike_4	287	763	1243	906	897	640	683	1937	Bike_4	287	353
12	1584	1568	1202	1860	919	1913	Bike_5	67	852	1369	1390	1062	1450	860	1854	Bike_5	67	793	1351	1242	727	1040	364	1863	Bike_5	67	297
13	1678	1662	1179	1929	1096	1888	Bike_5	244	852	1463	1484	1039	1519	1037	1829	Bike_5	244	793	1445	1336	704	1109	541	1838	Bike_5	244	297
14	1339	1323	840	2065	1272	1670	Bike_3	43	797	1124	1145	700	1655	1213	1611	Bike_3	43	657	1106	997	365	1245	717	1620	Bike_3	43	322
15	1310	1294	944	1888	1205	1803	Bike_3	147	797	1095	1116	804	1478	1146	1744	Bike_3	147	657	1077	968	469	1068	650	1753	Bike_3	147	322
16	1531	1515	1165	1944	1263	2024	Bike_3	368	797	1316	1337	1025	1534	1204	1965	Bike_3	368	657	1298	1189	690	1124	708	1974	Bike_3	368	322
17	1036	1020	1059	1762	1481	1530	Bike_2	284	736	821	842	919	1352	1422	1471	Bike_1	328	493	803	694	584	942	926	1480	Bike_3	262	322
18	1158	1142	1310	1884	1731	1407	Bike_2	406	736	943	964	1170	1474	1672	1348	Bike_1	450	493	925	816	835	1064	1176	1357	Bike_2	406	410
19	1358	1342	1254	2090	1614	1444	Bike_3	457	797	1143	1164	1114	1680	1555	1385	Bike_3	457	657	1125	1016	779	1270	1059	1394	Bike_3	457	322
20	1196	1180	1384	1928	1821	1376	Bike_2	444	736	981	1002	1244	1518	1762	1317	Bike_1	488	493	963	854	909	1108	1266	1326	Bike_2	444	410

Alternative 1: Walk only

Origin	Den Haag CS						
		Walk					
Destination	total trips	mm:ss	€ totaal	% trips	# trips	Total travel time	Generalised travel costs
1	**138**	19:18	€ 4,07	100%	138	20:18:28	€ 560,49
2	**51**	22:15	€ 4,69	100%	51	18:55:28	€ 239,39
3	**194**	24:04	€ 5,07	100%	194	05:48:56	€ 984,37
4	**215**	25:32	€ 5,38	100%	215	19:41:43	€ 1.159,95
5	**54**	27:06	€ 5,71	100%	54	00:19:17	€ 307,67
6	**470**	32:39	€ 6,88	100%	470	15:53:20	€ 3.237,00
7	**123**	31:35	€ 6,66	100%	123	16:44:00	€ 818,87
8	**45**	34:12	€ 7,21	100%	45	01:40:38	€ 324,82
9	**175**	35:43	€ 7,53	100%	175	08:25:51	€ 1.321,05
10	**42**	37:49	€ 7,97	100%	42	02:14:23	€ 331,93
11	**83**	39:23	€ 8,30	100%	83	06:38:16	€ 691,17
12	**226**	38:05	€ 8,03	100%	226	23:22:34	€ 1.813,71
13	**16**	37:16	€ 7,86	100%	16	10:03:07	€ 127,16
14	**194**	34:02	€ 7,18	100%	194	13:57:50	€ 1.391,04
15	**37**	36:21	€ 7,66	100%	37	22:33:06	€ 285,28
16	**126**	40:01	€ 8,44	100%	126	12:00:11	€ 1.062,64
17	**48**	31:47	€ 6,70	100%	48	01:17:28	€ 319,93
18	**33**	29:39	€ 6,25	100%	33	16:22:43	€ 207,19
19	**35**	30:27	€ 6,42	100%	35	18:00:51	€ 227,88
20	**21**	29:09	€ 6,15	100%	21	10:15:53	€ 129,85

Den Haag HS						
	Walk					
total trips	mm:ss	€ totaal	% trips	# trips	Total travel time	Generalised travel costs
577	14:25	€ 3,04	100%	577	18:35:35	€ 1.753,20
214	11:57	€ 2,52	100%	214	18:33:40	€ 538,40
812	18:46	€ 3,96	100%	812	14:05:34	€ 3.214,27
902	20:12	€ 4,26	100%	902	15:46:14	€ 3.842,70
225	18:05	€ 3,81	100%	225	19:57:35	€ 859,69
1969	23:38	€ 4,98	100%	1969	07:37:06	€ 9.811,57
515	25:48	€ 5,44	100%	515	05:26:01	€ 2.801,14
189	28:33	€ 6,02	100%	189	17:45:38	€ 1.135,47
735	30:04	€ 6,34	100%	735	08:07:37	€ 4.656,81
174	32:26	€ 6,84	100%	174	22:14:14	€ 1.192,10
349	34:00	€ 7,17	100%	349	05:31:18	€ 2.498,65
946	32:45	€ 6,90	100%	946	12:18:25	€ 6.531,28
68	31:56	€ 6,73	100%	68	12:04:08	€ 456,27
812	28:42	€ 6,05	100%	812	04:18:49	€ 4.912,17
156	31:06	€ 6,56	100%	156	08:47:44	€ 1.022,06
527	34:46	€ 7,33	100%	527	17:36:46	€ 3.866,00
200	26:32	€ 5,59	100%	200	16:24:45	€ 1.118,42
139	24:24	€ 5,14	100%	139	08:26:29	€ 713,98
149	25:07	€ 5,30	100%	149	14:13:20	€ 787,11
88	23:54	€ 5,04	100%	88	11:14:31	€ 445,81

Voorburg						
	Walk					
total trips	mm:ss	€ totaal	% trips	# trips	Total travel time	Generalised travel costs
121	29:24	€ 6,20	100%	121	11:03:28	€ 747,08
45	28:32	€ 6,02	100%	45	21:14:06	€ 268,62
170	30:21	€ 6,40	100%	170	13:51:55	€ 1.086,19
189	23:58	€ 5,05	100%	189	03:18:38	€ 952,68
47	27:48	€ 5,86	100%	47	21:49:51	€ 276,16
411	25:33	€ 5,39	100%	411	07:12:48	€ 2.216,45
108	24:08	€ 5,09	100%	108	19:16:51	€ 547,50
39	22:53	€ 4,82	100%	39	15:02:00	€ 190,17
154	21:16	€ 4,48	100%	154	06:24:30	€ 688,26
36	19:50	€ 4,18	100%	36	12:02:29	€ 152,32
73	14:39	€ 3,09	100%	73	17:47:02	€ 224,97
198	11:16	€ 2,38	100%	198	13:06:53	€ 469,50
14	08:43	€ 1,84	100%	14	02:03:26	€ 26,02
170	14:19	€ 3,02	100%	170	16:28:33	€ 512,02
33	15:53	€ 3,35	100%	33	08:37:20	€ 109,07
110	17:02	€ 3,59	100%	110	07:17:13	€ 395,78
42	19:25	€ 4,09	100%	42	13:31:09	€ 171,02
29	23:35	€ 4,97	100%	29	11:23:56	€ 144,20
31	19:50	€ 4,18	100%	31	10:16:00	€ 129,87
18	23:16	€ 4,91	100%	18	07:10:08	€ 90,69

Alternative 2: Bike + Walk

Origin	Den Haag CS																	
		Walk					Bike + walk											
							bike	walk							all travellers			
Destination	total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ bike	utility	€ totaal	% trips	# trips	total costs	total time	% gain gtc	weighted gain
1	**138**	19:18	-1,73	€ 4,07	62%	85	10:01	07:56	17:57	€ 1,00	-2,22	€ 4,78	38%	53	€ 598,06	19:07:34	-0,07	-0,40%
2	**51**	22:15	-2,00	€ 4,69	46%	24	10:01	03:46	13:47	€ 1,00	-1,84	€ 3,91	54%	27	€ 217,81	15:02:44	0,09	0,20%
3	**194**	24:04	-2,16	€ 5,07	35%	68	10:01	00:20	10:21	€ 1,00	-1,54	€ 3,18	65%	126	€ 745,19	00:54:51	0,24	2,03%
4	**215**	25:32	-2,29	€ 5,38	51%	109	10:01	09:08	19:09	€ 1,00	-2,33	€ 5,04	49%	106	€ 1.123,29	08:25:07	0,03	0,29%
5	**54**	27:06	-2,43	€ 5,71	39%	21	11:48	03:33	15:21	€ 1,00	-1,98	€ 4,24	61%	33	€ 259,09	17:52:58	0,16	0,37%
6	**470**	32:39	-2,93	€ 6,88	26%	122	11:48	02:24	14:12	€ 1,00	-1,88	€ 3,99	74%	348	€ 2.229,95	04:44:00	0,31	6,29%
7	**123**	31:35	-2,84	€ 6,66	29%	36	12:16	02:47	15:03	€ 1,00	-1,96	€ 4,17	71%	87	€ 602,85	16:47:10	0,26	1,39%
8	**45**	34:12	-3,07	€ 7,21	25%	11	12:16	02:43	14:59	€ 1,00	-1,95	€ 4,16	75%	34	€ 221,16	14:47:53	0,32	0,62%
9	**175**	35:43	-3,21	€ 7,53	25%	43	12:16	04:15	16:31	€ 1,00	-2,09	€ 4,48	75%	132	€ 918,00	14:06:56	0,31	2,30%
10	**42**	37:49	-3,40	€ 7,97	25%	10	12:16	06:23	18:39	€ 1,00	-2,28	€ 4,93	75%	31	€ 236,57	16:13:22	0,29	0,51%
11	**83**	39:23	-3,54	€ 8,30	25%	21	12:16	08:16	20:32	€ 1,00	-2,45	€ 5,33	75%	62	€ 506,01	11:04:47	0,27	0,96%
12	**226**	38:05	-3,42	€ 8,03	19%	43	14:12	01:07	15:19	€ 1,00	-1,98	€ 4,23	81%	183	€ 1.119,87	02:05:35	0,38	3,71%
13	**16**	37:16	-3,35	€ 7,86	25%	4	14:12	04:04	18:16	€ 1,00	-2,25	€ 4,85	75%	12	€ 90,65	06:12:22	0,29	0,20%
14	**194**	34:02	-3,06	€ 7,18	23%	45	13:17	00:43	14:00	€ 1,00	-1,86	€ 3,95	77%	149	€ 911,45	12:17:28	0,34	2,87%
15	**37**	36:21	-3,26	€ 7,66	22%	8	13:17	02:27	15:44	€ 1,00	-2,02	€ 4,32	78%	29	€ 188,53	12:37:05	0,34	0,54%
16	**126**	40:01	-3,59	€ 8,44	22%	28	13:17	06:08	19:25	€ 1,00	-2,35	€ 5,09	78%	98	€ 735,73	02:25:50	0,31	1,66%
17	**48**	31:47	-2,85	€ 6,70	33%	16	12:16	04:44	17:00	€ 1,00	-2,13	€ 4,58	67%	32	€ 251,91	17:22:24	0,21	0,44%
18	**33**	29:39	-2,66	€ 6,25	41%	14	12:16	06:46	19:02	€ 1,00	-2,32	€ 5,01	59%	19	€ 183,13	12:56:29	0,12	0,17%
19	**35**	30:27	-2,73	€ 6,42	44%	16	13:17	07:37	20:54	€ 1,00	-2,48	€ 5,41	56%	20	€ 207,64	14:50:06	0,09	0,14%
20	**21**	29:09	-2,62	€ 6,15	44%	9	12:16	07:24	19:40	€ 1,00	-2,37	€ 5,15	56%	12	€ 118,00	08:23:26	0,09	0,08%
	2327				32%	733							68%	1594	€ 4,93	20:07		24,37%

Den Haag HS																	
	Walk					Bike + walk											
						bike	walk							all travellers			
total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ bike	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
577	14:25	-1,29	€ 3,04	70%	402	09:02	07:56	16:58	€ 1,00	-2,13	€ 4,58	30%	175	€ 2.021,63	02:00:45	-15%	-0,91%
214	11:57	-1,07	€ 2,52	66%	142	09:02	03:46	12:48	€ 1,00	-1,76	€ 3,70	34%	72	€ 623,02	19:34:40	-16%	-0,34%
812	18:46	-1,69	€ 3,96	44%	358	09:02	00:20	09:22	€ 1,00	-1,45	€ 2,97	56%	454	€ 2.768,11	14:54:00	14%	1,16%
902	20:12	-1,81	€ 4,26	58%	527	08:13	09:01	17:14	€ 1,00	-2,15	€ 4,63	42%	375	€ 3.983,28	21:12:40	-4%	-0,34%
225	18:05	-1,62	€ 3,81	51%	115	08:13	03:33	11:46	€ 1,00	-1,66	€ 3,48	49%	111	€ 823,00	08:19:03	4%	0,10%
1969	23:38	-2,12	€ 4,98	36%	714	08:13	02:24	10:37	€ 1,00	-1,56	€ 3,24	64%	1255	€ 7.622,71	23:23:21	22%	4,51%
515	25:48	-2,32	€ 5,44	35%	179	09:18	02:47	12:05	€ 1,00	-1,69	€ 3,55	65%	336	€ 2.166,24	00:43:00	23%	1,20%
189	28:33	-2,56	€ 6,02	29%	55	09:18	02:43	12:01	€ 1,00	-1,68	€ 3,53	71%	133	€ 804,10	05:01:37	29%	0,56%
735	30:04	-2,70	€ 6,34	29%	216	09:18	04:15	13:33	€ 1,00	-1,82	€ 3,86	71%	519	€ 3.368,73	09:16:53	28%	2,09%
174	32:26	-2,91	€ 6,84	25%	43	12:43	00:29	13:12	€ 1,00	-1,79	€ 3,78	75%	132	€ 790,35	04:04:58	34%	0,60%
349	34:00	-3,05	€ 7,17	29%	102	12:43	04:47	17:30	€ 1,00	-2,18	€ 4,69	71%	246	€ 1.888,61	09:50:30	24%	0,87%
946	32:45	-2,94	€ 6,90	26%	245	13:13	01:07	14:20	€ 1,00	-1,89	€ 4,02	74%	700	€ 4.512,07	13:18:57	31%	3,00%
68	31:56	-2,87	€ 6,73	33%	22	13:13	04:04	17:17	€ 1,00	-2,16	€ 4,64	67%	45	€ 361,37	00:58:30	21%	0,14%
812	28:42	-2,58	€ 6,05	28%	231	10:57	00:43	11:40	€ 1,00	-1,65	€ 3,46	72%	581	€ 3.406,24	07:19:31	31%	2,55%
156	31:06	-2,79	€ 6,56	27%	42	10:57	02:27	13:24	€ 1,00	-1,81	€ 3,83	73%	113	€ 712,10	23:19:24	30%	0,49%
527	34:46	-3,12	€ 7,33	27%	144	10:57	06:08	17:05	€ 1,00	-2,14	€ 4,60	73%	384	€ 2.819,00	00:30:31	27%	1,47%
200	26:32	-2,38	€ 5,59	37%	73	08:13	05:28	13:41	€ 1,00	-1,83	€ 3,88	63%	127	€ 901,84	13:16:31	19%	0,40%
139	24:24	-2,19	€ 5,14	46%	63	08:13	07:30	15:43	€ 1,00	-2,02	€ 4,31	54%	75	€ 651,33	21:31:32	9%	0,12%
149	25:07	-2,26	€ 5,30	50%	75	10:57	07:37	18:34	€ 1,00	-2,27	€ 4,91	50%	74	€ 759,04	06:10:45	4%	0,05%
88	23:54	-2,15	€ 5,04	48%	43	08:13	08:08	16:21	€ 1,00	-2,07	€ 4,45	52%	46	€ 418,68	05:28:26	6%	0,06%
9746				39%	3793							61%	5953	€ 4,25	17:15		17,8%

Voorburg																	
	Walk					Bike + walk											
						bike	walk							all travellers			
total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ bike	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
121	29:24	-2,64	€ 6,20	38%	46	09:11	07:56	17:07	€ 1,00	-2,14	€ 4,61	62%	75	€ 627,92	19:42:46	16%	0,94%
45	28:32	-2,56	€ 6,02	31%	14	09:11	03:46	12:57	€ 1,00	-1,77	€ 3,73	69%	31	€ 198,34	13:14:53	26%	0,57%
170	30:21	-2,73	€ 6,40	22%	37	09:11	00:20	09:31	€ 1,00	-1,46	€ 3,01	78%	132	€ 637,04	15:53:34	41%	3,45%
189	23:58	-2,15	€ 5,05	49%	93	05:22	11:32	16:54	€ 1,00	-2,12	€ 4,56	51%	96	€ 905,82	16:02:47	5%	0,46%
47	27:48	-2,50	€ 5,86	30%	14	07:55	03:33	11:28	€ 1,00	-1,64	€ 3,42	70%	33	€ 195,23	12:48:53	29%	0,68%
411	25:33	-2,29	€ 5,39	32%	131	07:55	02:24	10:19	€ 1,00	-1,53	€ 3,18	68%	281	€ 1.595,90	07:58:40	28%	5,66%
108	24:08	-2,17	€ 5,09	33%	36	06:50	02:47	09:37	€ 1,00	-1,47	€ 3,03	67%	72	€ 399,43	01:53:44	27%	1,43%
39	22:53	-2,06	€ 4,82	36%	14	06:50	02:43	09:33	€ 1,00	-1,46	€ 3,01	64%	25	€ 144,21	09:23:38	24%	0,47%
154	21:16	-1,91	€ 4,48	40%	61	05:53	04:09	10:02	€ 1,00	-1,51	€ 3,12	60%	92	€ 562,35	13:10:47	18%	1,38%
36	19:50	-1,78	€ 4,18	35%	13	05:53	00:29	06:22	€ 1,00	-1,18	€ 2,34	65%	24	€ 109,01	06:45:19	28%	0,51%
73	14:39	-1,32	€ 3,09	56%	41	05:53	04:47	10:40	€ 1,00	-1,56	€ 3,25	44%	32	€ 230,08	15:39:51	-2%	-0,08%
198	11:16	-1,01	€ 2,38	53%	106	04:57	01:07	06:04	€ 1,00	-1,15	€ 2,28	47%	92	€ 460,64	05:08:32	2%	0,18%
14	08:43	-0,78	€ 1,84	65%	9	04:57	04:04	09:01	€ 1,00	-1,42	€ 2,90	35%	5	€ 31,25	02:04:55	-20%	-0,14%
170	14:19	-1,29	€ 3,02	47%	79	05:22	00:43	06:05	€ 1,00	-1,15	€ 2,28	53%	90	€ 445,44	04:03:34	13%	1,08%
33	15:53	-1,43	€ 3,35	47%	15	05:22	02:27	07:49	€ 1,00	-1,31	€ 2,65	53%	17	€ 96,98	06:18:10	11%	0,18%
110	17:02	-1,53	€ 3,59	53%	58	05:22	06:08	11:30	€ 1,00	-1,64	€ 3,42	47%	52	€ 387,10	02:28:51	2%	0,12%
42	19:25	-1,74	€ 4,09	43%	18	05:22	04:22	09:44	€ 1,00	-1,48	€ 3,05	57%	24	€ 146,41	09:42:20	14%	0,30%
29	23:35	-2,12	€ 4,97	43%	12	06:50	06:46	13:36	€ 1,00	-1,83	€ 3,87	57%	17	€ 125,86	08:38:16	13%	0,18%
31	19:50	-1,78	€ 4,18	50%	15	05:22	07:37	12:59	€ 1,00	-1,77	€ 3,74	50%	16	€ 122,94	08:29:07	5%	0,08%
18	23:16	-2,09	€ 4,91	45%	8	06:50	07:24	14:14	€ 1,00	-1,88	€ 4,00	55%	10	€ 81,47	05:38:04	10%	0,09%
2036				40%	821							60%	1215	€ 3,68	14:39		17,53%

Alternative 3: Tram + Walk

Origin	Den Haag CS																	
		Walk					Tram + walk											
							tram	walk							all travellers			
Destination	total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	Total gain [€]
1	**138**	19:18	-1,73	€ 4,07	66%	92	04:48	13:52	18:40	€ 1,32	-2,42	€ 5,25	34%	46	€ 615,20	19:49:12	-10%	-0,58%
2	**51**	22:15	-2,00	€ 4,69	58%	29	04:48	12:35	17:23	€ 1,32	-2,30	€ 4,98	42%	22	€ 245,72	17:10:01	-3%	-0,06%
3	**194**	24:04	-2,16	€ 5,07	57%	111	04:48	14:15	19:03	€ 1,32	-2,45	€ 5,33	43%	83	€ 1.005,98	22:52:31	-2%	-0,18%
4	**215**	25:32	-2,29	€ 5,38	39%	85	04:48	07:43	12:31	€ 1,32	-1,87	€ 3,96	61%	130	€ 973,88	15:23:45	16%	1,49%
5	**54**	27:06	-2,43	€ 5,71	37%	20	04:48	07:56	12:44	€ 1,32	-1,88	€ 4,00	63%	34	€ 249,26	16:08:50	19%	0,44%
6	**470**	32:39	-2,93	€ 6,88	22%	103	04:48	05:24	10:12	€ 1,32	-1,66	€ 3,47	78%	368	€ 1.981,71	22:21:39	39%	7,84%
7	**123**	31:35	-2,84	€ 6,66	21%	26	04:48	03:59	08:47	€ 1,32	-1,53	€ 3,17	79%	97	€ 481,22	03:57:29	41%	2,18%
8	**45**	34:12	-3,07	€ 7,21	21%	9	04:48	06:13	11:01	€ 1,32	-1,73	€ 3,64	79%	36	€ 197,35	11:52:48	39%	0,76%
9	**175**	35:43	-3,21	€ 7,53	21%	36	04:48	07:45	12:33	€ 1,32	-1,87	€ 3,96	79%	139	€ 825,27	02:45:17	38%	2,83%
10	**42**	37:49	-3,40	€ 7,97	20%	8	04:48	09:25	14:13	€ 1,32	-2,02	€ 4,32	80%	33	€ 210,30	13:09:36	37%	0,66%
11	**83**	39:23	-3,54	€ 8,30	20%	17	04:48	10:59	15:47	€ 1,32	-2,16	€ 4,65	80%	66	€ 447,98	04:29:09	35%	1,26%
12	**226**	38:05	-3,42	€ 8,03	21%	48	04:48	10:33	15:21	€ 1,32	-2,12	€ 4,55	79%	178	€ 1.196,78	04:06:33	34%	3,30%
13	**16**	37:16	-3,35	€ 7,86	25%	4	04:48	12:07	16:55	€ 1,32	-2,26	€ 4,88	75%	12	€ 91,19	05:56:51	28%	0,20%
14	**194**	34:02	-3,06	€ 7,18	21%	41	04:48	06:28	11:16	€ 1,32	-1,75	€ 3,69	79%	152	€ 860,16	04:06:43	38%	3,18%
15	**37**	36:21	-3,26	€ 7,66	17%	6	04:48	05:58	10:46	€ 1,32	-1,71	€ 3,59	83%	31	€ 159,98	09:26:36	44%	0,70%
16	**126**	40:01	-3,59	€ 8,44	17%	22	04:48	09:39	14:27	€ 1,32	-2,04	€ 4,36	83%	104	€ 639,14	15:41:25	40%	2,16%
17	**48**	31:47	-2,85	€ 6,70	17%	8	04:48	01:25	06:13	€ 1,32	-1,30	€ 2,63	83%	39	€ 159,40	08:29:37	50%	1,03%
18	**33**	29:39	-2,66	€ 6,25	22%	7	04:48	02:47	07:35	€ 1,32	-1,42	€ 2,92	78%	26	€ 121,46	06:55:23	41%	0,59%
19	**35**	30:27	-2,73	€ 6,42	27%	10	04:48	06:34	11:22	€ 1,32	-1,76	€ 3,71	73%	26	€ 158,19	09:49:17	31%	0,47%
20	**21**	29:09	-2,62	€ 6,15	25%	5	04:48	04:00	08:48	€ 1,32	-1,53	€ 3,17	75%	16	€ 82,89	04:54:23	36%	0,33%

Den Haag HS																	
	Walk					Tram + walk											
						tram	walk							all travellers			
total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
577	14:25	-1,29	€ 3,04	100%	577									€ 1.753,20	18:35:35	0,00	0,00
214	11:57	-1,07	€ 2,52	100%	214									€ 538,40	18:33:40	0,00	0,00
812	18:46	-1,69	€ 3,96	100%	812									€ 3.214,27	14:05:34	0,00	0,00
902	20:12	-1,81	€ 4,26	100%	902									€ 3.842,70	15:46:14	0,00	0,00
225	18:05	-1,62	€ 3,81	100%	225									€ 859,69	19:57:35	0,00	0,00
1969	23:38	-2,12	€ 4,98	100%	1969									€ 9.811,57	07:37:06	0,00	0,00
515	25:48	-2,32	€ 5,44	100%	515									€ 2.801,14	05:26:01	0,00	0,00
189	28:33	-2,56	€ 6,02	100%	189									€ 1.135,47	17:45:38	0,00	0,00
735	30:04	-2,70	€ 6,34	100%	735									€ 4.656,81	08:07:37	0,00	0,00
174	32:26	-2,91	€ 6,84	100%	174									€ 1.192,10	22:14:14	0,00	0,00
349	34:00	-3,05	€ 7,17	100%	349									€ 2.498,65	05:31:18	0,00	0,00
946	32:45	-2,94	€ 6,90	100%	946									€ 6.531,28	12:18:25	0,00	0,00
68	31:56	-2,87	€ 6,73	100%	68									€ 456,27	12:04:08	0,00	0,00
812	28:42	-2,58	€ 6,05	100%	812									€ 4.912,17	04:18:49	0,00	0,00
156	31:06	-2,79	€ 6,56	100%	156									€ 1.022,06	08:47:44	0,00	0,00
527	34:46	-3,12	€ 7,33	100%	527									€ 3.866,00	17:36:46	0,00	0,00
200	26:32	-2,38	€ 5,59	100%	200									€ 1.118,42	16:24:45	0,00	0,00
139	24:24	-2,19	€ 5,14	100%	139									€ 713,98	08:26:29	0,00	0,00
149	25:07	-2,26	€ 5,30	100%	149									€ 787,11	14:13:20	0,00	0,00
88	23:54	-2,15	€ 5,04	100%	88									€ 445,81	11:14:31	0,00	0,00

Voorburg																	
	Walk					Tram + walk											
						tram	walk							all travellers			
total trips	mm:ss	utility	€ totaal	% trips	# trips	mm:ss	mm:ss	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
121	29:24	-2,64	€ 6,20	41%	49	03:36	13:52	17:28	€ 1,23	-2,27	€ 4,92	59%	71	€ 655,78	20:53:56	12%	0,72%
45	28:32	-2,56	€ 6,02	40%	18	03:36	12:35	16:11	€ 1,23	-2,16	€ 4,65	60%	27	€ 231,93	15:43:24	14%	0,30%
170	30:21	-2,73	€ 6,40	40%	67	03:36	14:15	17:51	€ 1,23	-2,31	€ 5,00	60%	102	€ 942,72	16:32:37	13%	1,10%
189	23:58	-2,15	€ 5,05	39%	74	03:36	07:43	11:19	€ 1,23	-1,72	€ 3,62	61%	114	€ 788,86	03:13:01	17%	1,59%
47	27:48	-2,50	€ 5,86	32%	15	03:36	07:56	11:32	€ 1,23	-1,74	€ 3,67	68%	32	€ 205,75	13:08:19	25%	0,59%
411	25:33	-2,29	€ 5,39	31%	129	03:36	05:24	09:00	€ 1,23	-1,51	€ 3,13	69%	282	€ 1.579,76	01:21:35	29%	5,80%
108	24:08	-2,17	€ 5,09	31%	34	03:36	03:59	07:35	€ 1,23	-1,39	€ 2,83	69%	74	€ 380,99	22:55:14	30%	1,61%
39	22:53	-2,06	€ 4,82	38%	15	03:36	06:13	09:49	€ 1,23	-1,59	€ 3,30	62%	24	€ 153,29	09:45:13	19%	0,38%
154	21:16	-1,91	€ 4,48	45%	70	03:36	07:45	11:21	€ 1,23	-1,72	€ 3,63	55%	84	€ 616,38	16:32:58	10%	0,79%
36	19:50	-1,78	€ 4,18	52%	19	03:36	09:25	13:01	€ 1,23	-1,87	€ 3,98	48%	17	€ 148,79	10:04:05	2%	0,04%
73	14:39	-1,32	€ 3,09	67%	49	03:36	10:59	14:35	€ 1,23	-2,01	€ 4,31	33%	24	€ 254,45	17:45:25	-13%	-0,47%
198	11:16	-1,01	€ 2,38	72%	143	03:36	10:33	14:09	€ 1,23	-1,98	€ 4,22	28%	55	€ 569,98	15:44:12	-21%	-2,08%
14	08:43	-0,78	€ 1,84	79%	11	03:36	12:07	15:43	€ 1,23	-2,12	€ 4,55	21%	3	€ 34,03	02:24:06	-31%	-0,21%
170	14:19	-1,29	€ 3,02	58%	98	03:36	06:28	10:04	€ 1,23	-1,61	€ 3,36	42%	71	€ 536,05	11:25:52	-5%	-0,39%
33	15:53	-1,43	€ 3,35	53%	17	03:36	05:58	09:34	€ 1,23	-1,56	€ 3,25	47%	15	€ 107,58	07:01:32	1%	0,02%
110	17:02	-1,53	€ 3,59	59%	65	03:36	09:39	13:15	€ 1,23	-1,90	€ 4,03	41%	45	€ 415,46	04:26:24	-5%	-0,27%
42	19:25	-1,74	€ 4,09	36%	15	03:36	01:25	05:01	€ 1,23	-1,16	€ 2,29	64%	27	€ 122,60	07:04:22	28%	0,58%
29	23:35	-2,12	€ 4,97	30%	9	03:36	02:47	06:23	€ 1,23	-1,28	€ 2,58	70%	20	€ 95,73	05:35:34	34%	0,48%
31	19:50	-1,78	€ 4,18	46%	14	03:36	06:34	10:10	€ 1,23	-1,62	€ 3,38	54%	17	€ 116,36	07:33:40	10%	0,16%
18	23:16	-2,09	€ 4,91	33%	6	03:36	04:00	07:36	€ 1,23	-1,39	€ 2,84	67%	12	€ 65,10	03:56:29	28%	0,26%

Alternative 4: Tram or bike + walk

Den Haag CS																										
	Walk					Bike + walk								Tram + walk												
						bike	*walk*							*tram*	*walk*							*all travellers*				
total trips	mm:ss	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ bike	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
138	19:18	-1,73	€ 4,07	47%	65	*10:01*	*07:56*	17:57	€ 1,00	-2,22	€ 4,78	29%	40	*04:48*	*13:52*	18:40	€ 1,32	-2,42	€ 5,25	24%	33	€ 627,93	19:03:41	-12,03%	-0,71%
51	22:15	-2,00	€ 4,69	34%	18	*10:01*	*03:46*	13:47	€ 1,00	-1,84	€ 3,91	40%	21	*04:48*	*12:35*	17:23	€ 1,32	-2,30	€ 4,98	25%	13	€ 227,08	14:58:46	5,14%	0,11%
194	24:04	-2,16	€ 5,07	28%	54	*10:01*	*00:20*	10:21	€ 1,00	-1,54	€ 3,18	52%	100	*04:48*	*14:15*	19:03	€ 1,32	-2,45	€ 5,33	21%	40	€ 805,06	03:32:06	18,22%	1,52%
215	25:32	-2,29	€ 5,38	28%	61	*10:01*	*09:01*	19:02	€ 1,00	-2,32	€ 5,01	28%	60	*04:48*	*07:43*	12:31	€ 1,32	-1,87	€ 3,96	44%	94	€ 1.003,48	16:46:35	13,49%	1,25%
54	27:06	-2,43	€ 5,71	23%	13	*11:48*	*03:33*	15:21	€ 1,00	-1,98	€ 4,24	36%	20	*04:48*	*07:56*	12:44	€ 1,32	-1,88	€ 4,00	40%	22	€ 241,55	15:16:58	21,49%	0,50%
470	32:39	-2,93	€ 6,88	13%	63	*11:48*	*02:24*	14:12	€ 1,00	-1,88	€ 3,99	38%	181	*04:48*	*05:24*	10:12	€ 1,32	-1,66	€ 3,47	48%	226	€ 1.941,85	19:38:30	40,01%	8,08%
123	31:35	-2,84	€ 6,66	14%	17	*12:16*	*02:47*	15:03	€ 1,00	-1,96	€ 4,17	34%	42	*04:48*	*03:59*	08:47	€ 1,32	-1,53	€ 3,17	52%	64	€ 492,06	04:56:16	39,91%	2,11%
45	34:12	-3,07	€ 7,21	13%	6	*12:16*	*02:43*	14:59	€ 1,00	-1,95	€ 4,16	39%	18	*04:48*	*06:13*	11:01	€ 1,32	-1,73	€ 3,64	48%	22	€ 193,46	11:38:06	40,44%	0,78%
175	35:43	-3,21	€ 7,53	13%	22	*12:16*	*04:15*	16:31	€ 1,00	-2,09	€ 4,48	39%	68	*04:48*	*07:45*	12:33	€ 1,32	-1,87	€ 3,96	48%	85	€ 810,14	01:47:53	38,67%	2,92%
42	37:49	-3,40	€ 7,97	10%	4	*12:16*	*00:29*	12:45	€ 1,00	-1,75	€ 3,69	51%	21	*04:48*	*09:25*	14:13	€ 1,32	-2,02	€ 4,32	39%	16	€ 181,32	10:57:27	45,37%	0,81%
83	39:23	-3,54	€ 8,30	11%	9	*12:16*	*04:47*	17:03	€ 1,00	-2,14	€ 4,59	45%	37	*04:48*	*10:59*	15:47	€ 1,32	-2,16	€ 4,65	44%	37	€ 418,53	02:18:51	39,45%	1,41%
226	38:05	-3,42	€ 8,03	11%	25	*14:12*	*01:07*	15:19	€ 1,00	-1,98	€ 4,23	47%	107	*04:48*	*10:33*	15:21	€ 1,32	-2,12	€ 4,55	41%	93	€ 1.082,23	19:21:31	40,33%	3,91%
16	37:16	-3,35	€ 7,86	14%	2	*14:12*	*04:04*	18:16	€ 1,00	-2,25	€ 4,85	43%	7	*04:48*	*12:07*	16:55	€ 1,32	-2,26	€ 4,88	43%	7	€ 85,72	05:30:27	32,59%	0,23%
194	34:02	-3,06	€ 7,18	13%	24	*13:17*	*00:43*	14:00	€ 1,00	-1,86	€ 3,95	41%	80	*04:48*	*06:28*	11:16	€ 1,32	-1,75	€ 3,69	46%	89	€ 821,28	01:16:10	40,96%	3,41%
37	36:21	-3,26	€ 7,66	11%	4	*13:17*	*02:27*	15:44	€ 1,00	-2,02	€ 4,32	38%	14	*04:48*	*05:58*	10:46	€ 1,32	-1,71	€ 3,59	51%	19	€ 160,25	09:33:47	43,83%	0,70%
126	40:01	-3,59	€ 8,44	11%	14	*13:17*	*06:08*	19:25	€ 1,00	-2,35	€ 5,09	38%	47	*04:48*	*09:39*	14:27	€ 1,32	-2,04	€ 4,36	51%	65	€ 640,05	16:05:36	39,77%	2,15%
48	31:47	-2,85	€ 6,70	13%	6	*12:16*	*05:28*	17:44	€ 1,00	-2,20	€ 4,74	25%	12	*04:48*	*01:25*	06:13	€ 1,32	-1,30	€ 2,63	62%	30	€ 176,21	09:54:24	44,92%	0,92%
33	29:39	-2,66	€ 6,25	17%	6	*12:16*	*07:30*	19:46	€ 1,00	-2,38	€ 5,17	23%	8	*04:48*	*02:47*	07:35	€ 1,32	-1,42	€ 2,92	60%	20	€ 132,88	07:50:20	35,87%	0,51%
35	30:27	-2,73	€ 6,42	20%	7	*13:17*	*07:37*	20:54	€ 1,00	-2,48	€ 5,41	26%	9	*04:48*	*06:34*	11:22	€ 1,32	-1,76	€ 3,71	54%	19	€ 166,99	10:29:05	26,72%	0,41%
21	29:09	-2,62	€ 6,15	19%	4	*12:16*	*08:08*	20:24	€ 1,00	-2,44	€ 5,30	23%	5	*04:48*	*04:00*	08:48	€ 1,32	-1,53	€ 3,17	57%	12	€ 89,64	05:26:05	30,96%	0,28%

Den Haag HS

	Walk					Bike + walk								Tram + walk											
						bike	*walk*							*tram*	*walk*							*all travellers*			
total trips	mm:ss	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ bike	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
577	14:25	-1,29	€ 3,04	70%	402	*09:02*	*07:56*	16:58	€ 1,00	-2,13	€ 4,58	30%	175									€ 2.021,63	02:00:45	-15%	-0,91%
214	11:57	-1,07	€ 2,52	66%	142	*09:02*	*03:46*	12:48	€ 1,00	-1,76	€ 3,70	34%	72									€ 623,02	19:34:40	-16%	-0,34%
812	18:46	-1,69	€ 3,96	44%	358	*09:02*	*00:20*	09:22	€ 1,00	-1,45	€ 2,97	56%	454									€ 2.768,11	14:54:00	14%	1,16%
902	20:12	-1,81	€ 4,26	58%	527	*08:13*	*09:01*	17:14	€ 1,00	-2,15	€ 4,63	42%	375									€ 3.983,28	21:12:40	-4%	-0,34%
225	18:05	-1,62	€ 3,81	51%	115	*08:13*	*03:33*	11:46	€ 1,00	-1,66	€ 3,48	49%	111									€ 823,00	08:19:03	4%	0,10%
1969	23:38	-2,12	€ 4,98	36%	714	*08:13*	*02:24*	10:37	€ 1,00	-1,56	€ 3,24	64%	1255									€ 7.622,71	23:23:21	22%	4,51%
515	25:48	-2,32	€ 5,44	35%	179	*09:18*	*02:47*	12:05	€ 1,00	-1,69	€ 3,55	65%	336									€ 2.166,24	00:43:00	23%	1,20%
189	28:33	-2,56	€ 6,02	29%	55	*09:18*	*02:43*	12:01	€ 1,00	-1,68	€ 3,53	71%	133									€ 804,10	05:01:37	29%	0,56%
735	30:04	-2,70	€ 6,34	29%	216	*09:18*	*04:15*	13:33	€ 1,00	-1,82	€ 3,86	71%	519									€ 3.368,73	09:16:53	28%	2,09%
174	32:26	-2,91	€ 6,84	25%	43	*12:43*	*00:29*	13:12	€ 1,00	-1,79	€ 3,78	75%	132									€ 790,35	04:04:58	34%	0,60%
349	34:00	-3,05	€ 7,17	29%	102	*12:43*	*04:47*	17:30	€ 1,00	-2,18	€ 4,69	71%	246									€ 1.888,61	09:50:30	24%	0,87%
946	32:45	-2,94	€ 6,90	26%	245	*13:13*	*01:07*	14:20	€ 1,00	-1,89	€ 4,02	74%	700									€ 4.512,07	13:18:57	31%	3,00%
68	31:56	-2,87	€ 6,73	33%	22	*13:13*	*04:04*	17:17	€ 1,00	-2,16	€ 4,64	67%	45									€ 361,37	00:58:30	21%	0,14%
812	28:42	-2,58	€ 6,05	28%	231	*10:57*	*00:43*	11:40	€ 1,00	-1,65	€ 3,46	72%	581									€ 3.406,24	07:19:31	31%	2,55%
156	31:06	-2,79	€ 6,56	27%	42	*10:57*	*02:27*	13:24	€ 1,00	-1,81	€ 3,83	73%	113									€ 712,10	23:19:24	30%	0,49%
527	34:46	-3,12	€ 7,33	27%	144	*10:57*	*06:08*	17:05	€ 1,00	-2,14	€ 4,60	73%	384									€ 2.819,00	00:30:31	27%	1,47%
200	26:32	-2,38	€ 5,59	37%	73	*08:13*	*05:28*	13:41	€ 1,00	-1,83	€ 3,88	63%	127									€ 901,84	13:16:31	19%	0,40%
139	24:24	-2,19	€ 5,14	46%	63	*08:13*	*07:30*	15:43	€ 1,00	-2,02	€ 4,31	54%	75									€ 651,33	21:31:32	9%	0,12%
149	25:07	-2,26	€ 5,30	50%	75	*10:57*	*07:37*	18:34	€ 1,00	-2,27	€ 4,91	50%	74									€ 759,04	06:10:45	4%	0,05%
88	23:54	-2,15	€ 5,04	48%	43	*08:13*	*08:08*	16:21	€ 1,00	-2,07	€ 4,45	52%	46									€ 418,68	05:28:26	6%	0,06%

Voorburg

	Walk					Bike + walk								Tram + walk											
						bike	*walk*							*tram*	*walk*							*all travellers*			
total trips	mm:ss	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ bike	utility	€ totaal	% trips	# trips	*mm:ss*	*mm:ss*	mm:ss	€ tram	utility	€ totaal	% trips	# trips	total costs	total time	Gain [€/trip]	
121	29:24	-2,64	€ 6,20	24%	29	*09:11*	*07:56*	17:07	€ 1,00	-2,14	€ 4,61	40%	48	*03:36*	*13:52*	17:28	€ 1,23	-2,27	€ 4,92	35%	43	€ 615,42	16:40:04	18%	1,04%
45	28:32	-2,56	€ 6,02	21%	9	*09:11*	*03:46*	12:57	€ 1,00	-1,77	€ 3,73	47%	21	*03:36*	*12:35*	16:11	€ 1,23	-2,16	€ 4,65	32%	14	€ 201,23	12:51:54	25%	0,55%
170	30:21	-2,73	€ 6,40	16%	28	*09:11*	*00:20*	09:31	€ 1,00	-1,46	€ 3,01	58%	99	*03:36*	*14:15*	17:51	€ 1,23	-2,31	€ 5,00	25%	43	€ 689,92	18:32:57	36%	3,04%
189	23:58	-2,15	€ 5,05	28%	53	*05:22*	*11:32*	16:54	€ 1,00	-2,12	€ 4,56	29%	54	*03:36*	*07:43*	11:19	€ 1,23	-1,72	€ 3,62	43%	81	€ 809,47	03:45:42	15%	1,39%
47	27:48	-2,50	€ 5,86	18%	9	*07:55*	*03:33*	11:28	€ 1,00	-1,64	€ 3,42	43%	20	*03:36*	*07:56*	11:32	€ 1,23	-1,74	€ 3,67	39%	18	€ 186,49	11:21:31	32%	0,75%
411	25:33	-2,29	€ 5,39	19%	77	*07:55*	*02:24*	10:19	€ 1,00	-1,53	€ 3,18	40%	166	*03:36*	*05:24*	09:00	€ 1,23	-1,51	€ 3,13	41%	169	€ 1.469,78	14:39:10	34%	6,81%
108	24:08	-2,17	€ 5,09	19%	21	*06:50*	*02:47*	09:37	€ 1,00	-1,47	€ 3,03	39%	42	*03:36*	*03:59*	07:35	€ 1,23	-1,39	€ 2,83	42%	45	€ 359,63	20:43:30	34%	1,81%
39	22:53	-2,06	€ 4,82	23%	9	*06:50*	*02:43*	09:33	€ 1,00	-1,46	€ 3,01	41%	16	*03:36*	*06:13*	09:49	€ 1,23	-1,59	€ 3,30	36%	14	€ 139,13	08:19:33	27%	0,52%
154	21:16	-1,91	€ 4,48	27%	41	*05:53*	*04:09*	10:02	€ 1,00	-1,51	€ 3,12	40%	62	*03:36*	*07:45*	11:21	€ 1,23	-1,72	€ 3,63	33%	50	€ 560,50	10:31:51	19%	1,40%
36	19:50	-1,78	€ 4,18	27%	10	*05:53*	*00:29*	06:22	€ 1,00	-1,18	€ 2,34	49%	18	*03:36*	*09:25*	13:01	€ 1,23	-1,87	€ 3,98	24%	9	€ 117,75	07:02:06	23%	0,41%
73	14:39	-1,32	€ 3,09	44%	32	*05:53*	*04:47*	10:40	€ 1,00	-1,56	€ 3,25	34%	25	*03:36*	*10:59*	14:35	€ 1,23	-2,01	€ 4,31	22%	16	€ 248,35	16:06:33	-10%	-0,37%
198	11:16	-1,01	€ 2,38	44%	88	*04:57*	*01:07*	06:04	€ 1,00	-1,15	€ 2,28	39%	76	*03:36*	*10:33*	14:09	€ 1,23	-1,98	€ 4,22	17%	33	€ 523,77	08:06:03	-12%	-1,12%
14	08:43	-0,78	€ 1,84	56%	8	*04:57*	*04:04*	09:01	€ 1,00	-1,42	€ 2,90	30%	4	*03:36*	*12:07*	15:43	€ 1,23	-2,12	€ 4,55	15%	2	€ 36,11	02:19:15	-39%	-0,27%
170	14:19	-1,29	€ 3,02	35%	59	*05:22*	*00:43*	06:05	€ 1,00	-1,15	€ 2,28	40%	68	*03:36*	*06:28*	10:04	€ 1,23	-1,61	€ 3,36	25%	43	€ 476,69	04:09:39	7%	0,57%
33	15:53	-1,43	€ 3,35	33%	11	*05:22*	*02:27*	07:49	€ 1,00	-1,31	€ 2,65	38%	12	*03:36*	*05:58*	09:34	€ 1,23	-1,56	€ 3,25	29%	9	€ 99,57	05:58:49	9%	0,14%
110	17:02	-1,53	€ 3,59	39%	43	*05:22*	*06:08*	11:30	€ 1,00	-1,64	€ 3,42	35%	38	*03:36*	*09:39*	13:15	€ 1,23	-1,90	€ 4,03	27%	30	€ 402,29	01:54:24	-2%	-0,09%
42	19:25	-1,74	€ 4,09	24%	10	*05:22*	*04:22*	09:44	€ 1,00	-1,48	€ 3,05	32%	13	*03:36*	*01:25*	05:01	€ 1,23	-1,16	€ 2,29	44%	18	€ 124,16	06:58:44	27%	0,56%
29	23:35	-2,12	€ 4,97	21%	6	*06:50*	*06:46*	13:36	€ 1,00	-1,83	€ 3,87	29%	8	*03:36*	*02:47*	06:23	€ 1,23	-1,28	€ 2,58	50%	14	€ 100,45	05:52:29	30%	0,43%
31	19:50	-1,78	€ 4,18	31%	10	*05:22*	*07:37*	12:59	€ 1,00	-1,77	€ 3,74	32%	10	*03:36*	*06:34*	10:10	€ 1,23	-1,62	€ 3,38	37%	11	€ 116,27	07:17:42	10%	0,16%
18	23:16	-2,09	€ 4,91	24%	4	*06:50*	*07:24*	14:14	€ 1,00	-1,88	€ 4,00	29%	5	*03:36*	*04:00*	07:36	€ 1,23	-1,39	€ 2,84	48%	9	€ 67,67	04:04:11	25%	0,23%

% gain in generalised travel costs, compared to walk only

	Verwacht											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	13,00%	8,70%	3,17%	9%	28,57%	0,00%	11,00%	6%	25,56%	8,70%	7,67%	11%
2	14,94%	10,27%	6,06%	10%	28,57%	0,00%	11,00%	6%	26,09%	10,27%	9,33%	13%
3	19,25%	14,16%	10,59%	14%	28,57%	0,00%	11,00%	6%	27,50%	14,16%	12,80%	16%
4	19,25%	14,30%	11,63%	15%	28,57%	0,00%	11,00%	6%	27,79%	14,30%	13,60%	16%
5	20,50%	15,23%	13,47%	16%	28,57%	0,00%	11,00%	6%	28,38%	15,23%	15,33%	17%
6	24,37%	17,78%	17,53%	19%	28,57%	0,00%	11,00%	6%	31,31%	17,78%	17,97%	20%

% gain in generalised travel costs, compared to walk only

	Extreem											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	12,08%	7,77%	3,01%	7%	27,84%	0,00%	11,25%	6%	24,72%	7,77%	7,92%	11%
2	13,90%	9,22%	5,77%	9%	27,84%	0,00%	11,25%	6%	25,21%	9,22%	9,49%	12%
3	17,97%	12,86%	10,19%	12%	27,84%	0,00%	11,25%	6%	26,54%	12,86%	12,84%	15%
4	17,97%	12,98%	11,15%	12%	27,84%	0,00%	11,25%	6%	26,81%	12,98%	13,57%	15%
5	19,12%	13,85%	12,86%	13%	27,84%	0,00%	11,25%	6%	27,36%	13,85%	15,18%	16%
6	23,00%	16,27%	16,80%	15%	27,84%	0,00%	11,25%	6%	30,25%	16,27%	17,73%	19%

	Expected		
	Bike	Tram	Bike + Tram
1	9%	6%	11%
2	10%	6%	13%
3	14%	6%	16%
4	15%	6%	16%
5	16%	6%	17%
6	19%	6%	20%

	Extreme		
	Bike	Tram	Bike+Tram
1	7%	6%	11%
2	9%	6%	12%
3	12%	6%	15%
4	12%	6%	15%
5	13%	6%	16%
6	15%	6%	19%

Average travel time per traveller

	Verwacht												
	Bike				Tram				Bike + Tram				
	CS	HS	VB		CS	HS	VB		CS	HS	VB		
1	24:15	20:08	18:10	20:32	17:25	25:23	15:28	22:38	18:15	20:08	15:31	19:09	
2	23:29	19:36	17:24	19:56	17:25	25:23	15:28	22:38	18:04	19:36	15:07	18:42	
3	21:45	18:15	16:30	18:34	17:25	25:23	15:28	22:38	17:34	18:15	14:31	17:36	
4	21:45	18:12	16:17	18:30	17:25	25:23	15:28	22:38	17:27	18:12	14:22	17:31	
5	21:14	17:52	16:01	18:09	17:25	25:23	15:28	22:38	17:14	17:52	14:08	17:13	
6	20:07	17:15	14:39	17:21	17:25	25:23	15:28	22:38	16:27	17:15	13:18	16:33	

Average travel time per traveller

	Extreem											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	24:15	20:05	18:20	20:31	17:26	25:03	15:32	22:25	18:17	20:05	15:36	19:08
2	23:32	19:35	17:37	19:57	17:26	25:03	15:32	22:25	18:06	19:35	15:14	18:43
3	21:55	18:19	16:44	18:41	17:26	25:03	15:32	22:25	17:38	18:19	14:39	17:41
4	21:55	18:17	16:31	18:37	17:26	25:03	15:32	22:25	17:32	18:17	14:30	17:36
5	21:26	17:58	16:16	18:18	17:26	25:03	15:32	22:25	17:19	17:58	14:17	17:20
6	20:19	17:23	14:57	17:31	17:26	25:03	15:32	22:25	16:34	17:23	13:29	16:41

	Verwacht			
	Bike	Tram	Bike + Tram	Walk
1	20:32	22:38	19:09	25:55
2	19:56	22:38	18:42	25:55
3	18:34	22:38	17:36	25:55
4	18:30	22:38	17:31	25:55
5	18:09	22:38	17:13	25:55
6	17:21	22:38	16:33	25:55

Extreem		
Bike	Tram	Bike+Tram
20:31	22:25	19:08
19:57	22:25	18:43
18:41	22:25	17:41
18:37	22:25	17:36
18:18	22:25	17:20
17:31	22:25	16:41

Walk only			
CS	HS	VB	
31:40	25:23	21:53	25:55
31:40	25:23	21:53	25:55
31:40	25:23	21:53	25:55
31:40	25:23	21:53	25:55
31:40	25:23	21:53	25:55
31:40	25:23	21:53	25:55

Average generalised travel costs per traveller

	Verwacht											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	€ 5,70	€ 4,78	€ 4,29	€ 4,86	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,79	€ 4,78	€ 4,02	€ 4,67
2	€ 5,55	€ 4,68	€ 4,17	€ 4,75	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,75	€ 4,68	€ 3,95	€ 4,58
3	€ 5,22	€ 4,42	€ 4,03	€ 4,49	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,64	€ 4,42	€ 3,84	€ 4,37
4	€ 5,22	€ 4,41	€ 3,99	€ 4,48	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,62	€ 4,41	€ 3,81	€ 4,36
5	€ 5,12	€ 4,35	€ 3,94	€ 4,41	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,57	€ 4,35	€ 3,77	€ 4,30
6	€ 4,93	€ 4,25	€ 3,68	€ 4,28	€ 4,60	€ 5,35	€ 3,94	€ 5,02	€ 4,42	€ 4,25	€ 3,61	€ 4,18

Average generalised travel costs per traveller

	Extreem											
	Bike				Tram				Bike + Tram			
	CS	HS	VB		CS	HS	VB		CS	HS	VB	
1	€ 5,69	€ 4,76	€ 4,33	€ 4,85	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,79	€ 4,76	€ 4,04	€ 4,66
2	€ 5,55	€ 4,66	€ 4,21	€ 4,74	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,75	€ 4,66	€ 3,98	€ 4,58
3	€ 5,24	€ 4,42	€ 4,07	€ 4,51	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,65	€ 4,42	€ 3,87	€ 4,38
4	€ 5,24	€ 4,41	€ 4,03	€ 4,50	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,63	€ 4,41	€ 3,84	€ 4,37
5	€ 5,15	€ 4,36	€ 3,99	€ 4,43	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,58	€ 4,36	€ 3,81	€ 4,31
6	€ 4,95	€ 4,26	€ 3,74	€ 4,30	€ 4,59	€ 5,28	€ 3,96	€ 4,98	€ 4,44	€ 4,26	€ 3,65	€ 4,20

Percentage of travellers per mode

	Verwacht								
	Bike			Tram			Bike + Tram		
	Walk	Bike	Tram	Walk	Bike	Tram	Walk	Bike	Tram
1	47%	53%	-	80%	-	20%	41%	45%	14%
2	46%	54%	-	80%	-	20%	40%	47%	13%
3	42%	58%	-	80%	-	20%	37%	50%	13%
4	42%	58%	-	80%	-	20%	37%	50%	13%
5	41%	59%	-	80%	-	20%	37%	51%	12%
6	38%	62%	-	80%	-	20%	34%	54%	12%

Percentage of travellers per mode

Extreem								
Bike			Tram			Bike + Tram		
Walk	Bike	-	Walk	-	Tram	Walk	Bike	Tram
48%	52%	-	81%	-	19%	41%	44%	14%
46%	54%	-	81%	-	19%	40%	46%	14%
43%	57%	-	81%	-	19%	37%	50%	13%
43%	57%	-	81%	-	19%	37%	50%	13%
42%	58%	-	81%	-	19%	37%	50%	13%
39%	61%	-	81%	-	19%	35%	53%	12%