MASTER

Depaving the way towards the densified city

The potential of car-reduced neighborhoods in a densifying city

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The potential of car-reduced neighborhoods in a densifying city

Eindhoven, the Netherlands

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This project marks the end of my time as a student at the TU/e. Although this project has dragged on slightly too long for my liking, it learned me a lot. There were a lot of tough moments, weeks without progression, and moments of success. I can confidently say that, after surviving this project, reducing car-dependency is embedded in me forever.

The project has also helped me further establish and solidify my own vision on urban planning and its role in our world. And I want to thank all people involved in helping me succeed. I hope to continue working as hard as I did for this project in the future, and apply the things I learned in terms of planning and motivation.

This little project will also always remind me of the fun times on floor 5 of Vertigo. The countless hours of listening to almost any musical genre while slowly building towards the end. When I was stuck, I new energy by listening to either KINK.FM radio (thanks pap), energizing Drum and Bass, the dreamy guitars of the War on Drugs or the Haunted Youth, bass-heavy synth mixes by Skeler, or even the joyful John Tana.

I want to thank Dena and Gamze, not only for their valuable feedback for the entire year, but also the lovely shared experiences in Hamburg. I want to thank Wilco and Merijn, who endured the same struggles throughout the project. I also want to thank AnArchi and all my friends at the university who are graduating soon, or have recently graduated, the fun I had with you is forever with me. Lastly, I want to thank my family and friends, who have kept me sane when I needed it most.

See you around.

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Literature

Abstract

As a result of continued urbanization and population growth, cities continue to grow. As available land area is limited, cities opt to densify, rather than sprawl out further. In Eindhoven, the Netherlands, the municipality aims to add more than 35000 dwellings within the city before 2040. The addition of these new dwellings will stress the existing transport infrastructure. In dense environments, maintaining private vehicle ownership levels causes problems. However, the ambition to densify can provide an opportunity to revise the mobility system in the city. In densely populated areas, many facilities and amenities can be concentrated strategically, reducing overall distances that needs to be travelled.
Through a literature review, a list of neighborhood characteristics that contribute to car-reduced potential is created. Additionally, interventions which can possibly be taken in the neighborhoods are collected into an additional overview. A city-scale strategy is formed, based on the found interventions and an overview of the most important locations for a car-reducing mobility strategy. In the final phase of the project, the discovered interventions are applied on neighborhood scale, resulting in a redesign of the Gildebuurt and Woenselse Watermolen, both neighborhoods in central Eindhoven. The redevelopment proposal aims to densify the city by intervening in existing infrastructure in an attempt to reduce car-dependency through design.

Urban densification | Car-reduced | Accessibility | Car dependency | Land use

Introduction

1.1 PROBLEM STATEMENT

Due to continued population growth and urbanization, cities continue to grow (Bibri et al., 2020). Over the last 40 years, the global population share that lives in cities has risen from 39%, up to 56% (UNHabitat, 2022). This increase is projected to continue, with the expected world population share living in cities to reach 68% by the year 2050. As governments and municipalities have come to conclude that endlessly sprawling outwards is not sustainable, cities opt to apply a densification strategy (Gemeente Eindhoven, 2020b). Densification results in more people and services in smaller areas, affecting the demand for mobility. A densification strategy is important, as it helps to mitigate further urban sprawl, but also to appropriately adjust the systems functioning within a city. The interaction between population density and mobility demand has been studied extensively, as demonstrated by (Levinson et al., 1963). Sixty years ago, Levinson et al. already stated the necessity of shifting transportation modes in case of densification.

The car is a beacon of individual mobility and comfort, and has shaped the last century in terms of transport. It is a very important element of our current way of living as the human race. In addition to other advantages, the car has brought increased employment, technological advances and economic prosperity (M. J. Nieuwenhuijsen & Khreis, 2016b). A city reliant on cars for citizens' mobility needs increases difficulty in case of densification, since personal vehicles take up a large amount of space. Increasing the amount of people will also increase the amount of vehicles if similar ownership levels are maintained (Gemeente Eindhoven, 2020a). This limits the potential of the densification strategy. However, it is argued a dense city can help with reducing the necessity of the personal vehicle, as amenities can be in close proximity of living locations. This can reduce the necessity to travel large distances. (Cervero & Kockelman, 1997)

In any case, a city is only livable if the people remain able to access their desired destinations. Due to spatial constraints, providing a high level of accessibility is perhaps more difficult in a densely populated

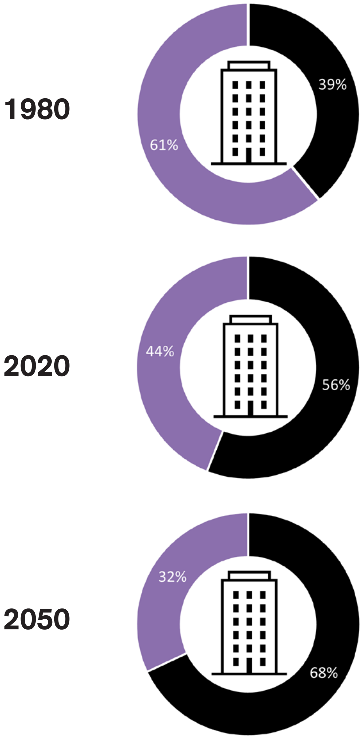

Figure 1 Urbanization trends & predictions

Figure 2 Diagramatic overview of the sprawling effect of urbanization on the city of Eindhoven

environment. Additionally, with a higher population density comes the increased amount of travel demand by all individuals. The city of Eindhoven is, by Dutch standards, a car-centric city (Gemeente Eindhoven, 2020b). If the city of Eindhoven wants to successfully commit to their proposed densification strategy, it is of value to determine in which parts of the city the personal vehicle can be limited, which in turn can affect the densification strategy of the municipality.

Furthermore, reducing personal vehicles also helps contribute to sustainability goals, as the transportation sector is responsible for a large portion of the greenhouse gas emissions (M. J. Nieuwenhuijsen & Khreis, 2016b).

Densification offers the opportunity to revise mobility structure of a city. In this research, a method to determine the extent to which various neighborhoods are able to adapt a car-reducing mobility strategy. This helps cities with aspirations to densify determine where strategies for car use reduction have the most potential.

1.2 STATE-OF-THE-ART

Citizens experience difficulty to let go of their vehicles, as it is the mode of transport they have grown accustomed to for decades (M. Nieuwenhuijsen et al., 2018). The urban environment can also leave the citizens without other feasible options, for instance access to remotely located stores, made attractive by large parking lots or drive-throughs is designed for car use. There are however recent developments that break this trend, as can be seen from car-free initiatives in Helsinki, Oslo or Paris (M. J. Nieuwenhuijsen & Khreis, 2016b).

New developments, like mobility as a service or vehicle sharing, attempt to fill the gap for people who do not own a private vehicle, but still need one to get to their destination. Creating inaccessibility to certain transport modes can disrupt the modal choice of many travelers (M. Nieuwenhuijsen et al., 2018). Car-free neighborhoods are known to function if the right conditions apply, and are desirable for high density urban environments (Hofstad, 2012).

However, feasible approaches should be investigated that are tailor-made to a specific context, in the case of this research the city of Eindhoven. It is proven difficult to change the public opinion on car-free, or car-reduced neighborhoods, as citizens tend to prefer to hold on to their personal vehicles (Alameri, 2011; Lagrell et al., 2018). This creates a mismatch between citizens and city planners.

To further underpin the problems, the municipality of Eindhoven has conducted a mobility stress test. This was done with the intention to test the current mobility system and what would happen when the envisioned densification is applied. The results can be seen in Figures 3 and 4 (Gemeente Eindhoven, 2020a). An enormous area in parking space, equal to the entire neighborhoods of Strijp-S and the University campus, would be needed to sufficiently supply the population growth and their mobility demands. Additionally, roads within the city ring road would suffer heavy congestion increases, locking the system. The current mobility system is insufficiently prepared for the envisioned densification. Thus, there is a demand for a mobility system that can handle the increase in density.

1.3 RESEARCH GAP

Newly built neighborhoods at edges of cities offer the freedom of introducing car-reduced design, but often lack the density of services to justify a car-reduced design. Physically modifying inner city neighborhoods, where services are in closer proximity, is a substantial challenge as pre-existing buildings and infrastructure have to be taken into account.

Next, applying car-reduced strategies to individual neighborhoods is not feasible. Neighborhoods are part of the city as a whole, thus a strategy per neighborhood also requires a city-wide strategy. The city of Eindhoven consists of a variety of neighborhoods with different densities and structures. Different conclusions might apply per neighborhood type. It is therefore important to find out how different neighborhoods fit into a city strategy. The necessity to transition towards a more sustainable form of transportation has been well-documented (Bibri et al., 2020; M. J. Nieuwenhuijsen & Khreis, 2016b; Rode, 2013). However, detailed conclusions focused on design of the city, in this case the city of Eindhoven, are often missing.

Determining the locations within the city where interventions have the most potential can be of great value. There is plenty of research conducted on the functioning of car-reduced neighborhoods, but feasible approaches for specific contexts are hardly described.

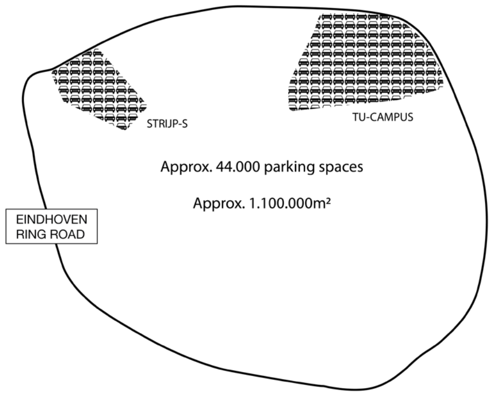

Figure 3 Mobility stress test Eindhoven: expected extra parking requirements

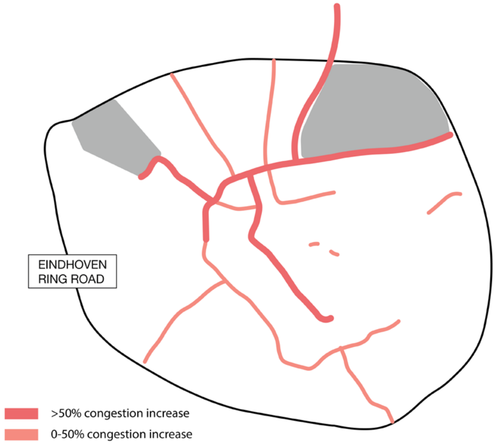

Figure 4 Mobility stress test Eindhoven: congestion increases

1.4 AIMS AND OBJECTIVES

The first objective will be to determine the factors that address accessibility and livability through literature and policy reviews, by looking for the characteristics which are included in a neighborhood suitable for car-reduced transportation.

Then, the discovered neighborhood characteristics are compared to the presence within the various neighborhoods of Eindhoven, providing an indication to where the reduction of car-dependency has the most potential. This will give an overview of the neighborhoods of Eindhoven, ranked on their adaptability towards a car-reduced mobility system.

In addition to forming an overview of the city neighborhoods, a city scale strategy is developed. The different neighborhoods work together, and form the basis of the city strategy. This includes the relationship between the built environment and modal choice of various transport modes. This also includes how different modes of transport co-exist, forming a base for guidelines.

After determining the neighborhoods with the most potential, the found interventions will be applied in the context of the various neighborhoods of Eindhoven. These steps will form an elaborate answer to the research question:

To what extent can the various neighborhoods of Eindhoven become car-reduced, and how can car-reducing interventions be applied within the context of densification?

The subquestions answered throughout the report can be found in Table 1.

To what extent can the various neighborhoods of Eindhoven become car-reduced, and how can car-reducing interventions be applied within the context of densification?

1.5 RELEVANCE

The issues faced by Eindhoven are not exclusive, more cities with ambitions to densify will be able to apply findings to different neighborhoods. It is thus useful to set up a set of guidelines, linked to findings from literature, that can be adjusted to a variety of contexts. Furthermore, this research can provide insights in how parts of the city function within a city strategy. How car-reduced neighborhoods function from within, and with other neighborhoods is an essential part of this research. Additionally, this research can provide new insights in the spatial characteristics of reducing car-dependency, which can be included in further research towards the potential outcomes of the mobility transition with other themes, like sustainability or health. Finally, the final design can provide insight into the similar situations in other cities and act as a case study.

In the forthcoming sections of this report, the theoretical framework will be established, followed by the methodology of the research methods used. Thereafter, a short historical context of car-free development is provided, after which the results of the various research methods are discussed.

Table 1 Sub questions in table overview

Sub question	Methods	Result
What does the historical development of reducing car dependence look like?	• Systematic literature review	• Background information on historical measures and implementation viability
What neighborhood characteristics are favorable for car-reduced mobility systems?	• Systematic literature review • Case studies	• Classification of neighborhood characteristics
Which car dependency-reducing interventions or policies are there, and have proven to be successful?	• Policy review	• Policy feasibility • Policy recommendations
Which stakeholders are involved, and what is their role in the interventions proven successful?	• Systematic literature review • Policy review	• Stakeholder overview
In terms of car dependency, what types of neighborhoods and what characteristics are present in the city of Eindhoven?	• Mapping analysis • GIS analysis	• Neighborhood classification
How can the car-reduced interventions be applied in the context of neighborhoods?	• Design	• Designing for reducing car-dependency in densifying cities

Theoretical framework

There is extensive evidence on the influence of the built environment on travel behavior (Litman, 2022). However, to clear up the relations explored in this research, an overview is provided in three steps. Firstly, the relationship between urban densification and the urban environment will be established. This is followed by the relationship between the urban environment and activities. This section is concluded by how these two steps link the relationship between urban densification and mobility behavior, resulting in a conceptual model. Table 2 provides an overview of the most important concepts related to mobility behavior in the densifying city, within the context of reducing car-dependency.

2.1 URBAN DENSIFICATION AND THE URBAN ENVIRONMENT

Density, design, diversity of land use, distance to transit and destination accessibility concern the five categories that make up the 5 D's of the built environment. These categories aid in explaining the effect of the built environment on transportation. Additionally, these categories aid in indicating how a transportation system can integrate better into the surrounding city. Each category describes a distinctive part of the built environment. In this research, the effect of densification is applied to the built environment. Densification will disrupt the subtopics within the five categories, which in turn will affect travel behavior.

2.2 THE URBAN ENVIRONMENT AND ACTIVITIES

The second thing to consider is the activities of people that take place within the urban environment. The decisionmaking can be described by the Land-use transport feedback cycle first developed by Michael Wegener and Franz Fuerst (2004), seen in Figure 6. The theory is based on the need for transportation as a result of the spatial separation of activities. The theory argues that the distribution of land uses, for instance residential or commercial, determines the locations of activities performed by citizens, for instance working, shopping or leisure. As mentioned before, the spatial separation of activities creates a demand for transportation. This demand is filled by the possibilities of the existing transport system. The availability of transport modes determines how accessible a location is. Lastly, differences in accessibility determine changes in land-use. These interactions create a feedback cycle of constant development (Wegener & Fuerst, 2004). Merging the established urban environment with the feedback cycle results in the diagram as seen in Figure 7. This forms the base for the conceptual model used throughout the project.

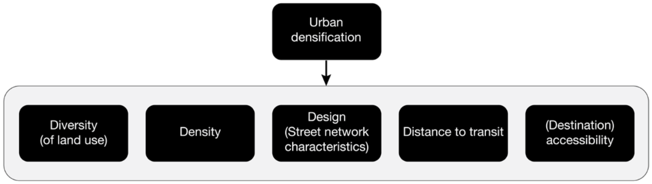

Figure 5 Schematic effect of densification on the urban environment

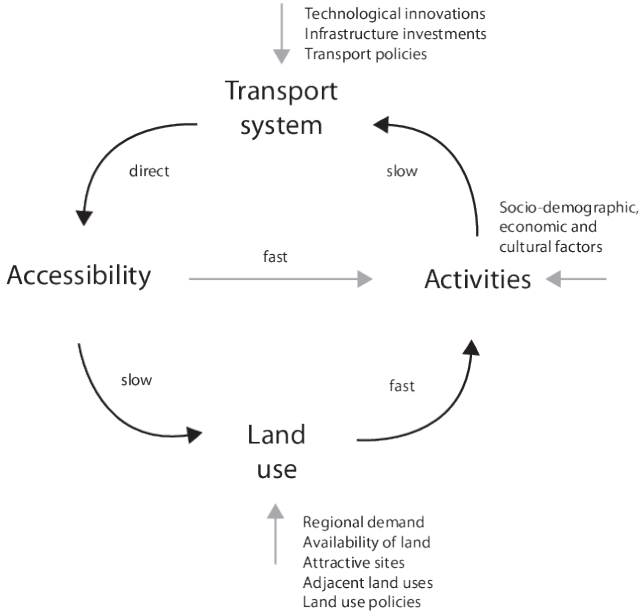

Figure 6 The Land-Use feedback cycle by Wegener and Fuerst (2004)

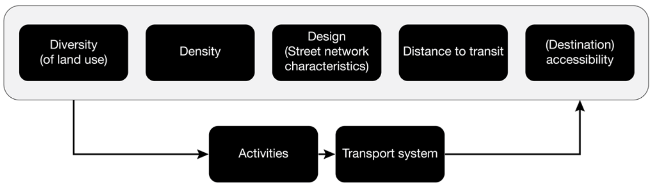

Figure 7 Schematic overview of the interaction of the urban environment and activities

2.3 URBAN DENSIFICATION AND BEHAVIOR

Firstly, the effect of densification on the built environment was explored and summarized by the 5D's of the built environment. Then, the interaction between the built environment and activities was explored and summarized by the land-use feedback cycle. These two theoretical approaches can be combined to extract the effect on mode choice in a densifying context.

Destination accessibility and Diversity of land use are both part of the 5D's of the urban environment and the land-use feedback cycle. As a result of densification, the five categories will change, resulting in a change in activities, and subsequent changes in the transport system. The change in activities and transport system results in more changes to the 5D's. Placing this conceptual model into the context of the car-reduced city allows for the exploration of the effect of urban densification on mode choice.

However, it should be mentioned that mode choice is only a part of the decisionmaking process. Other desicions also apply, but the most relevant decision throughout this project is the mode choice.

Within the context of the car-reduced city, the interactions between densification, the 5D's, the feedback cycle, and mode choice have been summarized in a conceptual model, which can be seen in Figure 8. Additionally, the key concepts used thoughout the project are briefly explained and collected in Table 2.

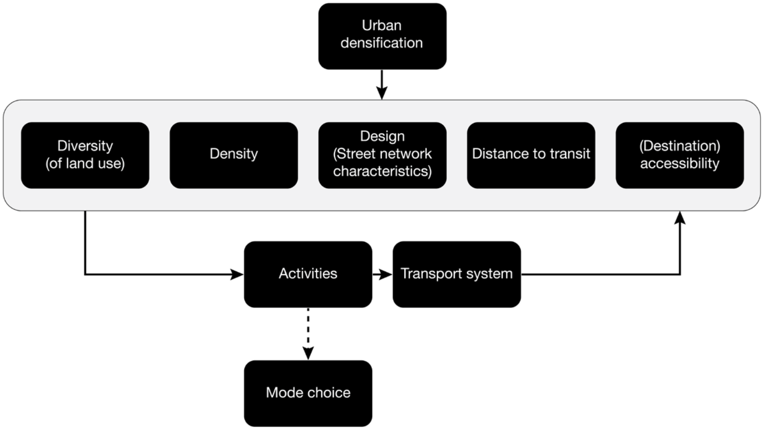

Figure 8 Conceptual model

Table 2 Overview of key concepts used throughout the project

Key concept	Definition
Urban densification	The process of increasing the ratio of housing units or people per unit of land area (Bibri et al., 2020).
Built environment	The space in which people live, work and recreate on a day-to-day basis, made by humans. This includes buildings, parks and transportation systems (Litman, 2022; Zhang et al., 2014).
Car-reduced	An environment where living and traveling is possible without using a car. A place where car ownership and usage is discouraged, but not made impossible (Crawford, 2009).
Travel behavior	An accumulation of complex decisions which influence the eventual path from point A to point B. This includes travel mode choice, destination selection, routing and many more factors (Litman, 2022).
Mobility mode choice	The type of transport that is chosen to travel between point A and B. Usually either the cheapest, fastest or most comfortable mode is dominant (Ewing & Cervero, 2010).
Design	Street network characteristics within an area, for instance the sizes of city blocks, proportions and amounts of intersections (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Litman, 2022; Zhang et al., 2014).
Density	The amount of people, jobs or houses per unit of land area, for in a square kilometer of land area (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Litman, 2022; Zhang et al., 2014).
Diversity of land use	The number of different land uses in a given area and the degree to which they are represented, for instance ratios comparing working locations to housing locations (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Litman, 2022; Zhang et al., 2014).
Distance to transit	The level of transit service at the residences or workplaces, for instance the distance to the nearest railway station or distance between public transit stops (Ewing & Cervero, 2010; Litman, 2022; Zhang et al., 2014).
Destination accessibility	Ease of access to trip attractions, for instance the distance towards a vibrant city center with many amenities or workplaces (Ewing & Cervero, 2010; Litman, 2022; Zhang et al., 2014).
Activities	Activities can be described as a series of events, consisting of trips. A trip from point A to point B can also be seen as an activity (Litman, 2022). The patial separation of activities creates travel demand (Wegener & Fuerst, 2004).
Transport system	An accumulation of tailored modes of transport used by people to reach their activities. Different transport modes within the system can coexist, or even cooperate. A varied transport system offers the highest level of mode choice freedom (Wegener & Fuerst, 2004).

Methodology

In this section of the report, the processes and different research methods are outlined. The general progression will follow a research phase, followed by preliminary results. These preliminary results will be used to work towards a final design.

The research phase will provide various types of information, focusing on creating a theoretical basis in understanding neighborhoods and car-dependency. The various types of research methods aim to provide specific information regarding neighborhood characteristics, policies, city networks and car-dependency indicators.

With this information as foundation, a neighborhood classification is created, accompanied by a city scale strategy. These two preliminary results form the basis for the eventual (re-)design of neighborhoods in Eindhoven, based on the car-reducing characteristics and interventions found in literature. A visual overview of the used research methods and the results can be seen on the next page, in Figure 9.

3.1 SYSTEMATIC LITERATURE REVIEW

The first research method used is a systematic literature review. The main goal of this review is to find characteristics of neighborhoods that support a car-reduced mobility system and influence modal choice in a densifying context. In addition to the neighborhood characteristics, car-reduced developments over time have been evaluated to provide historical context to contemporary developments. The literature review consisted of two parts; selecting and collecting the data, and reviewing the data.

3.2 MAPPING ANALYSIS WITHIN THE CONTEXT OF EINDHOVEN

The literature review is followed up by a mapping analysis. The main objective of the mapping analysis is to test the found characteristics of the literature review within the context of Eindhoven. The mapping analysis can be used to determine areas within the city that have potential to become car-reduced. Apart from neighborhood characteristics found in literature, travel patterns, modal splits and neighborhood typologies will be included to draw further conclusions on city structures. The findings of the mapping analysis determine the most suitable neighborhoods for intervention. Additionally, the mapping analysis forms the basis for the city scale strategy.

3.3 REGIONAL AND CITY SCALE STRATEGY

After concluding the mapping analysis, a regional and city scale strategy is formed, combining the findings of the literature review and the mapping analysis. The regional scale strategy and city scale strategy work together, as a system of mobility is connected through the various scales of urban design. It is also important to fit the neighborhood design within both the regional scale strategy and the city scale strategy.

3.4 NEIGHBORHOOD DESIGN

The report ends with a neighborhood design, based on the findings of the literature review, the results of the mapping analysis, and in close connection to both the regional and city scale strategies. Within the neighborhood design, all previous steps of the project return and result in design decisions on neighborhood scale level.

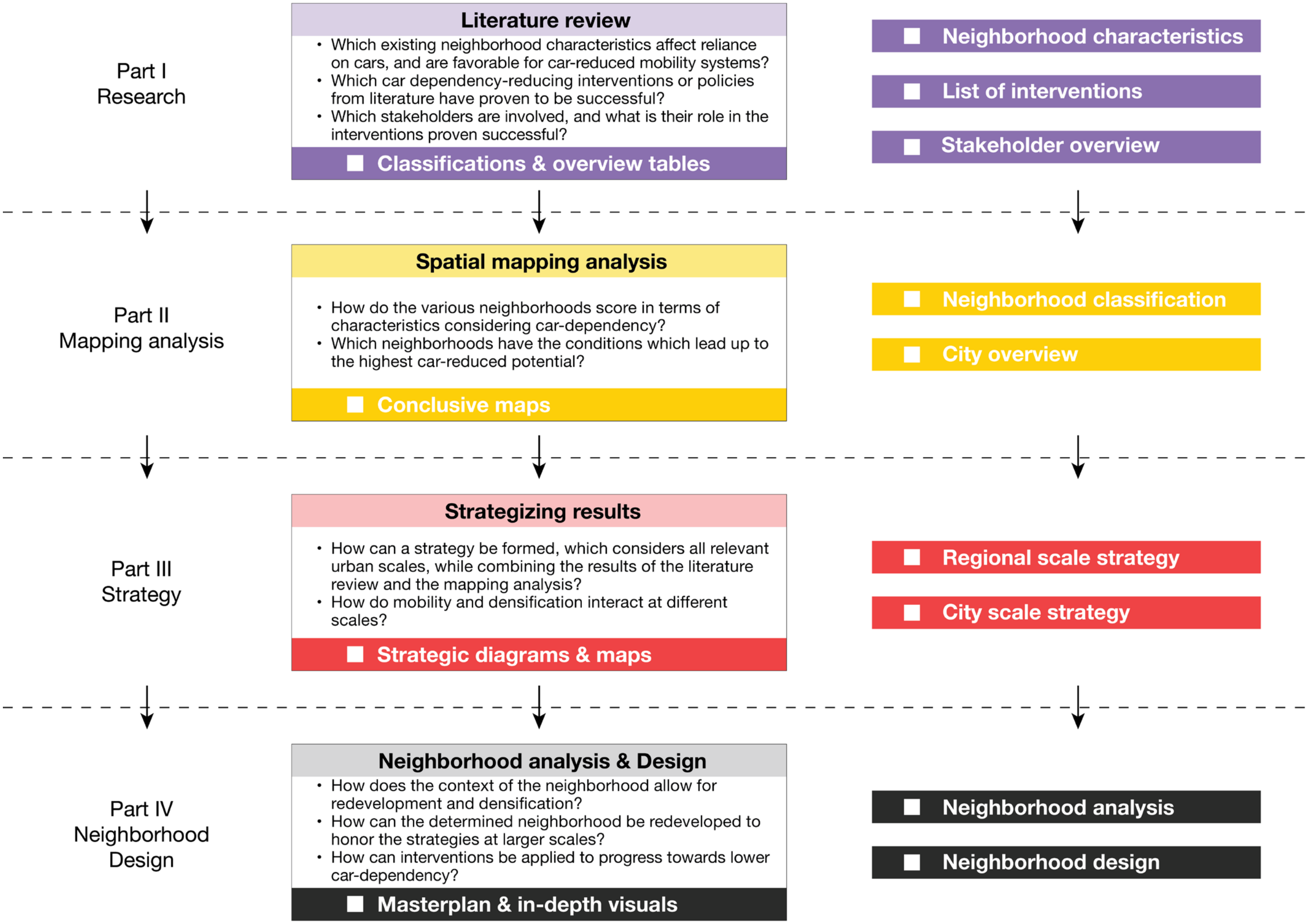

Figure 9 Overview of project methodology, step by step

Background

Figure 10 The Katy Freeway in Houston, Texas, North-America, a dramatic result of adding more infrastructure in an attempt to solve congestion
Photo: Getty Images

Many cities around the world have been shaped by the dominance of automobiles in their transportation systems and urban planning (Jones, 2014). However, there are still remains of urban structures from a time before car ownership became widespread. For example, the city of York has, in its growth from a small medieval town to a big city, adapted some if its urban layout to accommodate cars. However, certain parts of its historic core remain car-free. The preservation of these narrow streets is not just about preserving history; it is also because adapting them for cars would require demolishing the existing fabric of the city. These old streets were designed primarily for pedestrians, reflecting the common mode of transportation during their creation.

Another common aspect shared by European cities that predate the automobile era is the development around introduced train stations. The pivotal moment in the history of the car came in 1886, when Carl Benz developed the first stationary gasoline engine, laying the foundation for the modern automobile (Mercedes-Benz Group, 1886). Following World War II, the automobile industry experienced unprecedented growth, making cars accessible to the general public and no longer a luxury item (Huddle, 1945).

In response to the widespread availability of the car, cities opted for different developments. Some cities discouraged car use and focused on improving public transport and land-use planning. In contrast, others embraced cars, introducing car dependence by reducing investments in public transport and reallocating space previously used for markets and slow modes like cycling and walking (Jones, 2014). This shift in priorities was motivated by several benefits associated with cars.

Firstly, the car industry saw tremendous growth, resulting in increased employment rates and prosperity, leading to a direct link between economic growth and car dependency. Secondly, cars provided people with a sense of independence and safety, which remains a significant reason for car ownership to this day (Jones, 2014). Jones (2014) outlines three stages of car policy development. The initial stage, “traffic growth policies — a vehicle-based perspective,” dramatically influenced urban planning, redirecting the focus towards bringing cars closer to homes and workplaces while increasing distances between residential and commercial areas.

The second stage, described by Jones (2014) as “Traffic containment policies — a person trip perspective,” involved efforts to contain car-related growth. Research showed that public transport could compete with cars in terms of travel time. Subsequently, studies highlighted the negative impacts of cars on cities, including air pollution, noise, reduced physical activity, and increased accidents.

The final stage, Stage Three: “liveable cities — activities and quality of life perspectives,” represents the current state of policy making and urban planning. Cities now recognize the profound impact of car infrastructure on their environments and are driven to take action. Reducing car dependence fosters city development and enhances overall quality of life (Jones, 2014). To achieve this, many European cities have introduced pedestrianized city centers. Cities like Bologna, Aachen, and York have implemented zones in their inner cities where cars are prohibited. The primary goal is to attract more visitors to city centers and promote public transport. These pedestrianized zones represent the beginning of a series of policies and design interventions aimed at reducing car dominance.

While there is a growing acknowledgment of the need to reduce car dominance and initial steps have been taken, it’s essential to recognize that cars are deeply embedded in our society and cannot be abruptly removed from our lives.

The complexity of the problem is further underlined by theories like the Downs-Thompson Paradox and the Braess Paradox, which contradict the popular observation that building more roads will solve congestion. The Downs-Thompson Paradox, also known as the “fundamental law of road congestion,” is the observation that increasing road capacity (such as building more lanes or highways) to reduce traffic congestion often fails to alleviate congestion in the long run. Instead, it tends to attract more drivers to use the expanded roads, ultimately leading to a similar or even worse level of traffic congestion than before the expansion. This paradox highlights the counterintuitive nature of road expansion as a solution to traffic congestion.

Similarly, the Braess Paradox is a phenomenon in transportation theory that demonstrates how adding a new road or route to a network can potentially increase overall congestion and travel times for everyone. It occurs when drivers, in an attempt to minimize their individual travel times, choose the new route, overloading it, and causing congestion. This counterintuitive result shows that in some cases, discouraging the additions of large roads can improve traffic flow and reduce travel times in a network.

In any case, the process of reducing car dominance will require time and careful planning. Cars have become an integral part of society and people’s lives over the course of more than 80 years. Thus, any move towards car-free cities must be gradual to avoid resistance and ensure a smooth transition.

Results

4.1 SYSTEMATIC LITERATURE REVIEW

The systematic literature review is one of the research methods used to form an answer to the research question. Before the research question can be answered adequately, it is important to first answer a series of specific sub questions closely related to the main question.

Each neighborhood is different and contains different characteristics. This can be caused by the time period the neighborhood was built up, by the attitudes of people that live in the neighborhood or can be caused by influences from outside the neighborhood. An enumeration of neighborhood characteristics is a first step towards finding out which neighborhoods can become car-free. Each neighborhood characteristic has a certain influence on the potential of a car-free mobility system. It is not only about a car-free system explicitly, but also about the potential of altering user behavior to favor car-free mobility.
This leads to the first sub question:
1. Which existing neighborhood characteristics affect reliance on cars, and are favorable for car-reduced mobility systems?

After the neighborhood characteristics are determined, it is important to know what interventions are possible, and which interventions have proven to be successful. The interventions can be linked to the different neighborhood characteristics. In this way, an approach can be formed by knowing where to start, and what interventions to apply.
This leads to the second sub question:
2. Which car dependency-reducing interventions or policies from literature have proven to be successful?

Lastly, there are the stakeholders. Every intervention will affect stakeholders, it is important to know their roles. The cooperation between the various stakeholders is important because it can ease or worsen the potential of a successful implementation. Identifying the stakeholders, their positions and demands, can provide the final piece of insight to form a detailed city and neighborhood approach.

This leads to the third, and final sub question:
3. Which stakeholders are involved, and what is their role in the interventions proven successful?

4.2 LITERATURE REVIEW METHODOLOGY

The literature review consisted of two parts; selecting and collecting the data, and reviewing the data.

After determining the research question and relevant keywords, a search string was developed and used to search within the SCOPUS database. The following search string was used:

TITLE-ABS-KEY ((car AND free) OR (car-free) OR ((reduce OR lower) AND car AND dominance) AND (city OR urban OR neighborhood OR neighb*rhood) AND (planning OR design) AND (mobility OR transport) AND (policy OR legislation OR strategy OR system))

This search string resulted in 164 papers. These papers were reduced to 33 useful papers after multiple rounds of exclusion. These 33 papers can be seen in Table 3. The process of exclusion can be seen in Figure 11.

The results are presented in different tables containing data overviews. Additionally, graphs and schemes will be provided to elaborate on conclusions which were drawn from the tables. The first table will concern the neighborhood characteristics, from which the most important characteristics can be concluded. The second table will include all policies found in literature, with additional information to which neighborhood characteristic they apply. The third and last table will show the involved stakeholders and in which relationships they are involved.

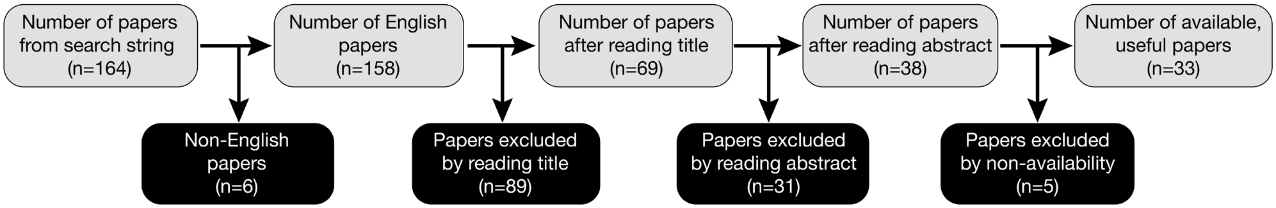

Figure 11 Literature review paper selection and exclusion methodology

Table 3 Overview of the papers used in the literature review

ID	Authors	Year	Title
1	van Wee B., van Bleek B.	1998	Influence of land-use on traffic and environmental impact of traffic
2	Hollenstein D., Bleisch S.	2016	Walkability for different urban granularities
3	Aldred R., Verlinghieri E., Sharkey M., Itova I., Goodman A.	2021	Equity in new active travel infrastructure: A spatial analysis of London's new Low Traffic Neighbourhoods
4	Selzer S.	2021	Car-reduced neighborhoods as blueprints for the transition toward an environmentally friendly urban transport system?
5	Khreis H., Nieuwenhuijsen M.J.	2021	Car-Free Cities
6	Lagrell E., Thulin E., Vilhelmson B.	2018	Accessibility strategies beyond the private car: A study of voluntarily carless families with young children in Gothenburg
7	Rydningen U., Høynes R.C., Kolltveit L.W.	2017	OSLO 2019: A car-free city centre
8	McEldowney M., Ryley T., Scott M., Smyth A.	2017	Urban form and reducing the demand for car travel: Towards an integrated policy agenda for the belfast metropolitan area?
9	Nieuwenhuijsen M.J., Khreis H.	2016	Car free cities: Pathway to healthy urban living
10	Alameri M.	2011	The car free city model
11	Klementschitz R., Stark J., Sammer G.	2007	Integrating mobility management in land development planning with off-street parking regulations
12	Topp H., Pharoah T.	1994	Car-free city centres
13	Olszewski P.S.	2007	Singapore motorisation restraint and its implications on travel behaviour and urban sustainability
14	Nobis C.	2003	The impact of car-free housing districts on mobility behaviour - Case study
15	Tomanek R.	2017	Free-fare public transport in the concept of sustainable urban mobility
16	Shi F.	2015	Research on transport subsidies for public transit and cars
17	Stubbs M.	2002	Car parking and residential development: Sustainability, design and planning policy, and public perceptions of parking provision
18	Basbas S., Campisi T., Papas T., Trouva M., Tesoriere G.	2023	THE 15-MINUTE CITY MODEL: THE CASE OF SICILY DURING AND AFTER COVID-19
19	Bartzokas-Tsiompras A.	2022	Utilizing OpenStreetMap data to measure and compare pedestrian street lengths in 992 cities around the world
20	Anggraini D., Odang S., Mustadjab I.	2017	Proposed design of bicycle lanes around Jakarta's East flood canal
21	Morris D., Enoch M., Pitfield D., Ison S.	2009	Car-free development through UK community travel plans
22	Vande Walle S., Steenberghen T., Paulley N., Pedler A., Martens M.	2004	The role of indicators in the assessment of integrated land-use and transport policies in European cities
23	Scorza F., Fortunato G.	2021	Cyclable Cities: Building Feasible Scenario through Urban Space Morphology Assessment
24	Nikitas A., Tsigdinos S., Karolemeas C., Kourmpa E., Bakogiannis E.	2021	Cycling in the era of covid-19: Lessons learnt and best practice policy recommendations for a more bike-centric future
25	Katoshevski-Cavari R., Bak N., Shiftan Y.	2018	Would free park-and-ride with a free shuttle service attract car drivers?
26	Loo B.P.Y.	2018	Realising car-free developments within compact cities
27	Sylliris N., Papagiannakis A., Vartholomaios A.	2023	Improving the Climate Resilience of Urban Road Networks: A Simulation of Microclimate and Air Quality Interventions in a Typology of Streets in Thessaloniki Historic Centre
28	Taylor D.E.	2021	Free parking for free people: German road laws and rights as constraints on local car parking management
29	Nieuwenhuijsen M, Bastiaanssen J, Sersli S et al.	2018	Implementing car-free cities: Rationale, requirements, barriers and facilitators
30	Kuss P, Nicholas K	2022	A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management
31	Melia S, Barton H, Parkhurst G	2013	Potential for carfree development in the UK
32	Melia S	2014	Carfree and Low-Car Development
33	Borges B, Goldner L	2015	Implementation of car-free neighbourhoods in medium-sized cities in Brazil, a case study in Florianópolis, Santa Catarina

4.3 NEIGHBORHOOD CHARACTERISTICS

Firstly, the neighborhood characteristics are discussed. Throughout the literature, neighborhood characteristics were found and categorized in three main categories. This was done in line with categorizational recommendations found in various papers underpinning the necessity of categorization (Melia et al., 2013; M. Nieuwenhuijsen et al., 2018; van Wee & van Bleek, 1998).

This has resulted in the categories Urban form, Transportation, and Sociodemographic neighborhood characteristics. Nieuwenhuijsen et al. (2018) state this categorization is required because neighborhoods have very different characteristics which cannot be compared without categorization. The characteristics found within each category require different approaches when intervening. Within each category, different neighborhood characteristics were found as shown in Table 4. The neighborhood characteristics found are context dependent and in some occasions very specific. Due to this, some characteristics are grouped into groups which were found to be of similar origin. An example of this is grouping obesity levels and disability levels into the category “impairments“.

Table 4 Categorization of neighborhood characteristics

Cat.	Characteristic	Definition	Neighborhood Characteristic	Characteristic Group
Urban form	Density	Population density	Amount of dwellings	Amount of dwellings
			Amount of inhabitants per area unit	Amount of inhabitants per area unit
	Diversity	Land-use mix	Amount of different services and residences	Amount of different services and residences
			Total amount of services and residences	Total amount of services and residences
			Different housing typologies	Different housing typologies
	Design	Street network characteristics	Amount of parking spaces	Amount of parking spaces
			Parking demand	Parking demand
			Parking norms	Parking norms
			Speed limits	Speed limits
			Traffic signs & lights	Car infrastructure
			One way roads & measurements	
			Intersections	
			Roundabouts	
			Highway access ramps	
			‘Woonerven‘	
			Safe crossings	
			Charging stations	
			Fuel stations	
			Car restricted areas	Car restricted areas
	Destination accessibility	The ease by which destinations can be reached	Distance to services	Distance to services
			Location of service clusters	
			Neigborhood accessibility from outside	Neigborhood accessibility from outside
	Distance to transit	Factors that increase the convenience of public transport	Public transit proximity	Public transit proximity
			Bike lanes	Bike lanes
			Sidewalks	Sidewalks
			Bike parking	Bike parking
Mobility	Costs	The amount of money needed to commute, for both individual and society	Parking costs	Parking costs
			Public transport costs	Car ownership and public transit use costs
			Vehicle taxes	
			Fuel costs	
			Car purchase costs	
			Insurance	
			Road infrastructure spending	Road infrastructure spending
	Travel times	The time it takes to travel from origin to destination	Commuting distances	Commuting distances
			Car ownership rates	Car ownership rates
Sociodemographic	Individual needs	Different life stages	Age	Age
			Income	Income
			Employment	Employment
	Health	Transport difficulties as a result of health conditions	Obesity	Impairments
			Disabilities	
			Air pollution levels	Air pollution levels
			Noise pollution levels	Noise pollution levels
			Urban heat island effect	Urban heat island effect
	Perceived safety	Feeling safe in the surrounding environment	Level & frequency of maintenance	Level & frequency of maintenance
			Street lighting levels	Greenery & Street ornaments
			Sightlines	

Table 5 Overview of appearances of neighborhood characteristics in literature

	Amount of dwellings	Amount of inhabitants per area unit	Amount different services and residences	Total amount of services and residences	Different housing typologies	Amount of parking spaces	Parking demand	Parking norms	Speed limits	Car infrastructure	Car-restricted areas	Distance to services	Neighborhood accessibility from outside	Public transit proximity	Bike lanes	Sidewalks	Bike parking	Parking costs	Car ownership, transit & other mobility costs	Road infrastructure investments	Commuting distances	Car ownership rates	Age	Income	Employment	Impairments	Air pollution levels	Noise pollution levels	Urban heat island effect	Level & frequency of maintenance	Greenery and street ornaments
	Urban form																	Mobility					Sociodemographic								
SUM	3	4	6	4	1	8	5	6	3	4	1	2	6	9	3	3	2	4	3	3	3	5	5	2	2	1	2	2	2	2	4
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32 different neighborhood characteristics were found, with each a different impact on transport mode choice. The impact on mode choice is defined as positive (+) or negative (-) in car-reduced context. The resulting characteristics, with the amount of literature mentions and hypothesized impact on mode share can be found in Table 5.

Some characteristics appeared more often than others, with 'Amount of parking spaces' and 'Public transport proximity' appearing the most (9 times). This could be an indication that these characteristics have most potential in changing mobility choice behavior. The characteristics which appeared the most can be observed in Figure 12.

In terms of car parking, it is suggested that parking minimum standards should be changed to maximum ceilings (Stubbs, 2002). Successful case studies, like in Vauban, Freiburg, even prohibited building parking space on private property (Nobis, 2003). Limiting, or completely removing, parking spaces will also permit higher density development by default and suggested is to move parking spaces to outer edges of the neighborhood to facilitate the necessary trips by car (Morris et al., 2009; Stubbs, 2002). In the end, allowing parking in the neighborhood invites car users, and limiting the parking supply will thus theoretically limit the amount of people using a car.

In terms of public transport proximity, it is regarded as the most important alternative to car use (Morris et al., 2009). Walking and cycling are only viable on short to moderate distances. When no car is available, public transport can provide the necessary means to travel further. It is also argued that creating proper public transport access should be taken as one of the first steps, before removing car access. Otherwise, people will be stranded without viable modes to travel (Selzer, 2021). A good measure is that a public transport stop should not be further away than 300 meters and should ride frequently (Vande Walle et al., 2004). A well-functioning public transport system has the potential to completely fulfill the mobility needs of citizens, removing the need for cars.

Other frequently appearing characteristics are the 'Amount of different services and residences', 'Parking norms', 'Accessibility to the neighborhood from outside', and 'Car ownership rates' with each 6 mentions.

The amount of different services and residences concerns the diversity in a neighborhood. If there is a large mix of services, travel distances are reduced (van Wee & van Bleek, 1998). This removes the necessity of using a car and increases the efficiency of public transport (Khreis & Nieuwenhuijsen, 2021; van Wee & van Bleek, 1998). Parking norms are

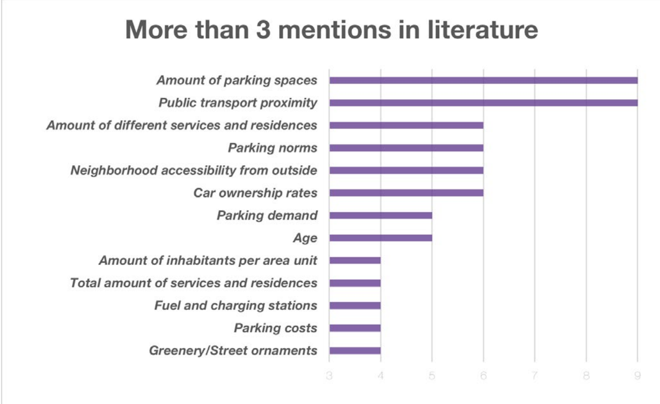


Figure 12 Highly relevant neighborhood characteristics, and the number of appearances

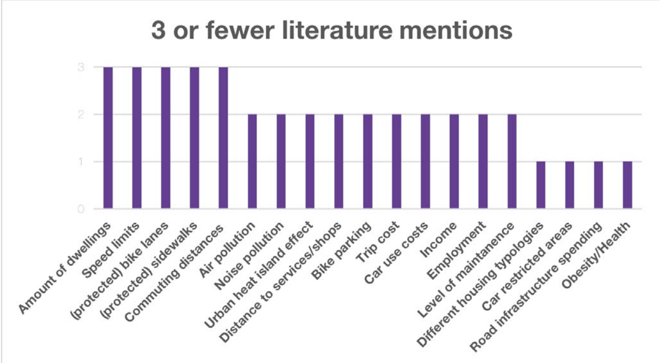


Figure 13 Neighborhood characteristics of lesser relevance, and the number of appearances

in place to ensure residents a parking place, but in a car-free scenario this norm is not desirable (Selzer, 2021). Again, opting to set maximum parking norms instead of minimums is recommended (Klementschitz et al., 2007; Loo, 2018).

Accessibility to the neighborhood from outside is equally important as accessibility inside the neighborhood. Without accessibility from outside, the neighborhood will function as an island (M. J. Nieuwenhuijsen & Khreis, 2016a; RYDNINGEN et al., 2017). A suggested solution are the infamous park-and-ride facilities at city edges, with great connectivity to public transit (Katoshevski-Cavari et al., 2018). Furthermore, car ownership rates are a great indicator of car-dependency in a neighborhood (Nobis, 2003). Lower car ownership rates are usually a sign of a neighborhood better adaptable to car-free mobility. Car-free developments succeed if the citizens do not have to change a large portion of their travel patterns (Melia, 2014).

There are also many characteristics which were mentioned 3 or less times in the literature, these can be observed in Figure 13. All these characteristics were mentioned at least once, so they have some form of impact, it is however unclear if they can be approached as decisive characteristics. 'Different housing typologies', 'Car restricted areas', 'Road infrastructure spending', and 'Obesity/Health' all were mentioned in only one paper, while their relevance is disputed. For instance, different housing typologies can make a difference if a parking spot is included in the housing typology (Selzer, 2021).

Likewise, car restricted areas are mentioned to not function optimally if they are in isolation. Topp & Pharoah (1994) suggest a widespread approach to combat the shift of congestion to another location (Topp & Pharoah, 1994).

In short, the amount of times a characteristic appeared in literature gives an indication which characteristics are the most impactful in changing modal choice behavior. However, it is not a comprehensive measurement, since lower mentioned characteristics can also provide valuable perspectives.

4.4 INTERVENTIONS

By first determining importance of neighborhood characteristics and their hypothesized impact on mode choice behavior, an opportunity arises to apply policies and interventions to these characteristics. To know which policies and interventions are available, and how successful they are, a list of interventions is set up, which is then linked to fitting neighborhood characteristics.

The interventions were categorized into four main groups, which can be seen in Table 6. Firstly, they were categorized by urban scale applicability. Secondly, a conceptual model by Stead (2022) distinguished between substantive policies, which directly impact plan goals, and procedural policies, which affect planning processes (Stead, 2022). Further classification involved policy instruments and approach types. Kuss & Nicholas (2022) adopted the IPCC classification, including Regulatory instruments, Economic instruments, Information & Education policies, and Public goods & Services. Lastly, interventions were categorized as push, pull, or push & pull approaches, where push discourages private car use, pull incentivizes alternative transportation, and a combination of both is often most effective (Kuss & Nicholas, 2022).

Table 6 Categorization of interventions

Scale levels:	
National scale	Nationally controlled or funded interventions
Regional scale	Regionally controlled or funded interventions
City scale	City controlled or funded interventions which need to be involved in city-wide networks
City center scale	City controlled or funded interventions which can be applied within the city center, without interacting with other areas
Neighborhood scale	City controlled or funded interventions which can be applied within the neighborhood, without interacting with other areas
Street scale	City or privately controlled or funded interventions which can be applied within a street
Building scale	City or privately controlled or funded interventions which can be applied within a building plot
Policy types:	
Substantive policies	Direct effect on the goals of a plan
Procedural policies	Affect the process of developing, reviewing or enforcing a plan
Policy instruments:	
Regulatory instruments	Rules, standards, prohibitions
Economic instruments	Taxes, subsidies, charges
Information & Education policies	Information campaigns, marketing, persuasion, feedback
Public goods & Services	Physical infrastructure, planning, provision of services
Approach types:	
Push-approach	Discourage private car use by regulating accessibility, fees, parking costs etc.
Pull-approach	Presenting alternatives to prevent the usage of the private car, for instance by improving public- or active transport
Push & pull approach	A combination of push and pull approaches, an example could be the narrowing of roads

Considering interventions, a distinction can be made between strategy and measures. In terms of strategy, it is advised to combine push and pull policies, as this provides the affected stakeholders who are pushed away with a place to adapt their behavior. An example is to promote public transport simultaneously with reducing car use. Reducing car use can come in various forms, and interventions can have multiple scales of impact. Traffic calming measures will have a more modest impact compared to the rerouting of through traffic. In any case, it is advised to introduce policies gradually, as this gives the stakeholders time to adapt to the changes (Bonnel, 1995). In terms of individual measures, each measure will have a varying effect dependent on context. In general, it is advised to combine interventions where possible.

After identifying the successful interventions, 9 categories were set up concerning different strategies. Plenty of categories have been subdivided into two intervention types. Per intervention type, different measures are suggested to affect the intervention type. An overview of these categories, intervention types, and measures can be observed in Table 7. These measures provide different approaches to affect each intervention type within the intervention categories, and thus can provide different approaches to affect neighborhood characteristics if the measure and characteristic match. The 9 categories of successful interventions can further be assigned to the neighborhood characteristics, and are color coded to match the similar category in neighborhood characteristics.

4.5 STAKEHOLDERS

Over the course of these two analyses, various stakeholders were identified. It is important to state their roles and responsibilities, so that they can be accounted for when applying the interventions to the neighborhoods. The most important stakeholder is the municipality, as it does not only execute interventions, it also is the stakeholder who informs other stakeholders, and organizes further implementation steps. The stakeholders and their interrelationships are visualized in Figure 14.

In general, four main groups of stakeholders can be distinguished. There is the group of stakeholders in the form of governmental bodies. This group is concerned with the bigger picture of transitioning society to car-free mobility, driven by optimization of society, but hindered by car lobbyists. Then, there are the local planners, who mostly act as designers of plans within boundaries set by the governmental bodies. The neighborhood collectives and Trade & Service industry stakeholder groups are mostly the recipients of the implementations. These two groups are the groups that need to be convinced the measures are for the better. The most important stakeholder relationships are the relationship between municipalities and public transport providers, and the relationship between municipalities and citizens. The citizens because they are the group which has to change behavior the most, and the public transport providers because they need to be able to facilitate the behavioral change of the citizens.

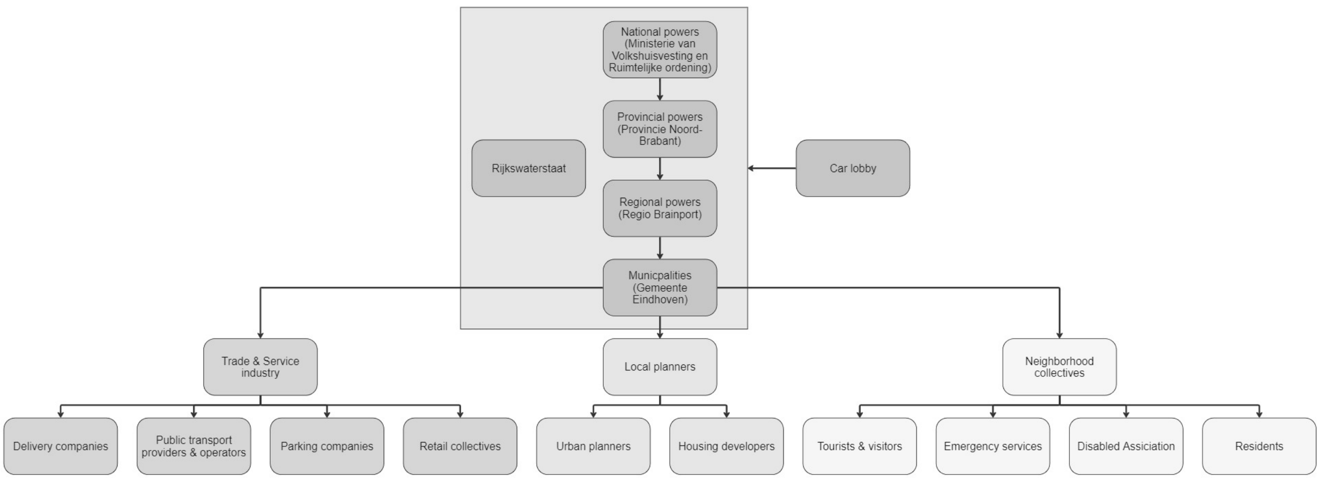


Figure 14 Stakeholder overview

Table 7 Overview of interventions, in 9 categories, original by Janssen, D. M. and adapted

Category	Intervention type	Strategy	Policy instruments	Measures
Access control	Limited traffic zones	Push & pull	• Regulatory • Public goods & Services	• Strict access control to the old towns or centers • Extension of pedestrian-only zones • Time and day-dependent access restrictions • Centre closed during shopping hours • Cycling and servicing vehicles are prohibited
Parking manage-ment	Relocate parking	Push & pull	• Regulatory • Public goods & Services • Information & Education	• Introduce carpark for long stay • Parking guidance system • Relocate on street parking to parking garages • On street parking for visitors and disabled
	Reduce parking	Push	• Regulatory • Public goods & Services	• Gradual reduction of parking spots • No provision of parking spaces in new buildings • Reduction of parking within 300m of public transport • Parking amount gradation based on location • Reduce number of parking spaces per household
Public transport system	Frequency and cost	Push & pull	• Regulatory • Public goods & Services • Economic	• Increase frequency of buses • Flattening peak hours • Free transit zones
	Routing	Push & pull	• Regulatory • Public goods & Services • Economic	• Free of charge transport to city center • Bus lines connected to car parking locations • Public transport within walking distance • Provide a direct connection to city center and central station • Public transport connections towards all suburbs • Extend network of bus lanes
	Accessible active transport infrastructure	Pull	• Public goods & Services • Economic	• Invest revenues from pricing systems in walking and cycling facilities • Regulate for maximum travel times to public transit stations for cycling and walking
Car infrastructure	Road design	Push & pull	• Regulatory • Public goods & Services • Economic • Information & Education	• Organize different sections of the road per transport mode • Stricter implementation of speed restrictions • Special surfaces to indicate type of transport • Prioritize cyclists and pedestrians • Partially remove sidewalks to create shared spaces • Prioritize the improvement of cycling infrastructure • Temporary cycling lanes to test functionality and usage
	Road network	Push	• Regulatory • Public goods & Services	• Increased use of one-way roads • Prioritizing a city ring road to divert through-traffic
Pricing system	Investments	Pull	• Regulatory • Public goods & Services • Economic	• Toll earnings are invested in public transport • Free public transport pass for employees • Free public transport pass for students • Free public transport for citizens
	Costs	Push	• Regulatory • Public goods & services • Economic	• Distance based charging • Time dependent charging • Charging for car parking spaces at workplaces • Charges based on congestion
Awareness	Personal awareness	Push & pull	• Information & Education	• Rewarding working from home • Assisting and providing travel plan advice • Creating and promoting an app for sustainable choices
	General awareness	Push & pull	• Regulatory • Information & Education	• Providing detailed and understandable information on new measures • Promotion of biking and parking in vulnerable communities • Annual events: Car free days
Subsidies	Stimulating (e-bike)use	Pull	• Economic	• Subsidies for (E-)bikes
Services	Infrastructural facilities in proximity	Pull	• Public goods & Services	• Cheap Park & Ride facilities • Offering plenty of bike storage space • Prioritizing car sharing over private cars • Providing cargo (e-)bike sharing facilities
	Land use facilities in proximity	Pull	• Public goods & Services • Information & Education	• Supermarkets within walking distance • Schools within walking distance • The availability of recreation space within walking distance • The availability of playgrounds within walking distance • Showers at work and office locations
Land use	Area development	Push & pull	• Regulatory • Public goods & Services	• The introduction of low traffic neighborhoods in dense areas

4.6 CONCLUSION

Urban density and car-free implementations are strongly related. Higher density levels make for higher success rates with implementation of the interventions. In terms of interventions, push and pull measures should always be implemented together. This is to make sure the stakeholders affected by the push method have somewhere to go, in this case the pull intervention. Only using push methods will cause resistance from stakeholders. Finally, interventions should be introduced gradually, as people do not like sudden change. Gradual change allows stakeholders to adapt.

To conclude this literature review, this brief section will start with answers to the sub questions and end with design takeaways for the remainder of this graduation project. The neighborhood characteristics found in literature were categorized and ranked on their frequency of appearance. This provided an indication to which characteristics are the most important in creating a neighborhood environment where car-free mode choice is favored. Not only does this provide an overview on which characteristics to apply interventions, it also provides a starting point to determine where to start a city strategy since an isolated car-free district hardly functions on its own. The large amount of neighborhood characteristics should be plenty of data to collect and rank neighborhoods on 'readiness' to transform to car-reduced or car-free mobility patterns.

Next to the neighborhood characteristics, the policies and interventions were summarized. This summary provides an overview of measures which can be taken to improve neighborhood conditions towards car-free transportation. In combination with the neighborhood characteristics, the interventions provide an overview where to intervene, and what should be done to intervene. This provides a strong base for the design phase of the graduation project. As far as measures go, all 9 categories provide different options to apply to different neighborhood characteristics. Since unsuccessful measures have been left out, the table of measures should contain only viable options which will result in positive change. Again, this should be done through combination of push and pull measures.

Lastly, the various stakeholders are examined. Four groups of stakeholders have been identified, with the municipality being the most prominent stakeholder. The groups fulfill different roles. It is very important that receiving stakeholders, like for instance residents or business holders, do not feel threatened because they have to change their mobility behavior. This is why, in every step of redevelopment, it should be carefully considered which parties are involved.

The combination of characteristics, measures and stakeholders can be used to form a solid (re)design during the design phase of the project. Most interesting will be finding out if the found characteristics are equally well applicable to the neighborhoods of Eindhoven, and if characteristics are found which have not been revealed in the analysis. The focal points will be transit proximity and parking spaces. Additionally, car ownership rates, accessibility to the neighborhood and diversity within the neighborhood will play the most prominent roles. To intervene in these categories, measures from all categories can be used, however some align better than others. In any case, interventions stay context dependent.

As a result of the literature review, the focal points of neighborhood characteristics are now known. To assess neighborhoods on these characteristics quantitative data of each characteristic is to be collected. After using case studies to define the desired amount of a certain category, the data of Eindhoven can be compared to the benchmarks and conclusions can be drawn. Should neighborhood characteristics come short, the measures and stakeholder analysis can provide context on improving the situation and aid in the design phase.

4.7 OUTTAKES FOR DESIGN AND PLANNING

The findings from the literature review form a foundation for recognising neighborhood typologies and what interventions to apply. Specific interventions are listed in table x, which can be used when a neighborhood needs a specific approach. For instance, a neighborhood can be examined which has adequate urban form characteristics, but is lacking in mobility characteristics. In this case, the interventions in the categories concerning mobility can be applied.

In addition to this specific approach, a synthesized set of design principles is created. The set consists of 5 principles, which can be briefly explained as follows:

1) the region functions as a whole system. Introducing changes affects the whole system. Therefore, a comprehensive system at the regional scale must be provided.

2) Within the system there is a hierarchy of transport modes. Active transport at the top, public & shared mobility second, and the car third.

3) Changes to the system should be favorable for the mobility transition, and aim to rebalance the usage of transport modes.

4) The strategy and design should aim to achieve a modal & mental

shift. To make these two shifts succeed, the strategy and design need:
- changes in parking strategy,
- a strategy to facilitate behavioral change,
- changes to infrastructure & public space.

5) The importance of mobility hubs. Mobility hubs are the key element of the mobility strategy, serving as points where users can change transport modes swiftly, and form an important pillar for urban densification.

This set of 5 principles can be observed in Figure 15. The principles serve the purpose of incorporating the conclusions of the literature review into instructions to follow during the design phase.

4.8 DISCUSSION

Reducing car use in cities is a topic gaining increasingly more attention, although literature prior to the year 2000 also already has extensive findings on car-free neighborhoods. Most articles mentioned an interaction between infrastructure and land use. In context of redeveloping and densifying Eindhoven, it is most interesting to know how urban planning can be used to influence modal choice behavior.

Since the city of Eindhoven is aiming to ambitiously densify in the foreseeable future, opting for a car-free approach might seem favorable. It is however important to know which neighborhood characteristics and measures are available, to determine the most optimal starting point. In terms of interventions, it will be valuable to see what policies and interventions are already adopted by the municipality of Eindhoven and see where they can improve or expand to increase impact.

4.9 LIMITATIONS

The recognition of the value of a car-free neighborhood is widespread in literature. However, the relationship between neighborhood characteristics and mode choice was not always present in the literature. Policy or interventions are more focused on infrastructure and land use, but information on pre-existing conditions was more difficult to find. Next, articles about electric vehicle fleets and car sharing fleets were mostly excluded. These interventions provide solutions for some problems, but in the end fail to reach the goal of a car-free neighborhood.

In the end, included neighborhood characteristics which were not encountered in literature were removed from the results table. Additionally, some characteristics had some overlap, for instance distance to services/shops and the characteristics concerning density. These findings have been kept separated if enough distinction between the characteristics remained.

By excluding based on amount of mentions in literature, some relevant topics might be excluded while the actual relevance remains unknown. An important topic might only be covered by one paper, and thus have been excluded. Similarly, more general topics can appear more often in literature and are therefore more likely to be included.

The built environment covers a great number of topics, and thus it is difficult to incorporate all topics in a literature review. It might also be possible that the articles which were found in Scopus covered similar topics, skewing the results of the analysis.

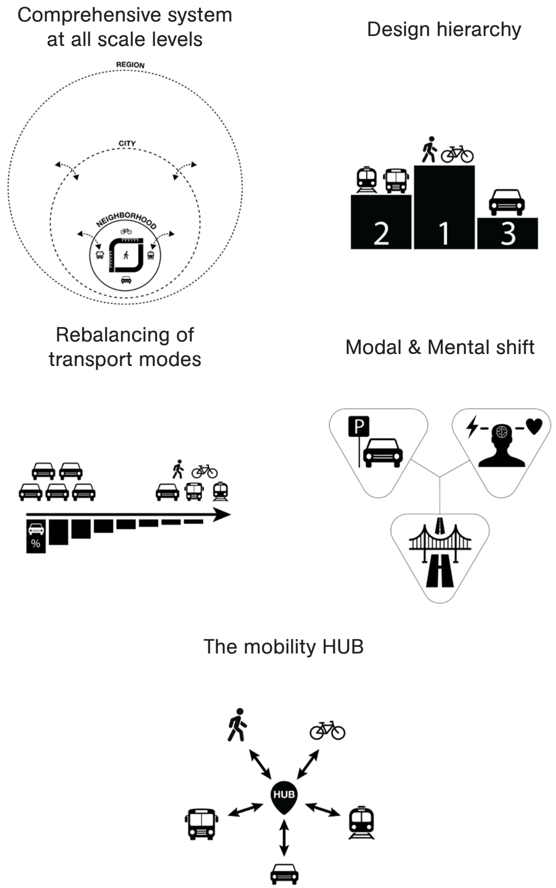


Figure 15 Design principles derived from the literature review

II

Part II:
Mapping

Mapping analysis

5.1 INDICATORS FOR ANALYSIS

This chapter covers the spatial mapping analysis of relevant topics regarding densification and car-reduced mobility, as discovered by the literature review. The mapping analysis consists of 14 indicators in total.

The indicators are categorized along the same categorization as used in the literature review; urban form, mobility and sociodemographics. By mapping these categories, a visual overview is established which provides a basis for the city scale strategy. Each category is assigned a score based on the indicators that contribute towards the category.

The scores per category are combined into a map which represents the potential of car-reduced mobility in different neighborhoods of Eindhoven. This map is a crucial contribution towards determining which neighborhoods can be further developed in the design phase of the studio. The indicators that will be mapped can be seen in Table 8.

Each indicator is assigned a weight, based on the frequency of mentions in the systematic literature review. These weights were then used to calculate the impact of each category towards car-reduced potential. The combined map depicting the car-reduced potential is used as a basis to form a city scale strategy, together with modal split, work-related car travel and neighborhood types, which have been additionally mapped.

5.2 MAPPING THE CATEGORIES

5.2.1 URBAN FORM

The most important indicators for the urban form category have been determined in the literature review. The overall urban form score was determined by the weights assigned to each indicator.

The following equation was used:

$$\text{URBAN FORM} = \frac{((FSI) + (3 * (MXI)) + (3 * (Fac.dist.)) + (Fac.tot.))}{8}$$

Table 8 Overview of mapped characteristics, matching data indicators, assigned weights and sources

Category	Characteristic	Indicator	Count	Weight	Map data source
Urban form	Neighborhood density	Floor Space Index	3	1	Rudifun
	Amount of different services and residences	Mixed Use Index	5	3	Rudifun
		Average distance to amenities	5	3	Eindhoven in cijfers
	Total amount of services	Total amenities	3	1	OpenStreetMap
Sociodemographic	Age	Young people population share	4	2	Eindhoven in cijfers
Mobility	Amount of parking spaces	Parking place coverage	8	6	Eindhoven open data & OpenStreetMap
	Parking norms	Parking norm	5	3	Parkeernota Eindhoven
	Parking costs	Parking costs	3	1	Eindhoven in cijfers & Eindhoven open data
	Fuel & Charging stations	Distance to fuel station	3	1	Eindhoven open data & OpenStreetMap
		Charging station capacity	3	1	Eindhoven open data & OpenStreetMap
	Neighborhood accessibility from outside	Perceived accessibility	5	3	Eindhoven in cijfers
	Public transport proximity	Distance to train station	8	6	Eindhoven in cijfers & OpenStreetMap
		Distance to bus stop	8	6	Eindhoven in cijfers & OpenStreetMap
	Car ownership rates	Cars per household	5	3	Eindhoven in cijfers

5.2.2 FLOOR SPACE INDEX

The first indicator concerns floor space index (FSI). The FSI is an indicator of density. It is calculated by using the plot ratio and multiplying it with the amount of floors in a building. Buildings with multiple floors contribute to a higher FSI, whereas single-family houses with gardens cause lower FSI scores. According to the 'carfree design manual', author J.H. Crawford recommends a FSI of 1.5 for the optimal conditions of car-reduced design (Crawford, 2009, p108).

In Eindhoven, only a small selection of neighborhoods comes close to this FSI. The neighborhoods in the center, as well as Strijp-S score adequately, while the other neighborhoods have a FSI that is lower. This indicates a lot of opportunities for densification, while simultaneously indicating lower car-reduced potential.

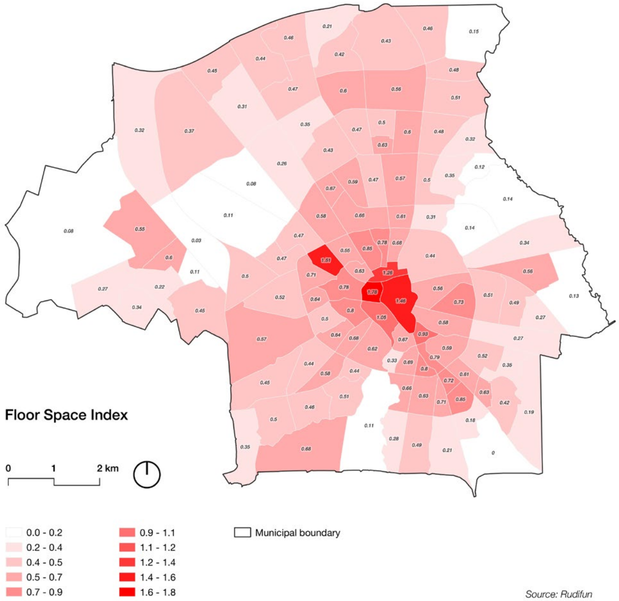


Figure 16 Floor Space Index per neighborhood

5.2.3 MIXED USE INDEX

Next is the mixed use index (MXI). The MXI is a way to indicate the mixture of functions of buildings in an area. The MXI in the Rudifun dataset is calculated by dividing the floor area of buildings with the function of living by the total floor area of the building. Singh and Hachem-Vermette (2019) state that an optimal share of commercial functions in a mixed use neighborhood ranges between 22% and 32% (Hachem-Vermette & Singh, 2019).

Using this ratio leads to a residential share ranging between 68% and 78%. Because of this, the optimal MXI in the Rudifun dataset are the values closest to 0.73. Neighborhoods with a MXI close to 0.73 have a higher potential to become car-reduced.

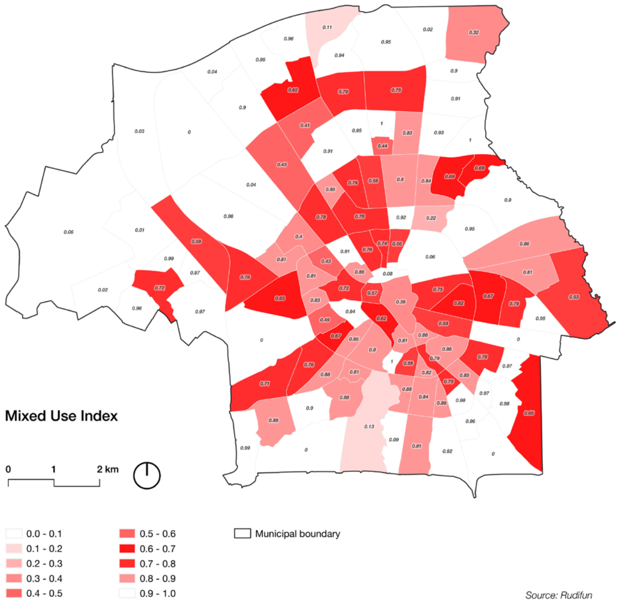


Figure 17 Mixed Use Index per neighborhood

5.2.4 AVERAGE DISTANCE TO FACILITIES

A lower distance to facilities causes civilians to have lower average mobility requirements. When mobility demand is lower, transport modes other than the automobile become more attractive. Thus, the neighborhoods where the average distance to facilities is lowest, score the highest on car-reduced potential.

To calculate the average distance to facilities, data from Eindhoven in Cijfers was used. The data included the average distance (in km) to 14 different amenity types per neighborhood. By calculating the average distance of these 14 types, a neighborhood classification was made with results between 0.84km and 2.44km.

The included facility types are: Pharmacy, Primary school, Library, Cinema, Extracurricular care, Café, Snackbar, Supermarket, Daycare, Museum, Restaurant, High school, Hospital, and Swimming pool.

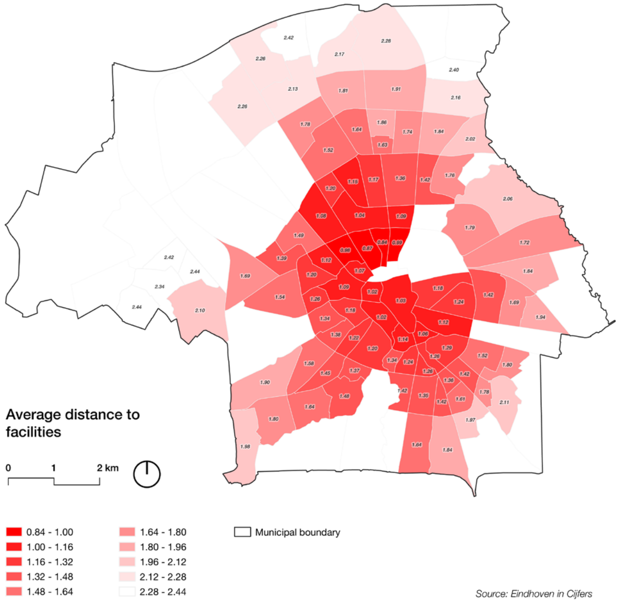


Figure 18 Average distance to facilities per neighborhood

5.2.5 TOTAL FACILITIES PER NEIGHBORHOOD

In addition to the average distance to facilities, it is also valuable to know the total amount of facilities per neighborhood. A higher amount of facilities usually provides larger variety of facilities, and reduces average distances even further. The higher the total amount of facilities, the lower the distance inhabitants have to travel to said facility type.

A high amount of facilities also indicates facility clusters, where a large variety of facilities can usually be found. The total facilities per neighborhood were summed up, the results can be seen in Figure 19.

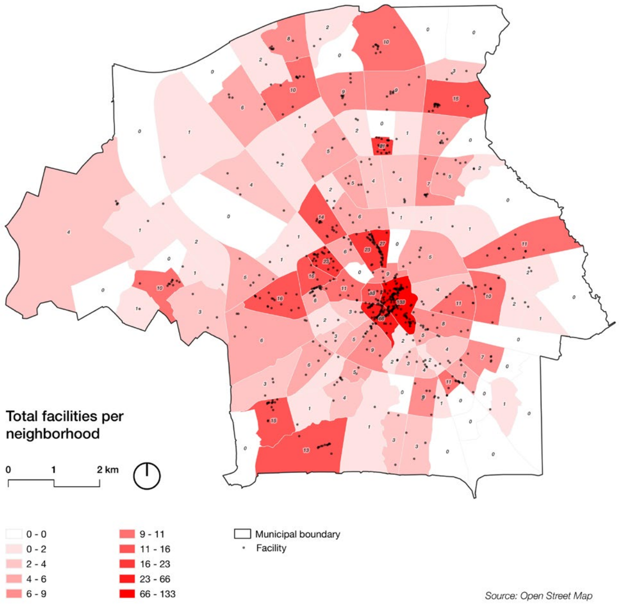


Figure 19 Total facilities per neighborhood

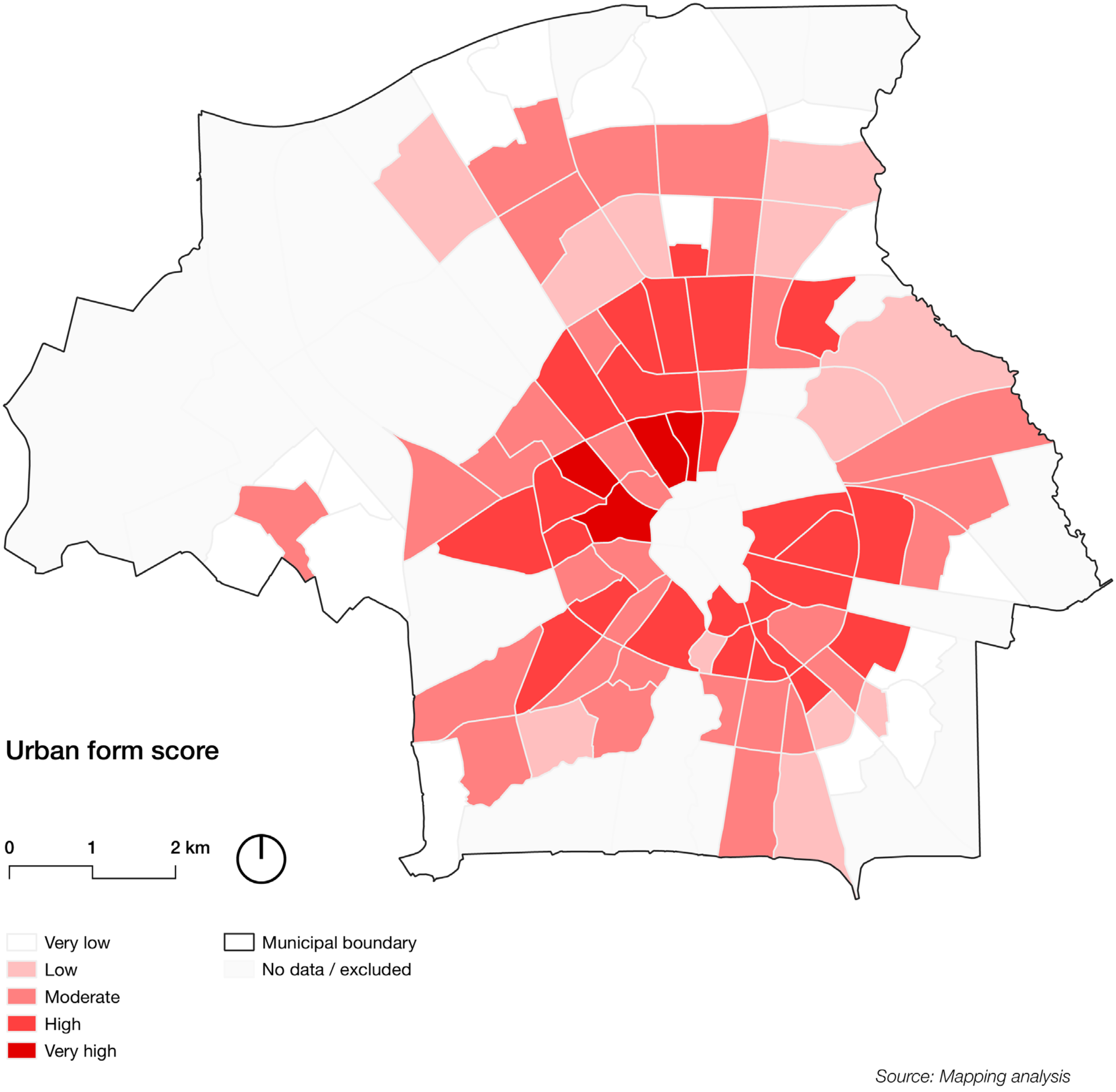


Figure 20 Urban form score per neighborhood

5.2.6 SOCIODEMOGRAPHICS

Within the sociodemographics category, only one indicator was found to be relevant in the literature review. This indicator concerns the age distribution of young people across the city. To enrich the sociodemographical overview, the student and elderly distribution has also been mapped. These two groups of people are the strongest beneficiaries of car-reduced neighborhoods, and can be seen in Figures 22 & 23.

6.2.7 POPULATION SHARE AGED 18 TO 30 YEARS OLD

Citizens of all ages should be able to travel in a city, and also in a car-reduced city. However, younger people are at lower risk of impaired movement. Additionally, young adults raising children are known to favor car-free development. Car-free neighborhoods are favorable places to raise children. Considering age groups, young families are most likely to favor living in a car-free neighborhood.

If age groups corresponding with young families are overrepresented, this positively impacts car-free mode choice. This makes the best target group people of younger ages (Melia, 2014; Nobis, 2003; Vande Walle et al., 2004). The population share of people aged between 18 and 30 years old was mapped, where the neighborhoods with the highest shares have the highest potential for car-reduced mobility.

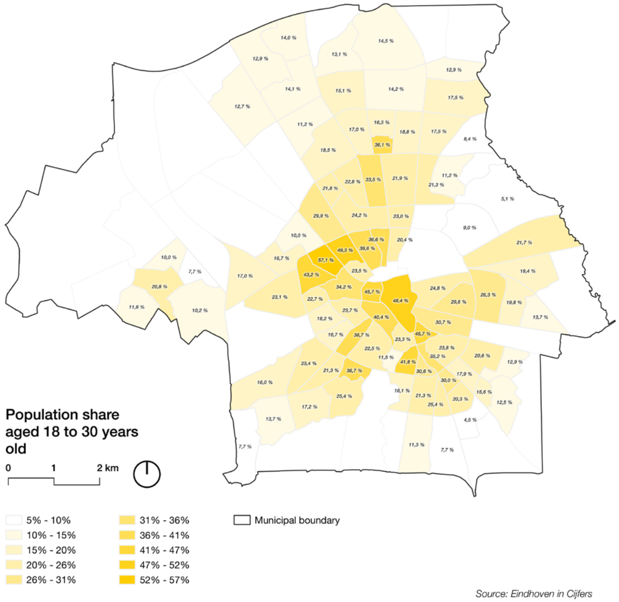


Figure 21 Population share aged 18 to 30 years old per neighborhood

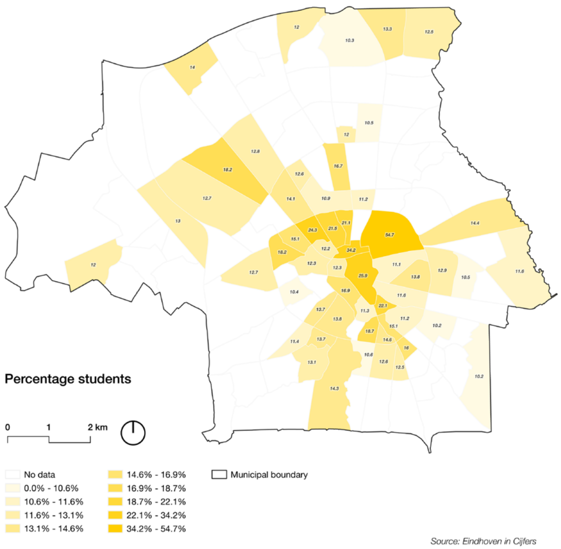


Figure 22 Percentage of population ‘students‘ per neighborhood

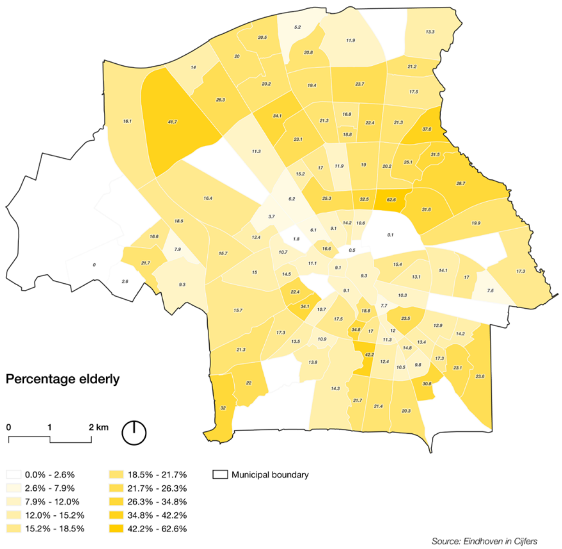


Figure 23 Percentage of population ‘elderly‘ per neighborhood

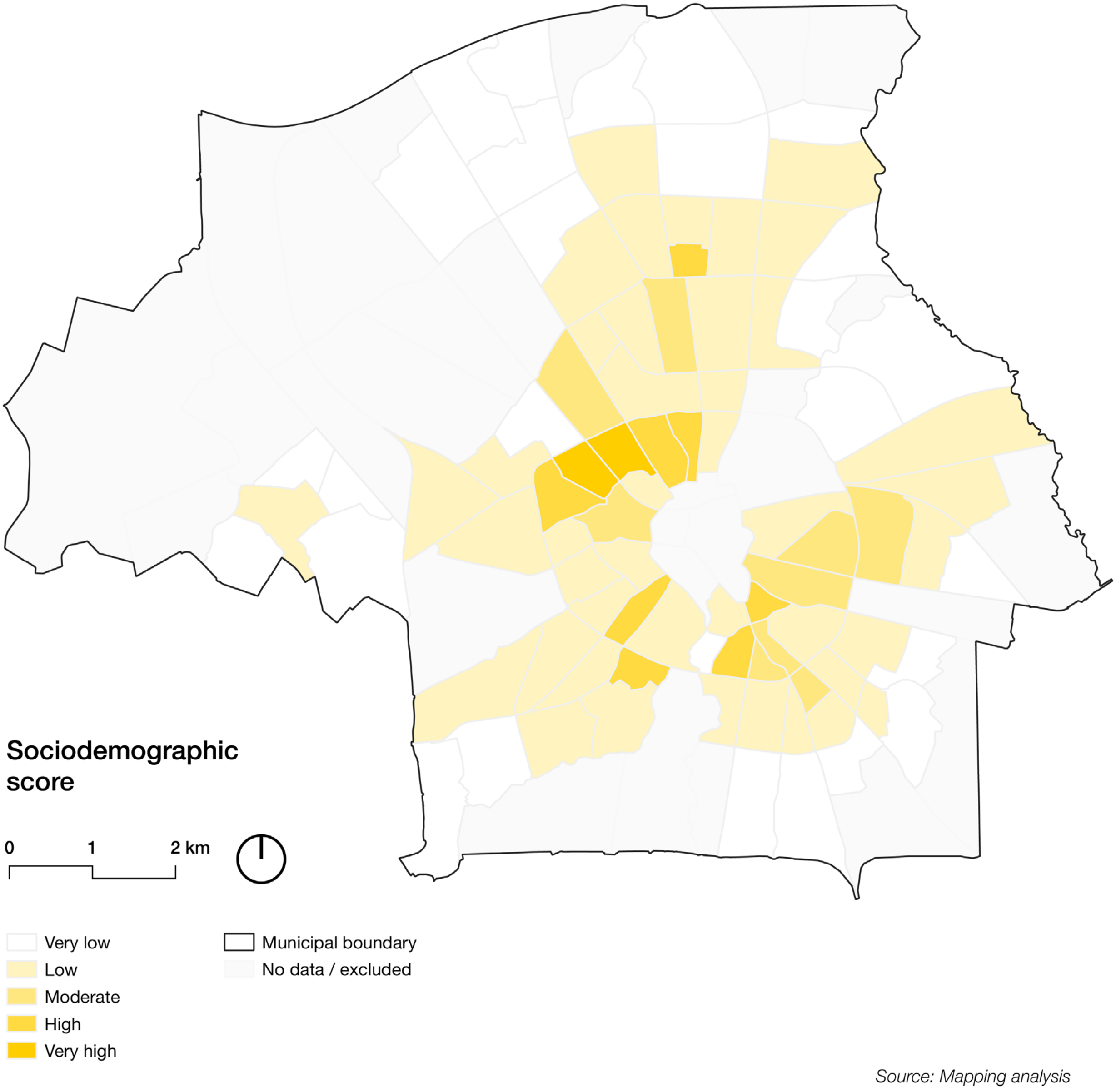


Figure 24 Sociodemographic score per neighborhood

5.2.8 MOBILITY

Once again, the literature review was used to determine the most important indicators for the transportation category. The transportation category covers a lot of indicators, ranging from parking to public transport proximity. The overall transportation score was determined by the weights assigned to each indicator.

The following equation was used:

$$\mathbf{MOBILITY} = \frac{\begin{array}{c}((6*(Park.Cov))+(3*(Park.Norm))+(Park.Cost)\\ +(Dist.Fuel)+(Charging)+(3*(Access))\\ +(6*(Dist.train))+(6*(Dist.bus))+(3*(cars))\end{array}}{30}$$

5.2.9 PERCENTAGE PARKING COVERAGE

While neighborhood characteristics connected to density play an important role in determining the highest car-reduced potential in neighborhoods, characteristics connected to mobility play an equally important role. Starting off with parking, perhaps the most important characteristic. Neighborhoods are covered in parking, and each neighborhood has a percentage of area which is assigned to parking. The higher this percentage, the more parking is available. High parking availability attracts car use, but on the other hand, also offers more opportunities to densify once parking is no longer in high demand.

Another issue are parking garages, in essence layered areas of parking. Parking garages attract more car traffic per area unit than ground parking. Additionally, parking garages are not easy to transform to other functions, and are often massive structures. The location of these public parking garages is thus very important.

The parking area percentage is calculated by dividing the area of parking by the total area of the neighborhood. High percentages can be found in neighborhoods Winkelcentrum Woensel and Fellenoord. The high amount of parking garages in the city center, and on the High Tech Campus also indicates the dominant role of the car in these two areas of the city.

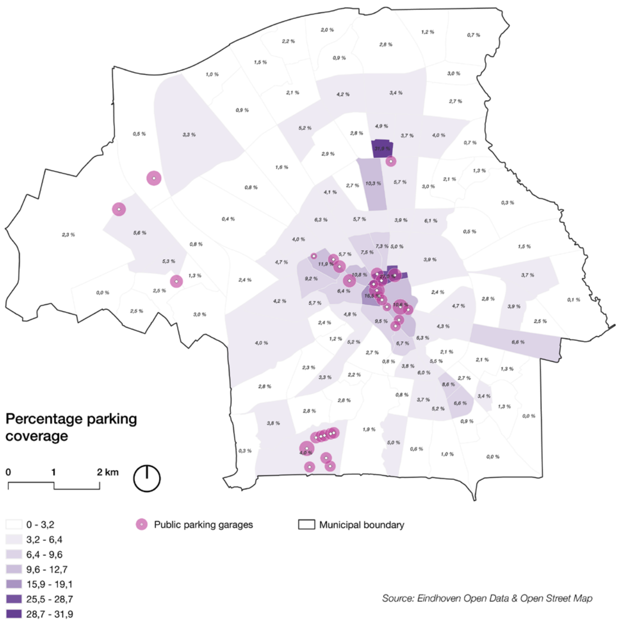


Figure 25 Percentage parking coverage per neighborhood

5.2.10 PARKING NORM

Continuing with parking, the parking norm is a good indicator for determining the amount of parking is deemed necessary in a neighborhood. However, the parking norm is also restricting car-reduced development. Developers are often required to add parking to a development, depending on the location of the development. Additionally, the parking added is often free of charge for inhabitants, automatically pushing people towards car ownership.

A stricter parking norm has a positive effect on car-reduced mode choice, since this will lower the parking place total. A simple change in parking norms would be to change the minimum parking area to a maximum (Klementschitz et al., 2007). The parking norms of Eindhoven can be observed in Figure 26.

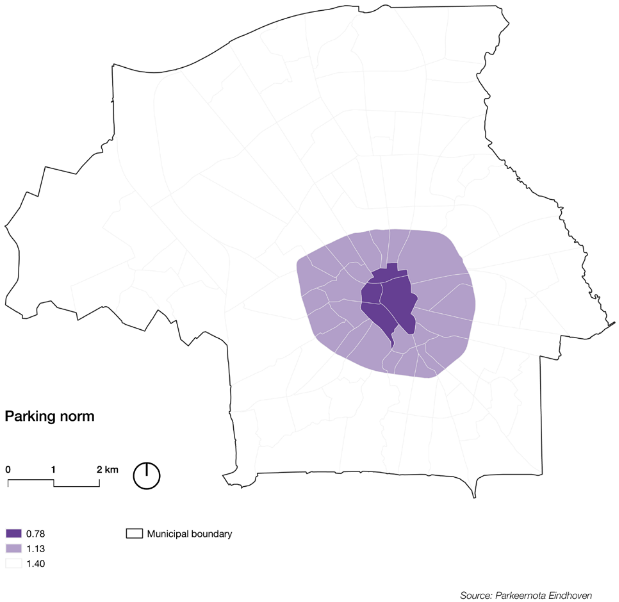


Figure 26 Parking norms per neighborhood

5.2.11 PARKING TARIFFS

There is more to parking than area coverage and norms. Parking costs also play an important role. In general, the higher the cost, the less attractive the parking spot is (Selzer, 2021). The approach by the municipality of Eindhoven is to remove free parking from the area within the ring road. There are however still locations within the ring road where free parking is possible. This map shows the neighborhoods where paying for parking is to be expected. This does not guarantee that only paid parking is available. The location of parking meters is also added to the map, with the dots scaled to the price paid at the meter. The parking price in Eindhoven is between 60 cents per hour, and 19 euros and 80 cents per hour. A sidenote is that this high tariff is paid for per day, and is there to limit short term parking.

Raising parking costs reduces the amount of people visiting by car, and as can be seen from the map, there are still a lot of opportunities for raising parking costs, or expand paid parking zones. The zones with paid parking contribute to a more favorable environment for car-reduced mobility.

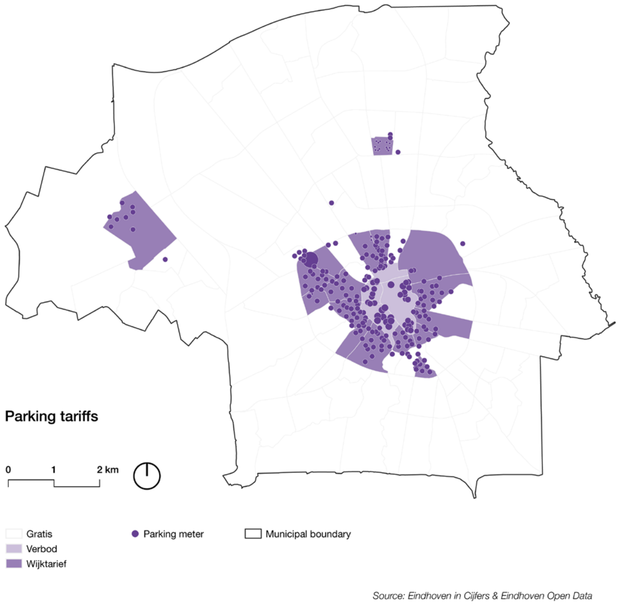


Figure 27 Parking tariffs per neighborhood

5.2.12 AVERAGE DISTANCE TO FUEL STATIONS

Locations to fuel a car attract car use. More people are tempted to use the car if fueling it is convenient. The locations of fuel stations in Eindhoven has been mapped, as well as the average distance towards a fuel station. Neighborhoods score higher when there is a larger distance to fuel stations.

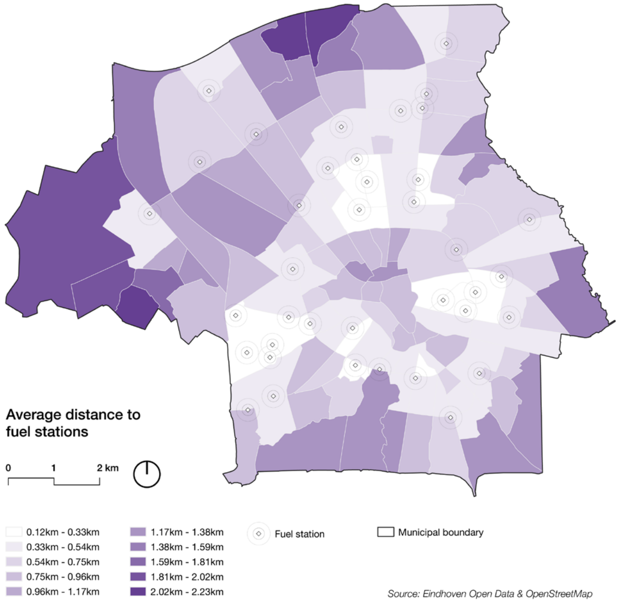


Figure 28 Average distance to fuel stations per neighborhood

5.2.13 CHARGING STATION CAPACITY

Similar to fuel stations, charging stations attract car use. The division of charging stations has spread out rapidly over the last years. Charging stations act as small fuel stations for electric vehicles. The larger the amount of charging stations in a neighborhood, the worse it scores for car-reduced mobility. All charging locations have been mapped, as well as charging hotspots with larger capacity. Neighborhoods without car charging capacity score highest for car-reduced development.

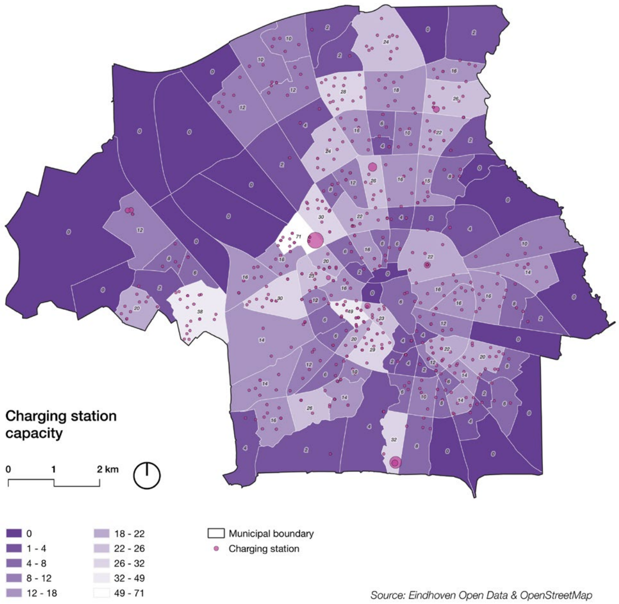


Figure 29 Charging station capacity per neighborhood

5.2.14 PERCEIVED NEIGHBORHOOD ACCESIBILITY

Measuring accessibility is not simple, as it is a concept depending on many factors. Researching the factors that contribute to accessibility per transport mode requires a dedicated research. An alternative way of researching accessibility is to do a survey. The municipality of Eindhoven has data regarding accessibility, it is based on survey results. In this survey, the respondents were asked to assign a score to the accessibility of the city center, per transport mode, as seen from their neighborhood. The respondents were able to differentiate between car, bus and bike. An average of the three transport modes is used to determine the accessibility of the neighborhoods. The results are visible in Figure 30.

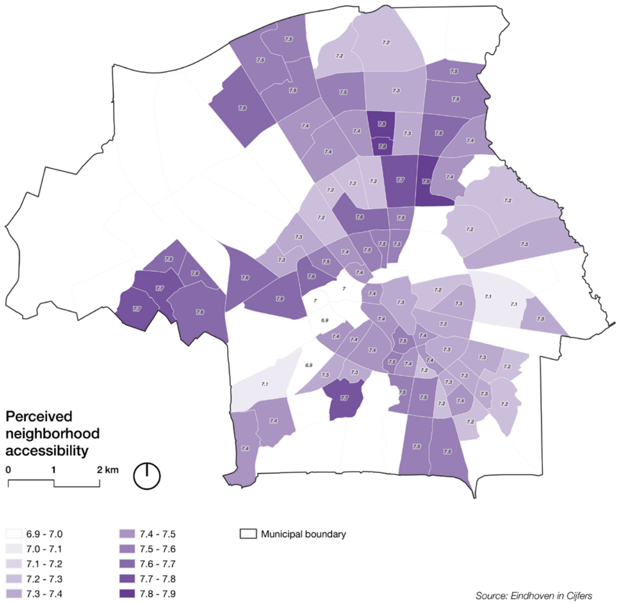


Figure 30 Perceived neighborhood accessibility per neighborhood

5.2.15 DISTANCE TO TRAIN STATIONS

The next category concerns the average distance to a train station. The distance to a train station is also a contributing factor to the feasibility of public transport of a neighborhood. Public transport can be a solid alternative to car use, but the further it is away, the worse it is for car-reduced development. Public transport should be convenient to use, and proximity is a part of convenience. Especially trains can be used to travel further distances to compete with car use. Neighborhoods that are further away from train stations score worse in this category.

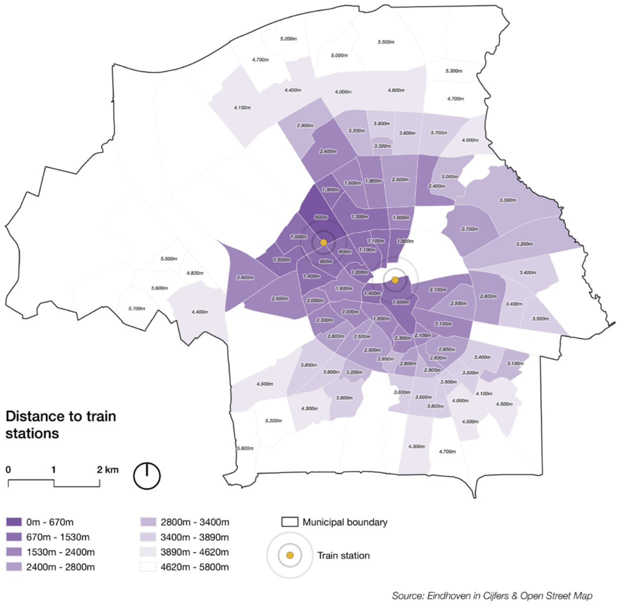


Figure 31 Average distance to train stations per neighborhood

5.2.16 DISTANCE TO BUS STOPS

Distance to bus stops is very similar to distance to train stations. Their importance is based on similar logic, closer proximity of public transport reduces the barrier of using public transport. Bus stops are perhaps more important than train stations within the boundaries of the city, since they are used to travel mostly within the city, whereas train stations are mostly used to travel to other places outside the city. Nevertheless, both train stations and bus stops are part of the public transport network and should be regarded important for improving car-reduced conditions.

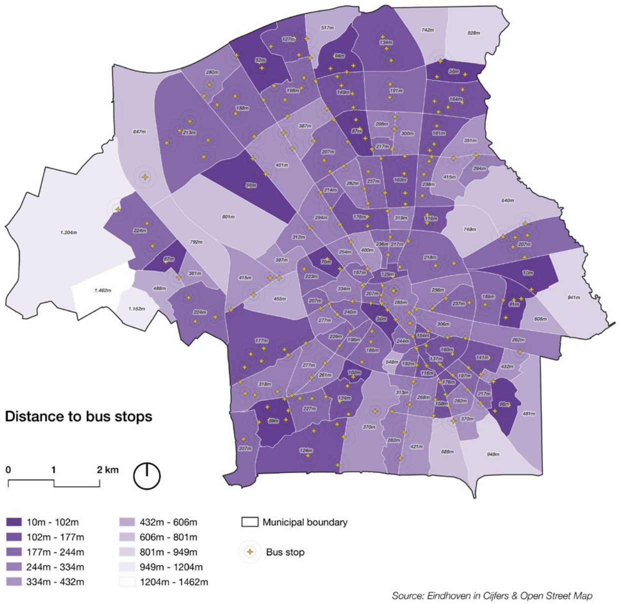


Figure 32 Average distance to bus stops per neighborhood

5.2.17 AVERAGE CARS PER HOUSEHOLD

The last category to contribute to the car-free degree are the cars per household. A lower rate of car ownership usually indicates that the area is well-suited for alternative modes of transportation, whereas a high level of car ownership usually means convenient car use. A higher rate of car ownership can also be the result of economic prosperity, or have other causes (Selzer, 2021). Higher car ownership rates are awarded a lower score, as neighborhoods with a high amount of car ownership has lower potential to become car-reduced.

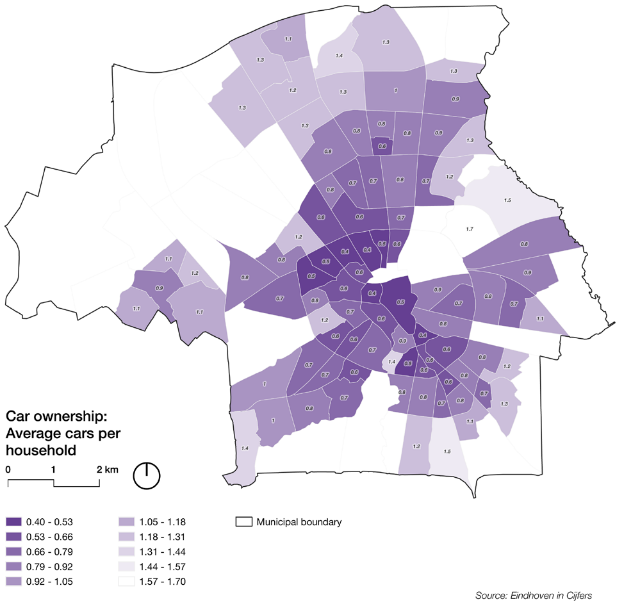


Figure 33 Average car ownership per household per neighborhood

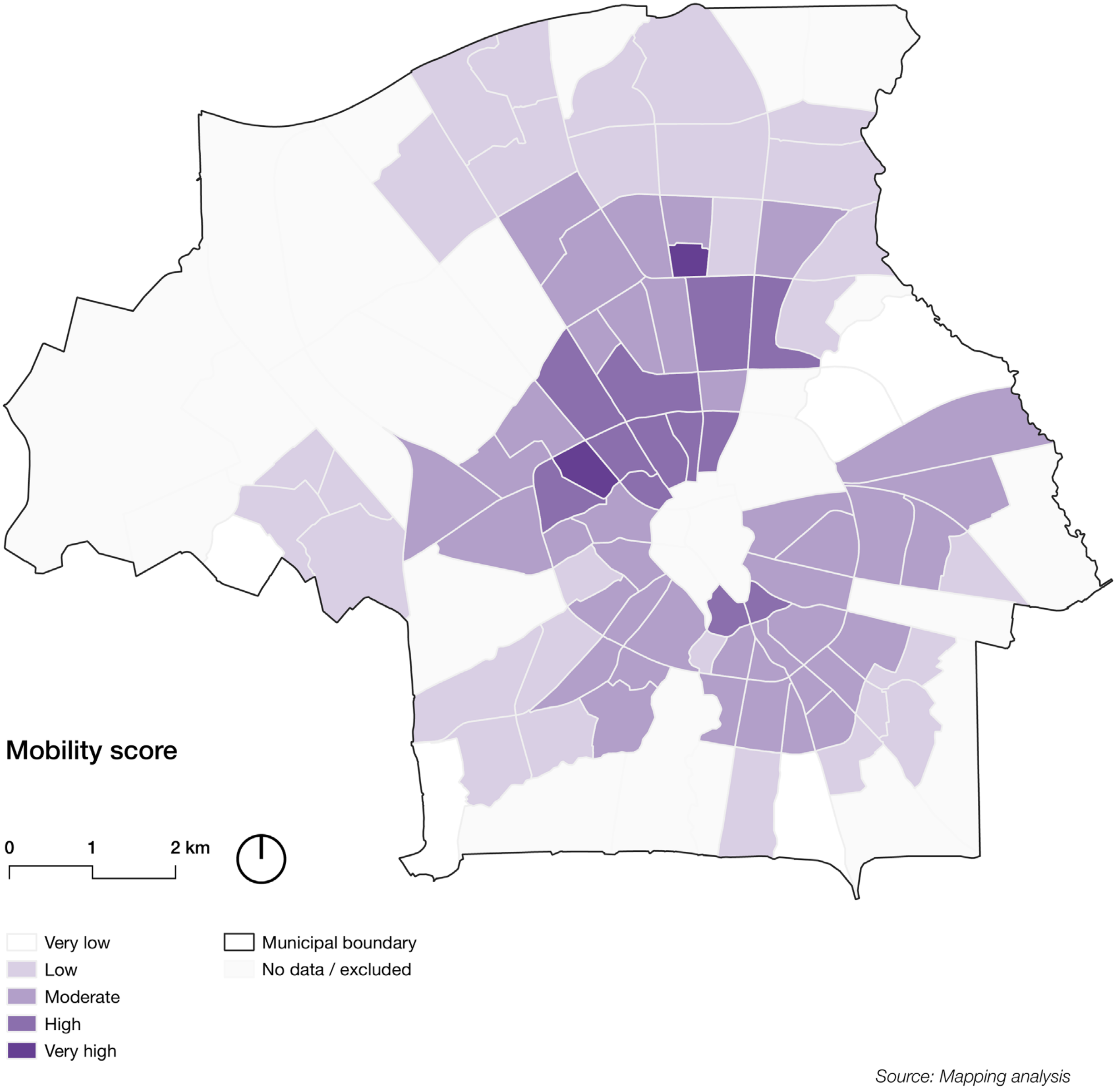


Figure 34 Mobility score per neighborhood

5.2.18 CAR-REDUCED POTENTIAL

After all indicators have been explored, it is time to combine them together and determine what neighborhoods have the highest potential to transform towards a car-reduced mobility system.

The results of the previous section of the mapping analysis are combined in the following way: the scores for urban form, sociodemographic and transportation are multiplied by their respective covered indicators and added up. This total is then divided by the total amount of indicators covered. Lastly, the result is normalized and visualized in Figure 36.

The city center and less populous neighborhoods were excluded with different reasons. Some neighborhoods were excluded because of a lack of data, mostly influenced by low population amounts. This is unfortunate for neighborhoods like Fellenoord, which had high potential for car-reduced development in the categories for which there is data. Additionally, the neighborhoods in the city center were excluded, since the results were skewed too much if they had been included. The city center is expected to be the area best suited for car-reduced development, since it has the optimal conditions in nearly all categories. It is more valuable to know what needs to be done in the surrounding neighborhoods, which do not always have the most favorable conditions.

The first conclusions to be drawn from the car-reduced potential map include the high potential of old Woensel, including the northern part of old Strijp and Strijp-S. These neighborhoods form a strong stretch along the ring road in the north of the center of Eindhoven. All these neighborhoods score very strong in at least one of the categories.

Other positive outliers include the central north part of Eindhoven, towards the shopping mall Woensxl. Additionally, most positive neighborhoods are located within the city ring road, with a very high scoring neighborhood in old Stratum, Rochusbuurt.

Even with excluding the city center, the neighborhoods within the city ring score higher on average.

$$\text{CAR-REDUCED POTENTIAL} = \frac{(4*(URBANFORM)) + (2*(SOCIO)) + (9*(MOBILITY))}{14}$$

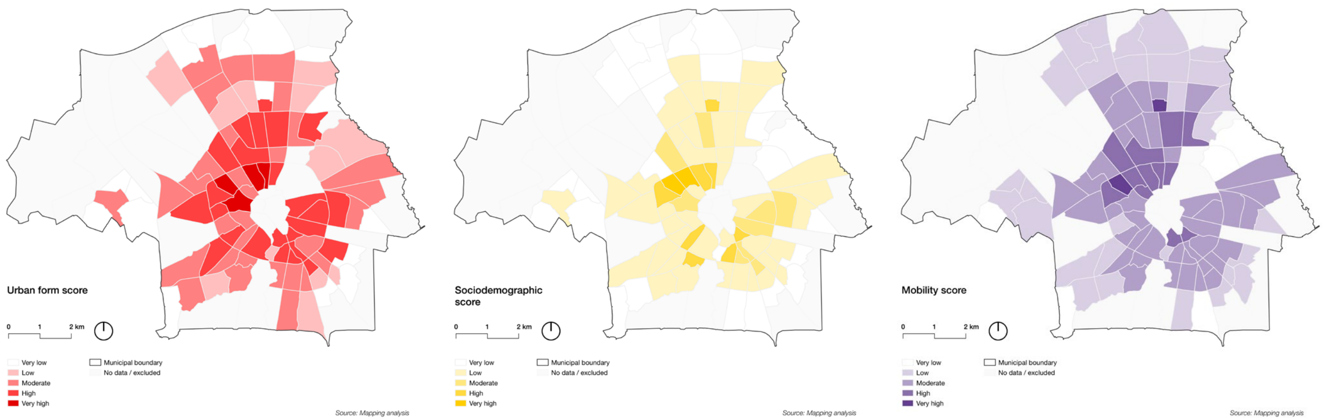


Figure 35 Overview of the three scores per neighborhood

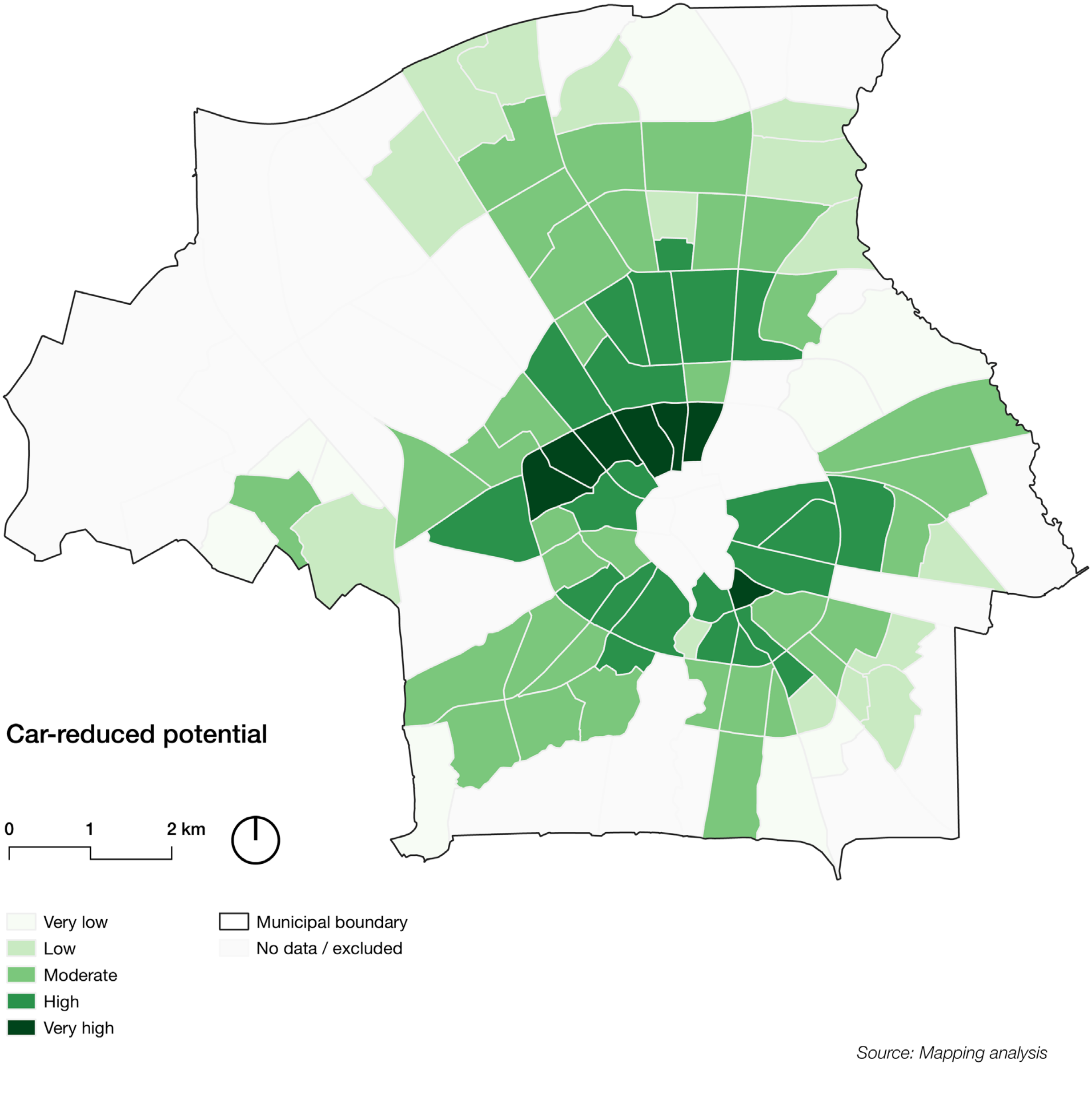


Figure 36 Car-reduced potential per neighborhood

5.3 CRITERIA FOR SELECTING NEIGHBORHOODS

In the remaining section of the mapping analysis, the results of the car-reduced potential map are compared to other relevant data. This is done to determine what neighborhoods are chosen for the following part of this research.

The car-reduced potential map is compared to the modal split per neighborhood, the various neighborhood typologies, and lastly the work-related travel patterns from surrounding municipalities.

Table 9 provides an overview of the influence the criteria have in deciding the neighborhoods to (re-)develop, including sources.

Table 9 Criteria for selecting intervention neighborhoods

Criteria influence	Mapped topic	Source
The neighborhood needs to have an adequate score on car-reduced potential. Different potential scores will require different interventions.	Car-free degree	Mapping analysis
Mismatches between modal split and car-reduced potential are explored, a higher mismatch provides an interesting challenge.	Modal split	Eindhoven in Cijfers
Different neighborhood typologies require different approaches.	Neighborhood typologies	Klimaateffectatlas
A high volume of work related travel poses higher challenges for neigborhoods.	Work-related travel patterns	Urban Labs TU/e

5.3.1 MODAL SPLIT

To check whether the car-reduced potential of a neighborhood aligns with the mobility behavior of the inhabitants of a neighborhood, it is valuable to take a look at the modal split per neighborhood. The modal split contains transport mode data expressed in percentages of total trips. Neighborhoods with a higher share for car use, while having favorable conditions for a car-reduced mobility system need further evaluation. The same is true for the other way round, neighborhoods with lower share of car use, while having unfavorable conditions for car-reduced mobility systems.

In the modal split map, a small pie chart is provided per neighborhood showing the individual splits of the different considered transport modes. The modes include driving, using public transport, biking and walking. To make distinction between neighborhoods simple, the neighborhoods are assigned a color, where a darker color corresponds with a higher share of alternative modes to driving. Thus, the darkest neighborhoods have the lowest share of driving.

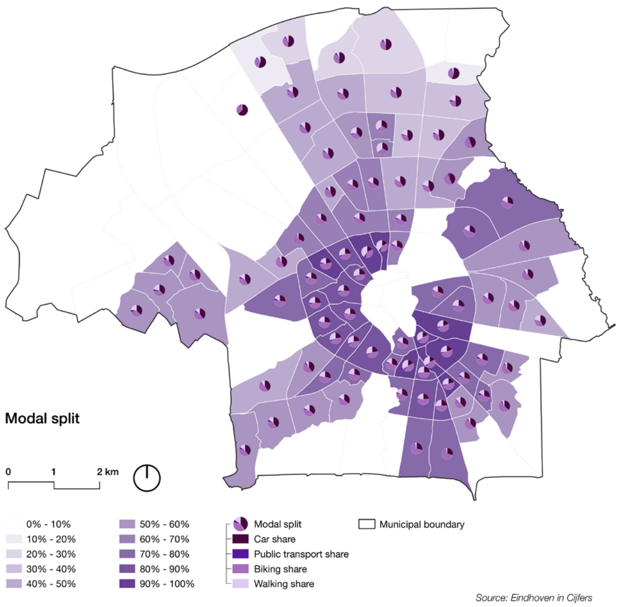


Figure 37 Modal split per neighborhood

5.3.2 NEIGHBORHOOD TYPOLOGIES

The neighborhood type map describes what types of neighborhoods there are, and how they are scattered around in Eindhoven. Different neighborhood types usually correspond to different times of construction, and the corresponding urban zeitgeist. Denser neighborhood types can provide more opportunities for car-reduced mobility. It can also be valuable to find correlations between neighborhood types, modal splits and car-free potential.

The map makes a distinction between 15 different neighborhood types at a level more detailed than neighborhoods. A high level of detail is chosen, since taking average values would remove a significant neighborhood type in case of a near 50-50 type split. In this way, a neighborhood can consist of multiple types.

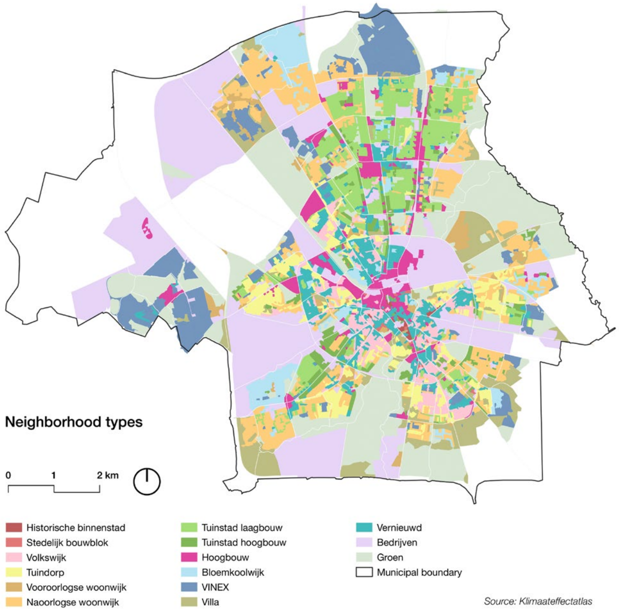


Figure 38 Neighborhood typologies

5.3.3 WORK-RELATED TRAVEL PATTERNS

The previous categories provide information of the system within the city. This is very useful, but it should not be forgotten there are a lot of people who do not live within the city, but have to reach the city regarless. People visit the city for many different reasons, a prominent reason is work. In a 2022 publication of Urban Labs, in collaboration with various neighboring municipalities, the travel patterns of people to and from the city of Eindhoven has been researched.

The city can achieve higher levels of density and mixture of functions compared to the surrounding villages. Public transport towards the city is also of lesser frequency, therefore car use is more practical. This means there is a high chance that the people visiting the city will continue to do so by car.

As can be seen in Figure 39, the largest amount of travelers uses the south-eastern part of the highway system, as this combines the travelers of three different municipalities. The amount of people entering the city from the south is also high, as this is a combination of three municipalities as well. The main stress is concentrated in the south of the city, and the city strategy should be formed in correspondence with this issue.

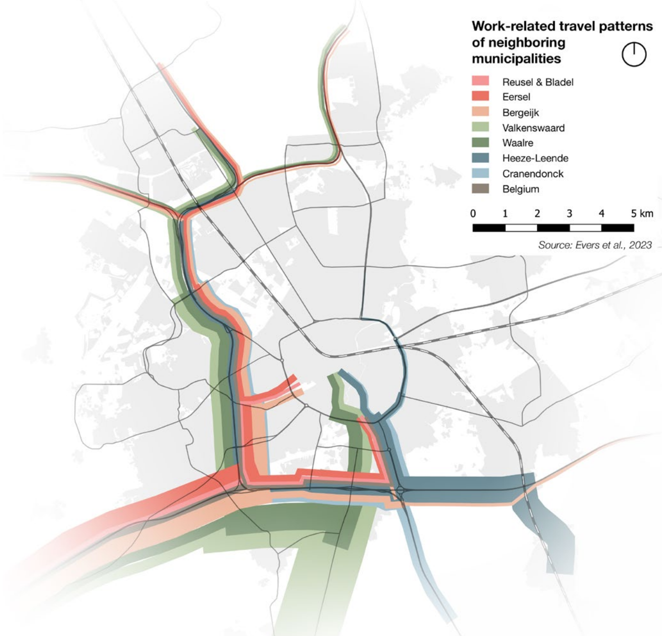


Figure 39 Work-related travel patterns

5.4 CONCLUSION & SELECTED NEIGHBORHOODS

After comparing the car-reduced potential to the maps of the modal split per neighborhood, the neighborhood typologies and the work-related travel patterns, several conclusions can be drawn. Firstly, the neighborhood typology “Hoogbouw“, together with the “Volkswijk“ typology are the most favorable typologies for car-reduced densification. Moderate potential can be found in the typologies “Tuinstad“, “Tuindorp“ and “Bloemkoolwijk“. The “VINEX“ and “Villa“ typologies are the worst for car-reduced potential. The remaining typologies show varying, sub-optimal results.

In terms of comparing modal split and the results of the car-reduced potential, a general overlap can be recognized, but there are some outliers. The highest discrepancies can be found in the south-eastern part of the city, especially in “Oud stratum“ neighborhoods. Other outliers appear mostly at the edges of the city, this can be explained by the functioning of other municipalities that could influence these neighborhoods.

In terms of work related travel patterns, the most challenges appear in the southern and western parts of the city. This can be explained by the presence of the many highway ramps and intersections in this part of the city. There are also large points of attraction in this area of the city, with the High Tech Campus and the ASML campus as important nodes. In conclusion, this forms a challenge for the neighborhoods in close proximity to these highway ramps.

In line with the conclusions and densification potential, a neighborhood is chosen to redevelop in the design phase of the project. The selection procedure is not a subtraction of all illegible locations. Instead, wider context is regarded in combiation with the findings of this chapter.

As becomes evident from the work-related travel patterns, inner city neighborhoods and outer city neighborhoods require a different approach. To limit the scope of this project, only neighborhoods within the inner city are chosen. This is in line with the highest car-reduced potential.

The neighborhood that was chosen is the neighborhood “Woenselse Watermolen“, in combination with “Gildebuurt“, both are llocated just north of the city center, as can be observed in Figure 40, and in Figure 41 on the next page. The neighborhoods are located next to eachother and can be regarded as one bigger neighborhood.

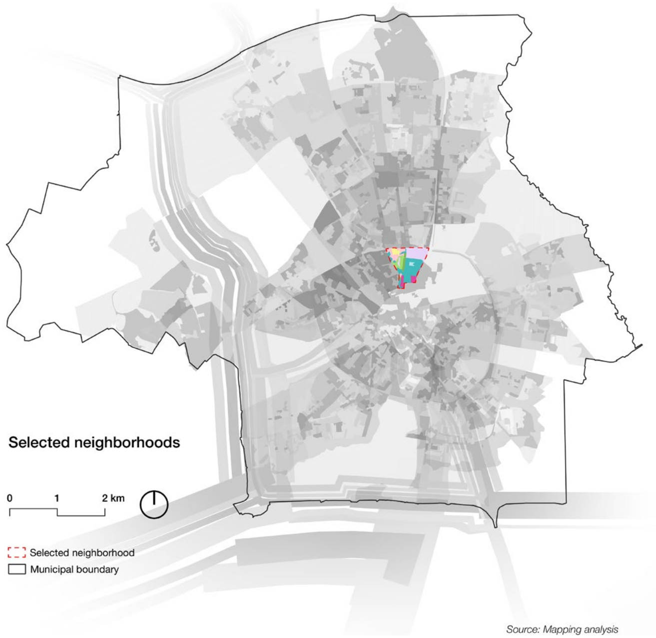


Figure 40 Selected neighborhoods

Woenselse Watermolen scores high on car-reduced potential. However, a below-average sociodemographic score can be observed. This indicates even higher potential if the right sociodemographic conditions can arise. In terms of urban form and transportation, the neighborhood scores very high. Further remarkable characteristics of the neighborhood are a low FSI and the complete lack of amenities. This can however be alleviated by the close proximity of the city center and the Woenselse markt.

The barrier to the Woenselse markt is the Gildebuurt. Combining both neighborhoods into one redevelopment project can potentially strenghten both neighborhoods. The Gildebuurt scores moderately high in all categories, making it a good candidate by default.

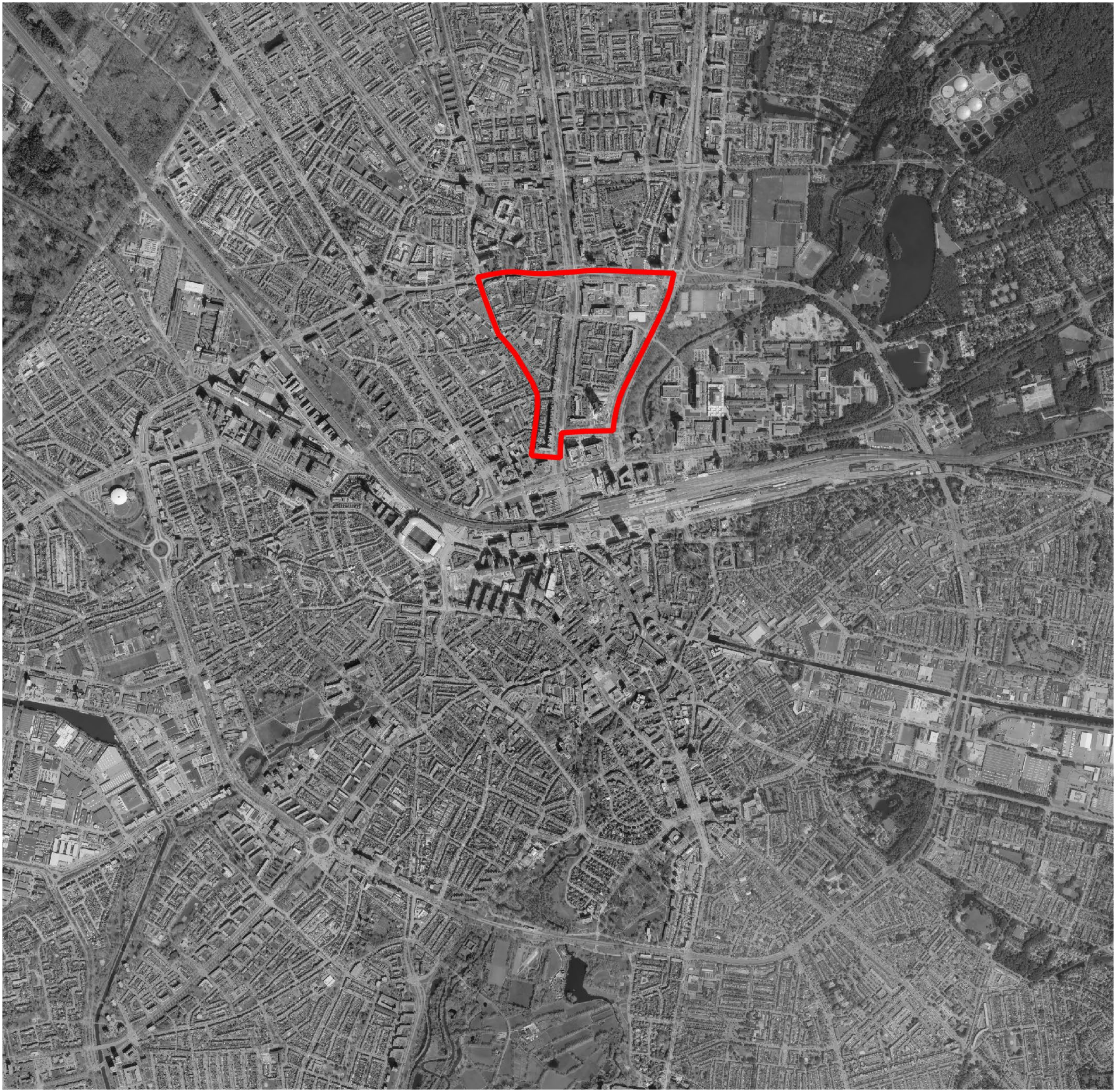


Figure 41 Aerial picture with selected neighborhoods highlighted (Google Earth, 2023)

III

Part III:
Design

Introduction

In the first part of the project, a series of neighborhood characteristics was defined, which applies to a car-reduced mobility system within a densifying city. The characteristics were split into three different categories; urban form, sociodemographic, and mobility. This paper covers the case study of the city of Eindhoven. Therefore, a spatial analysis was conducted, with the purpose of determining the areas in which the contemporary situation could be improved. The area which was chosen is the combined area of Woenselse Watermolen and the Gildebuurt neighborhoods.

The following part of this paper elaborates on the proposed strategy of the city. In the city of the future, the car plays a role of lower significance. With lower reliance on cars, the city can open up and find space to densify. Further increases in density can further reduce the need to rely on a car for everyday tasks.

This chapter contains the design phase of the project, and starts off with a city scale strategy, focusing on densification in combination with the challenges of a car-reduced city. The strategy will be followed by neighborhood design. The redevelopment of this neighborhood is focused on taking advantage of the pre-existing conditions regarding urban form and transportation, while simultaneously attempting to improve the sociodemographic aspects of the neighborhood.

City scale strategy

The literature review and spatial analysis have resulted in a set of neighborhood characteristics, a set of interventions, and a set of locations with potential to intervene and introduce a car-reduced mobility system. The neighborhood characteristics were subdivided into three categories:

- Urban form
- Sociodemographic
- Transportation

In terms of interventions found, some are scale level specific, while some interventions can be applied across many scale levels. Since the topic of this graduation project is strongly connected to mobility, the system in the entire region has to be respected. This refers back to the first design principle established at the end of the research phase.

To provide a strategy covering the entire region, a regional scale strategy was formed, which precedes the city scale strategy. After the regional scale strategy, the city scale strategy will follow, which aligns with the regional scale strategy.

The city scale strategy is split into two parts, specificly the parts of densification and mobility. The neighborhood characteristics that appear under the category of transportation are met with interventions in the mobility section, while the neighborhood characteristics under urban form and sociodemographic are mostly met with interventions in the density section.

The city strategy is mainly focused on the following topics:

1. Creating a base for intervening on neighborhood level, where eventual interventions will have effect on the entire system, up to regional scale level.
2. Respecting the hierarchy of transport modes established in the conclusion of principles of the literature review.
3. A strong public transport system, accompanied by a bike lane network, which aims to reduce the dependency on cars.
4. A mobility strategy based on multimodal hubs spread strategically throughout the city, connected via high quality public transit for swift transitions between mobility modes.
5. Densification of the city in appropriate areas, supported by the results of reducing car dependency, enabling and strengthening denser environments.

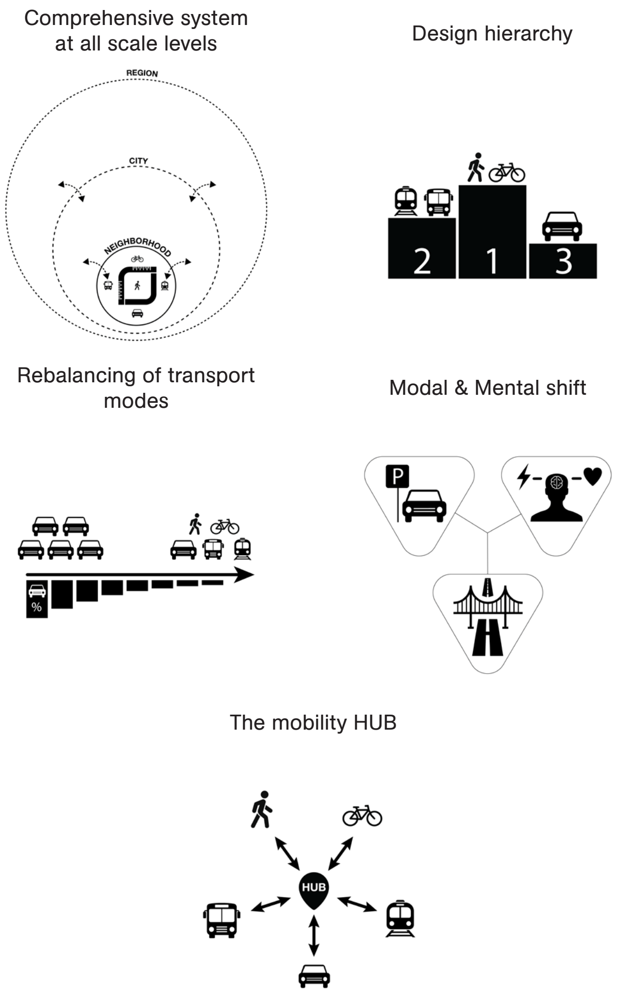


Figure 42 Design principles derived from the literature review

6.1 THE HUB

The mobility hub is a physical structure with the purpose of ensuring integration of private and shared modes of transportation. Mobility hubs are a relatively recent trend in urban development, but are know to function better at higher densities. A goal of implementing mobility hubs is to eliminate private car dependency. Mobility hubs offer travelers a range of alternatives by providing a location where switching between travel modes is easy. This promotes eco-mobility and provides alternatives to private cars.

A mobility hub requires the right conditions to be successful in practice. A successful mobility hub needs to comply with four indicators of success: Mobility supply, services, orientation, and spatial integration. The most important aspect is providing mobility, but scale and diversity may differ depending on the context of the hub. In terms of services, hubs can add to the mixed use factor of an area by providing services for nearby citizens. This category has an important connection to density, as density provides the requirements for the services that can be provided at the hub. Furthermore, a hub should be easy to use and navigate. Lastly, a hub should be integrated well into the direct surroundings. This concerns the connectivity to the hub, as well as the offering the appropriate services. Again, a high density and mix of functions create a better base for the functioning of the hub (Evers et al., 2023).

A distinction between four types of hubs can be made. The types of hubs, and their characteristics can be seen in Table 10. Depending on context, different types of hubs can be applied. An indication of the application of different types of hubs can be seen in Figure 43.

The studied impact of hubs varies slightly. On average, a successful mobility hub can replace 13 to 16 personal vehicles with shared mobility. In any case, a mobility hub helps citizens transition towards more sustainable modes of transport.

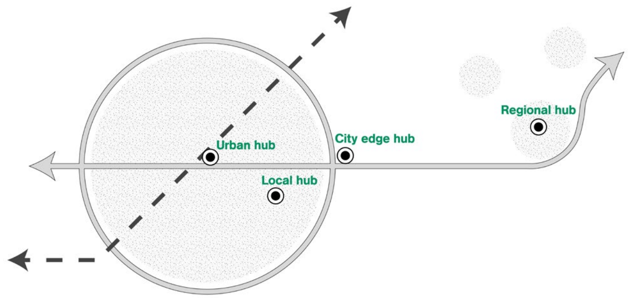


Figure 43 Application of various hub typologies

Within the city strategy, the various hub typologies are applied to the context of Eindhoven. The city has two train stations which function as large urban hubs. If opportunities arise, these large urban hubs can cover the mobility needs of a large area, but are more difficult to implement in existing urban fabric. Nevertheless, potential locations for large urban hubs would be along the railway in the east of the city, as well as a hub at the High Tech Campus. The regional hubs do not apply directly to the city of Eindhoven, and are better suited for important locations in surrounding municipalities.

Then, there are two types of hubs that are simpler to apply in existing urban fabric. First is the city edge hub, mostly applicable to city visitors from outside. These hubs are preferably located strategically at exits of the arteries of the city. This ensures a swift entry and depart from the city. These hubs function similarly to current P+R hubs, offering a large amount of transport options into the city, leaving the car on the outskirts. To determine potential usage rates of these hubs, findings by Kim Raijmakers' in her thesis are used. This research recommends the following: In order to optimize the usage of the hubs, location matters only slightly. It is most important that these hubs do not significantly increase travel times, thus frequent bus connections to the city center are mandatory. Furthermore, there should be a small cost to using the hubs, as these hubs will attract inner city users otherwise. Lastly, the main contributor to hub usage is increasing prices in city center parking, this push measurement was found to be most effective (Raijmakers, 2019).

Lastly, there are the local hubs, which are located within the city. The function of these hubs is to primarily provide inhabitants with a way to travel to locations outside the city, and back to their homes. These hubs focus on shared mobility, since providing parking places for all inhabitants is not feasible, nor sustainable in case of further densification.

Table 10 Hub typologies overview

Type	Location	Scale	Description
Urban hub	Central orientation	Regional / National	Large scale HOV points, where first and last mile complement the connections to far destinations.
Local hub	Urban neighborhood	City or Neighborhood	Small location to transfer between various modes of shared mobility, can offer places to store private vehicles.
City edge hub	City edge	Regional	Transfer locations and places to carpool. Locations where mostly car users switch to HOV or railway travel.
Regional hub	Outside city boundary	Regional	Location to switch from car or bike towards public transport. There is also room for flexible transport options.

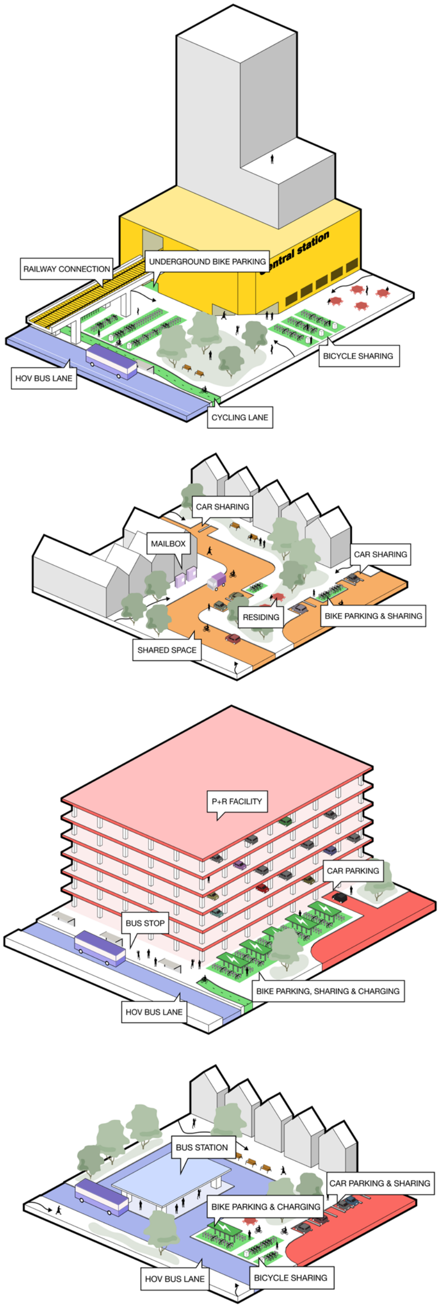


Figure 44 Hub typologies with transport mode switch options in context

To provide sufficient accessibility, hub typologies are preferably connected through HOV (Hoogwaardig openbaar vervoer) lines to the city center. These public transport lines will have priority to ensure swift transition into and out of the city. In combination with cycling highways, this forms an intricate network of fast, sustainable transport within the city boundaries.

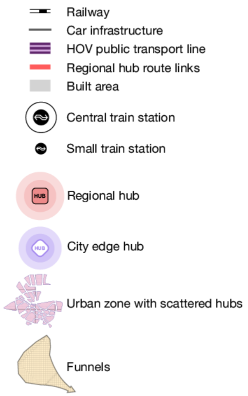
In general, it is better to comine the functions hubs serve, to ensure higher usage rate. If a hub can supply both mobility demand from outside the city, as demand from inside the city, the hub has a higher potential to succeed. Hubs do thus not have to be limited to serving one type of mobility demand. The working of two ways has the most potential for the city edge hub, where a large volume of car traffic towards the city center is met with a large volume of mobility in the other direction.

Regarding the list of interventions from literature, there are 30 possible interventions that can be used in the form of a hub. This is over half of the total interventions found. This means that the hub can be a versitle way to tackle the problems in current neighborhoods.

6.2 REGIONAL SCALE STRATEGY

The main goal of the regional scale strategy is to limit the volume of car traffic into the city. This is done by facilitating alternative efficient transport modes, which are accessible via the regional hubs. In Figure 45, the regional scale strategy is visible, and the envisioned locations of these regional hubs can be observed.

The regional hubs are located strategically in or around bigger villages, close to the border of the municipality of Eindhoven. In this way, these hubs can be connected to HOV lines of the city, maximizing efficient public transit. Additionally, the location of these hubs allows for the creation of funnels, where residents of villages located further away from the city of Eindhoven are encouraged to use the regional hub of their funnel. These hubs are targeted towards residents of the rural villages around Eindhoven, and offers them a way to remain connected to the city via a place where they can switch from car to public transit. This balances flows of people, while also servicing all villages in the region.



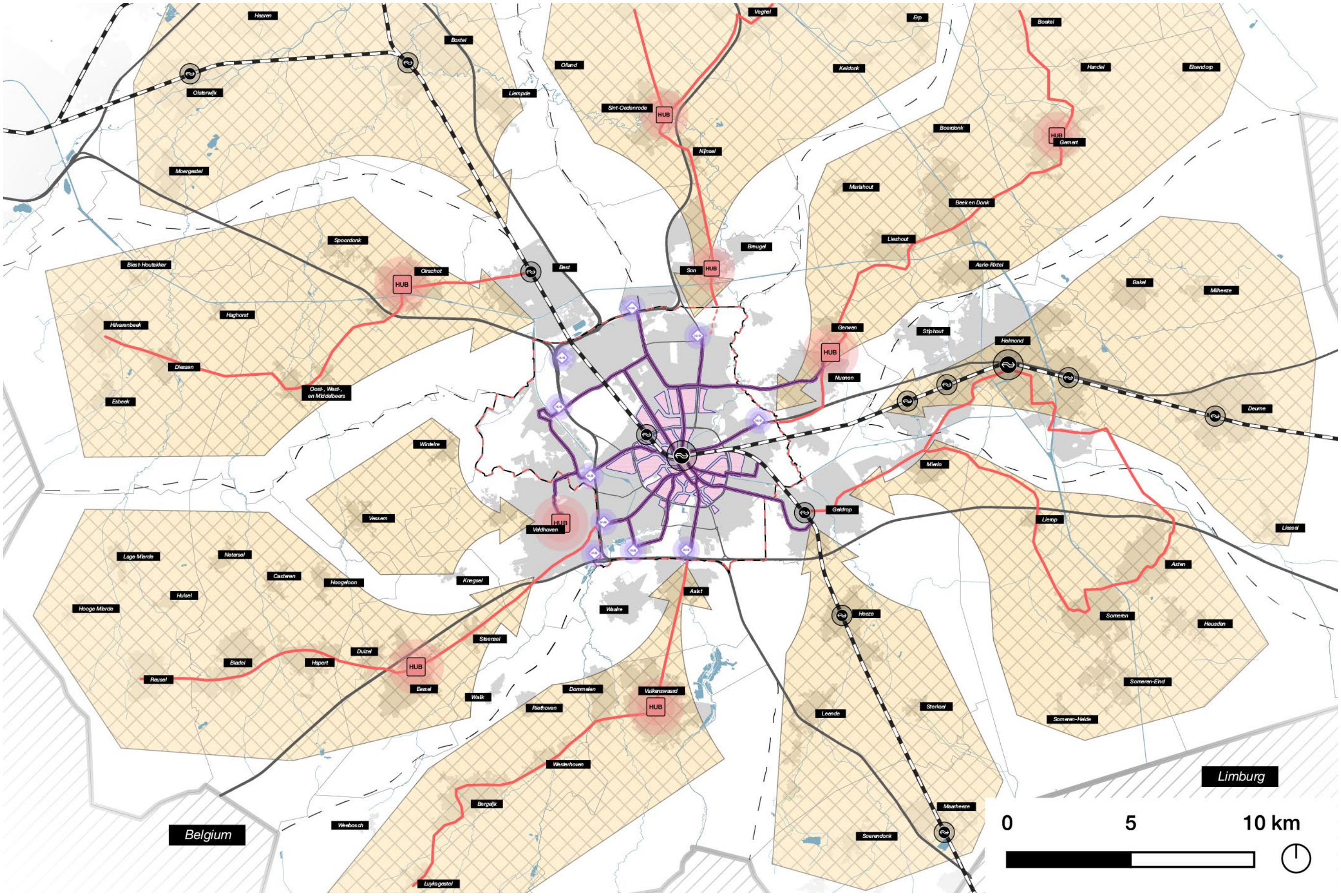


Figure 45 Regional scale strategy

6.3 MOBILITY STRATEGY

The mobility strategy consists out of three parts, briefly explained in order of significance. First, the implementation of active transport networks is discussed, followed by the implementation of hubs and public transit networks. The strategy is finalized with the implementations regarding car use.

6.3.1 ACTIVE TRANSPORT

In terms of active transport infrastructure, the focus is on providing cycling networks, where people can use the bicycle to travel the entire city. While the quality of cycling infrastructure is already high in the Netherlands, there is always room for improvement. The proposed network can be seen as a series of cycling highways.

Cycling highways are bike lanes with hardly any crossings with other modes of transport. These cycling highways form an intricate web within the ring, allowing swift movement. A trip from east to west within the ring only takes slightly more than 10 minutes by bike. The cycling highways will connect to outer villages and provide a network where citizens are encouraged to travel in an active way.

6.3.2 PUBLIC TRANSPORT

In terms of public transport, the most significant change is the proposal to introduce a fast Hoogwaardig Openbaar Vervoer (HOV) line towards the High Tech Campus. This line can either be an expansion of the bus network, or can be done by reintroducing the former railway line connecting Eindhoven with the Belgian city of Hasselt. In the Toekomstbeeld OV vision document of the Dutch government, a train line between Weert and Hamont is proposed (Ministerie van Infrastructuur en Waterstaat, 2021). While this is a good proposition to further connect the Dutch and Belgian railway networks, adding this railway line would introduce the possibility to add train stations at the High Tech Campus, a now car-dominated area, and reconnect the village of Valkenswaard to Eindhoven by train. The area within the ring road will be ruled by bus lanes and cycling highways.

6.3.3 HUBS

To provide places where people can swiftly change transport modes, various hub typologies are implemented. Most notably, the city edge hubs located around the highway partly surrounding Eindhoven. Within the city center, there is room for the local hubs, these can come in various sizes, depending on context. Examples of these hubs will be detailed in the neighborhood design section.

6.3.4 CAR TRAFFIC REGULATION

Besides providing hubs to change modes of transport, reducing available roads for private vehicles is a way to reduce the share of car use. Currently, it is faster, and even encouraged, to drive directly through the city center of Eindhoven, rather than utilizing the ring road. Denying through traffic is important in ensuring the ring road functions as intended.

The Professor Doctor Dorgelolaan, Fellenoord, Vonderweg, PSV-laan, final stretches of the John F. Kennedylaan, Veldmaarschalk Montgomerylaan and Boschdijk will all be reduced in size, or closed. The existance and size of these streets are the main causes for through traffic. Besides the large road infrastructure, the parking garages in the city center also form a large contributor to car-use. These garages can unfortunately not be closed on short-term due to long contracts with the municipality (Gemeente Eindhoven, 2020a).

After reducing the through traffic, the ring road needs interventions to improve flow. The proposition is to reduce the total amount of ring road crossings from 23 to 10. These 10 crossings limit access to the ring road to larger city arteries, connecting to outer parts of the city. Some former crossings are transformed to public transport and cycling only. A lower amount of crossings means that car traffic does not have to stop as often.

6.3.5 TOTAL MOBLITY STRATEGY

In the combined mobility strategy, the topics discussed in the first part of this chapter are combined. The vision can be observed in Figure 46. This is a vision concentrated on the challenges around mobility in a city with aspirations to densify. How subsequent densification will progress is discussed in the next part of this chapter. For this densification strategy, the literature review, mapping analysis and this part of the city strategy are all considered.

City scale strategy:
Mobility

- Railway
- High priority bicycle network
- HOV public transport line
- Car infrastructure
- Water infrastructure
- City centre built area
- Inner city built area
- Outer city built area
- Airport
- Central train station
- Small train station
- Proposed new train station
- Regional hub
- City edge hub
- Local hub zone
- Ring road crossing altered
- Large road presence reduction

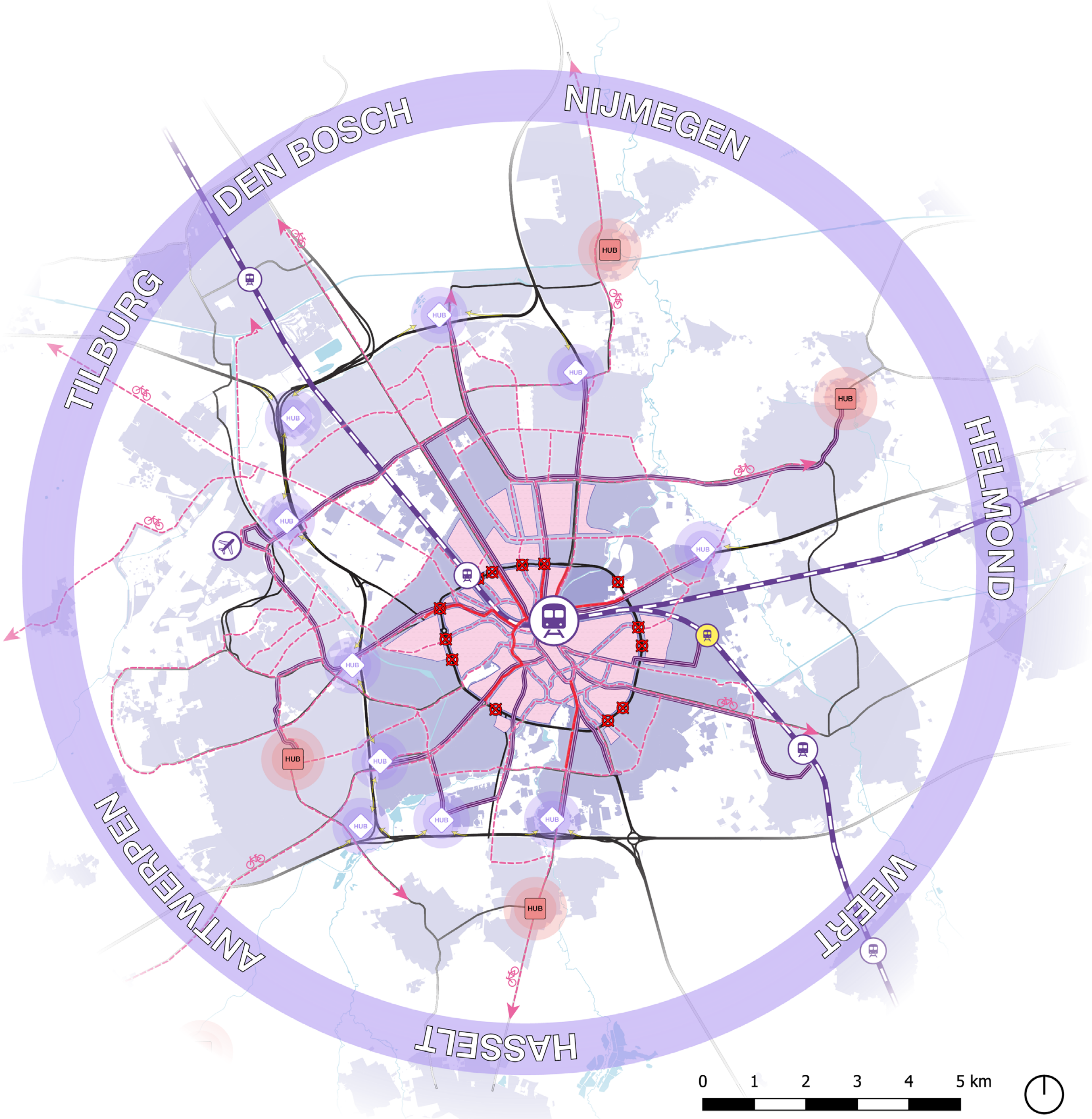


Figure 46 Mobility strategy

6.4 DENSIFICATION STRATEGY

Similar to the mobility strategy, the densification strategy consists out of three parts. First, the the restrictions for densification are discussed. This is followed by the significance of car-reduced potential and the locations of parking spots throughout the city. Finally, the densification is discussed, based on the previously discussed topics, in addition to the influence of the mobility strategy.

6.4.1 RESTRICTIONS

There are limits to the area that can be densified and area restrictions also need to be determined. There are (parts of) neighborhoods in Eindhoven with protected status, or valued highly in terms of urban planning or architecture. These neighborhoods are difficult to densify, as this will harm their status. Three distinctions are made. Firstly, there are the protected city structures, which cannot be touched (Rijksdienst voor het Cultureel Erfgoed, 2023). Secondly, there are the highly valued city structures, which can only be transformed with high exception. And thirdly are the old village structures of Eindhoven, which can be touched, but under careful considerations (Gemeente Eindhoven, n.d.).

6.4.2 PARKING

With the introduction of the hub system, further reductions in private vehicle parking can be made. In terms of densification, a significant portion of former parking can be used to densify. There are a few types of parking spaces which offer different opportunities. On street parking is difficult to transform towards higher density, as this type of parking follows street structures. This type of parking can perhaps better be repurposed to greenery, or shared mobility spaces. In any case, prices for parking should be introduced, or increased, to increase the functioning of the proposed hubs.

Secondly, there are parking garages. These buildings are mostly located in the city center, and act as a magnet for car traffic. Raising the price of parking here substantially, or perhaps closing these buildings, is vital to ensure the usage of the hubs. The low parking price in the city center is already a problem with the P+R locations currently in use.

Lastly, there are the ground floor parking lots. These large plots of land can easily be repurposed by densifying. Neighborhoods with a larger share of ground floor parking lots have a larger potential to densify in this way. The spatial analysis included parking place coverage. This information can be used to determine areas with potential for densification.

6.4.3 DENSIFICATION

After discussing the mobility system, hubs, parking and restrictions, the areas of densification can be determined. The locations of the hubs throughout the city offer opportunities for densification, but it is also important to look at city hotspots, and the level of car-free potential. Additionally, the (new) train stations offer more densification opportunities. Besides the areas in proximity of hubs and train stations, areas with a large share of parking availability offer good densification opportunities. The areas with restricted zones are hardly considered for densification. However, in some cases, restricted areas can still be used to densify if the right conditions apply.

The densification potential is higher within the ring road, especially around the northern part of the ring road. There are a few locations outside of the ring road that stand out. This includes the neighborhoods of Winkelcentrum Woensel, Hanevoet, Doornakkers-Oost and the area around the High Tech Campus.

The total densification strategy, where all parts are combined, can be observed in Figure 47.

City scale strategy:
Densification

Railway
Car infrastructure
Water infrastructure
City centre built area
Inner city built area
Outer city built area
Central train station
Small train station
Mobility hub P+R
Parking lot

Old village structure
State-protected city structure
Very highly-valued urban structu
Highly-valued urban structure
Very high parking area percenta
High parking area percentage
Moderate parking area percenta

City Hotspot

Densification tier 1
Densification tier 2
Densification tier 3

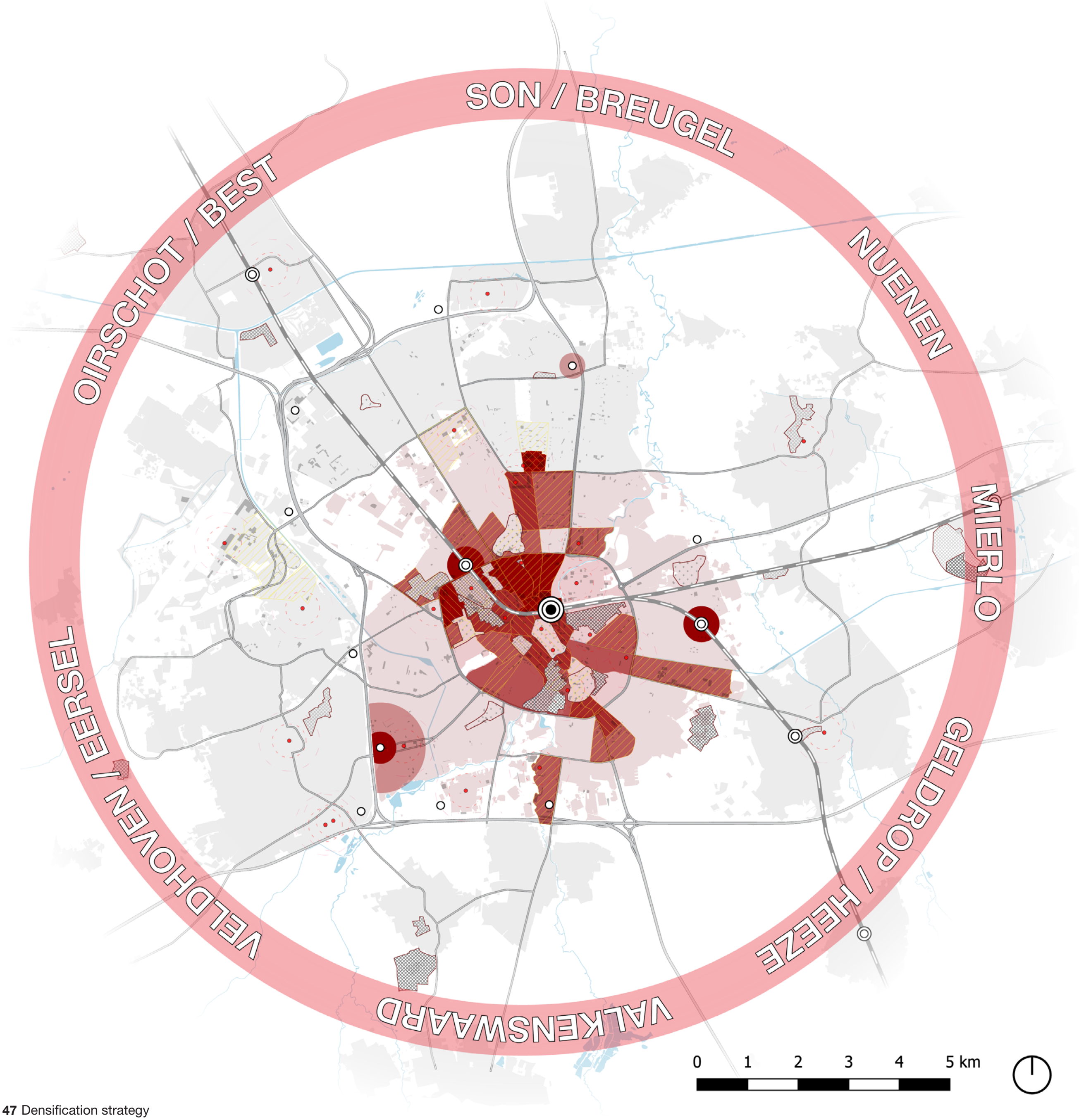


Figure 47 Densification strategy

6.5 CONCLUSION - CITY SCALE STRATEGY

To conclude the city scale strategy, both the mobility strategy and densification strategy are combined in one overview. This overview establishes many different systems which can form the base for detailed design, not only in the chosen redevelopment neighborhood, but many more parts of the city. The combined city-scale strategy can be observed in Figure 48.

The proposed mobility system lays a foundation for car reduced densification throughout the entire city, and to municipalities beyond the boundaries of Eindhoven. It is important to keep in mind that, by introducing changes to the infrastructure, a seed is planted for the necessary shift in mentality of inhabitants and city visitors. By providing an attractive network, more people will opt for a choice of mobility that does not only favor the environment, but allows space-efficient transport within the city.

City scale strategy

- Railway
- High priority bicycle network
- HOV public transport line
- Car infrastructure
- Water infrastructure
- City centre built area
- Inner city built area
- Outer city built area
- Airport
- Central train station
- Small train station
- Proposed new train station
- Regional hub
- City edge hub
- Local hub zone
- Ring road crossing altered
- Large road presence reduction
- Old village structure
- State-protected city structure
- Very highly-valued urban structure
- Highly-valued urban structure
- Very high parking area percentage
- High parking area percentage
- Moderate parking area percentage
- City Hotspot
- Densification tier 1
- Densification tier 2
- Densification tier 3
- Parking lot

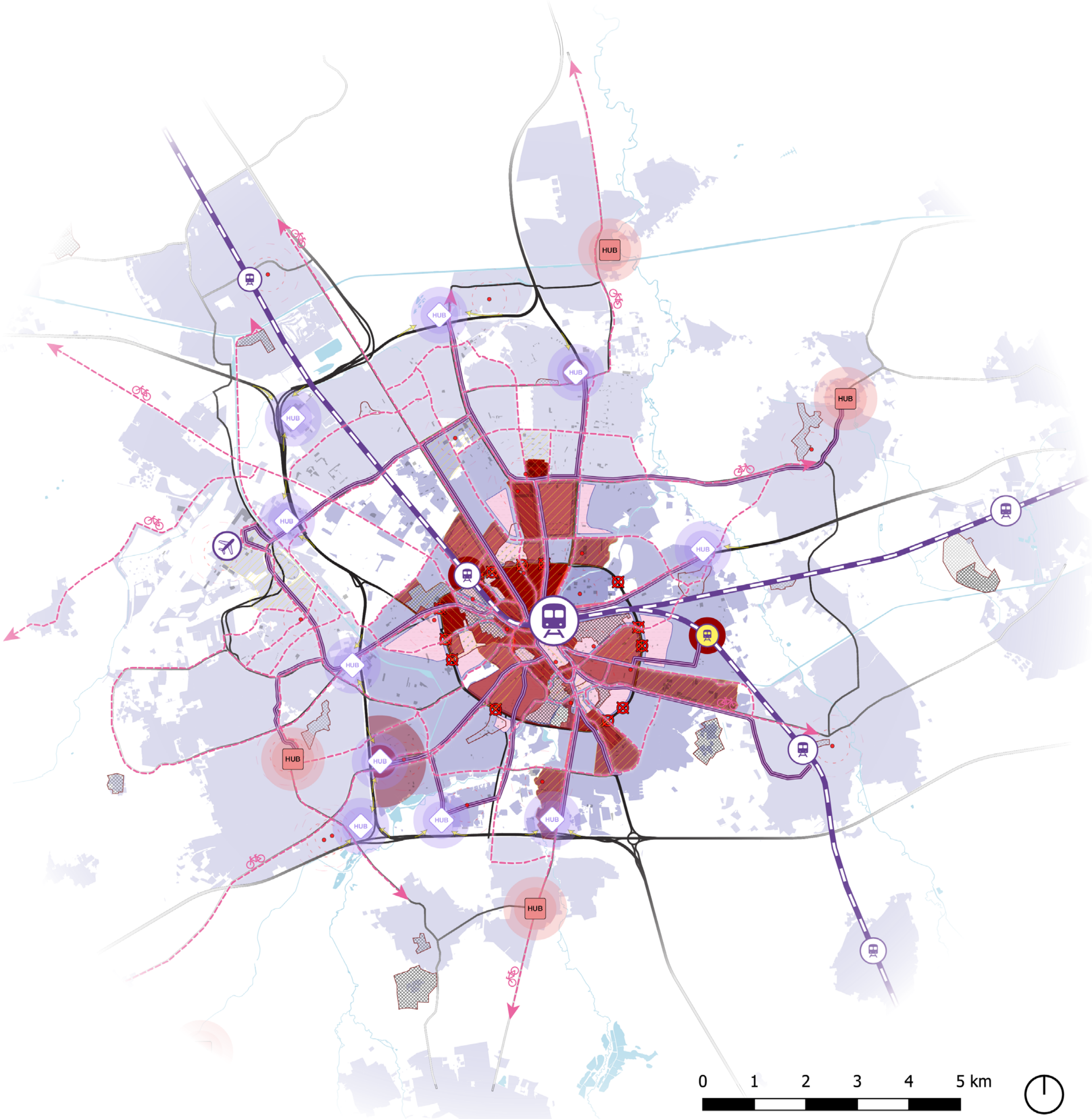
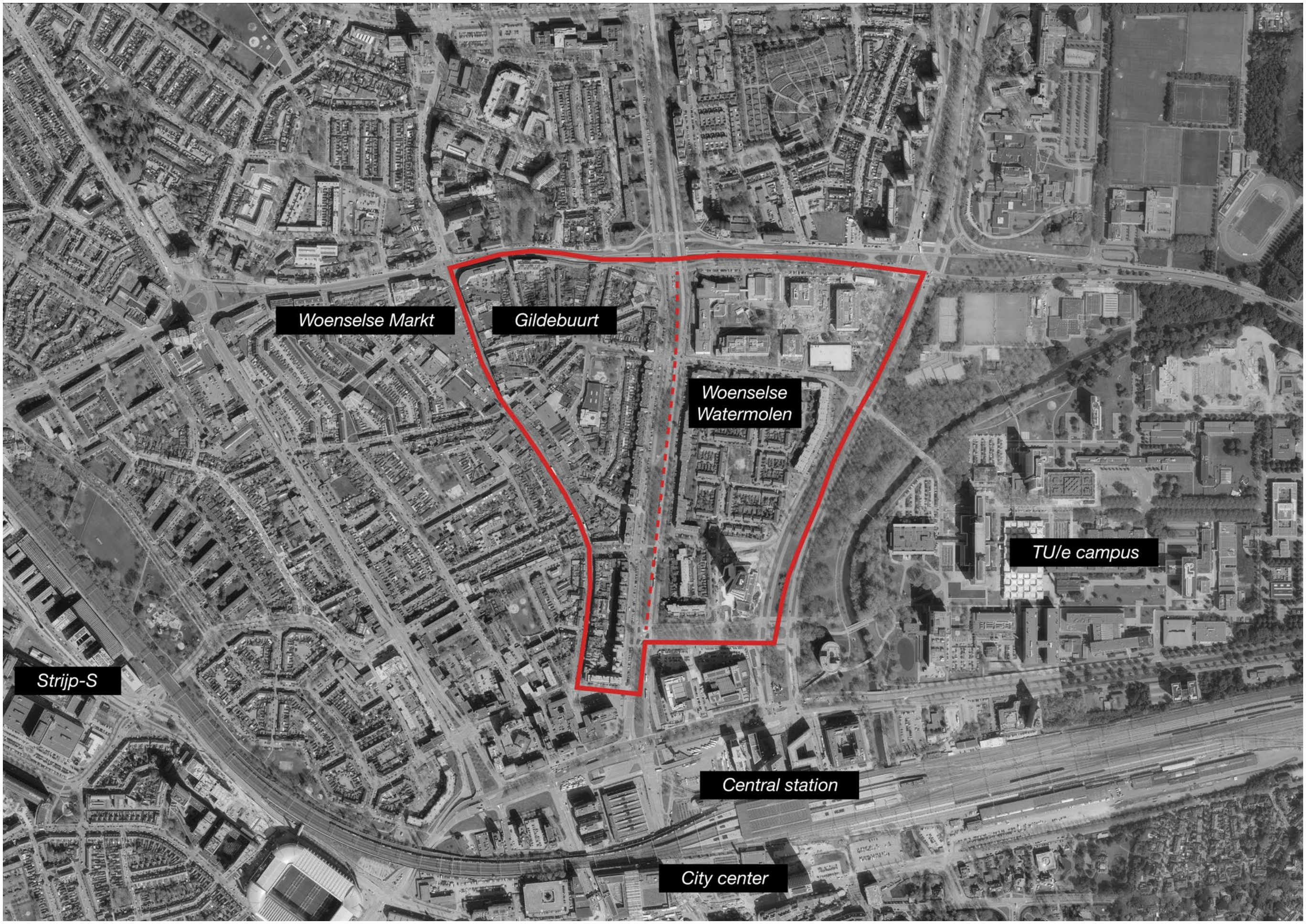


Figure 48 City-scale strategy

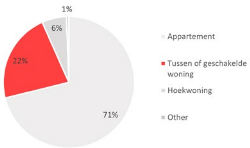
Neighborhood design



Woenselse Watermolen + Gildebuurt

1590 dwellings

3910 inhabintants



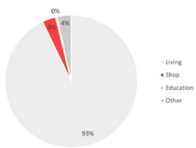
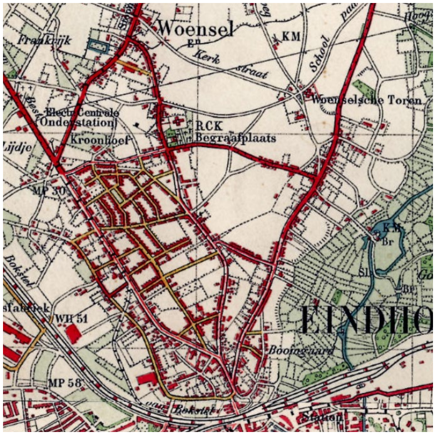
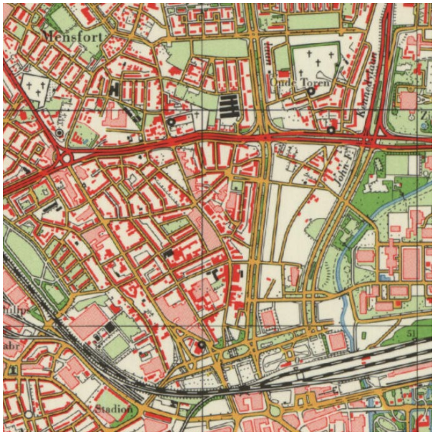


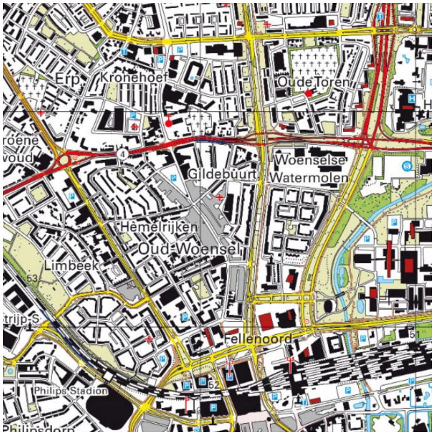
Figure 49 Visual overview and statistics of project site



1942 *(Topotijdreis, Kadaster, 2024)*



1982 *(Topotijdreis, Kadaster, 2024)*



2022 *(Topotijdreis, Kadaster, 2024)*

Figure 50 Historical overview

7.1 INTRODUCTION

The neighborhoods Woenselse Watermolen and Gildebuurt are situated in the old part of Woensel, and both have a rich history. While this is still visible in the Gildebuurt, Woenselse Watermolen has undergone a significant change throughout history.

Most important is the presence of the Kruisstraat and Woenselse markt in the western part of the ensemble, home to plenty of facilities. In addition, the eastern part of the ensemble borders the Dommel river, giving a strong green quality to the area. In the south, the neighborhoods are located very close to the central station of Eindhoven, leading to high levels of public transit connectivity. In the north, the neighborhoods are bodered by the city ring, and the Fontys campus.

7.1.1 HISTORICAL BACKGROUND

Gildebuurt
The Gildebuurt is a residential neighborhood mostly formed by 1950's and 1960's city expansion around the Kruisstraat. A large portion of the neighborhood is social housing. Before the expansions, the neighborhood consisted of some streets which formed the connection between the Kruisstraat and the Dommel river (Gemeente Eindhoven, 2024).

Woenselse Watermolen
The neighborhood of Woenselse Watermolen is home to both residential functions, as well as the Fontys campus. This divides the neighborhood. In early history, the neigbhorhood consisted of only one street, connecting the center of Eindhoven towards farms in the north-east lands around the small city. The neighborhood is named after the former largest watermill of Noord -Brabant, which was located on the Dommel, approximately where the Auditorium building of the TU/e currently is located. The watermill was demolished illegally in 1956 to expand the Technische Hogeschool Eindhoven (Buijks, 2021). Beside the single street, a few perpendicular streets connecting the watermill to the Kruisstraat completed the neighborhood. This street, named the Broekseweg, has since disappeared in the neighborhood renovations of the 1980's.

During the renovations, all of the neighborhood was bulldozed, except for one building, the Bunker. New row housing was constructed, as well as a campus for what nowadays is the Fontys. In more recent developments, the (at the moment of writing) highest tower of Eindhoven is part of the neighborhood, the Bunkertoren.

7.1.2 POSITION OF THE NEIGHBORHOOD

The neighborhood is located within the city ring road of Eindhoven, and in very close proximity of the central train station. The central location makes all areas with a lot of places to work at good distances to cycle. The location of the neighborhoods, and work hotspots can be seen in Figure 51.

The Kruisstraat, apart from having a lot of facilities, also functions as an important cycling connection between the city center and the north of the city. Lastly, the close presence of the Dommel causes the neighborhoods to be located in close range to one of the three green wedges of Eindhoven.

7.2 NEIGHBORHOOD ANALYSIS

A brief neighborhood analysis can be observed in Figure 52. Both the Gildebuurt and Woenselse Watermolen are compared to the average of the entire city. There are some differences to be noted. For instance the age distribution, as in Woenselse Watermolen, more than half of the inhabitants are of the same age group. In case of demographic origin, a large non-western group resides in Woenselse Watermolen. Another striking difference is the construction year of most buildings in the neighborhoods. In Woenselse Watermolen, only a very small fraction of the total building stock was built before 1970.

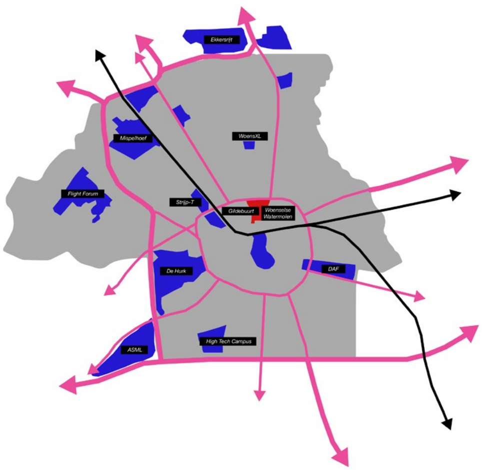


Figure 51 Project site, major connections and work locations

Figure 52 Brief overview of data concerning the site and the average of Eindhoven

7.2.1 SPATIAL ANALYSIS

In terms of building structures, different patterns can be observed in both neighborhoods. The more organic growth is visible in the Gildebuurt, while a system can be observed in the Woenselse Watermolen. Additionally, the larger share of corporation owned buildings is visible in Figure 54. Additionally, there is attention for energy labels of buildings, this can aid in deciding what buildings to demolish or renovate.

In terms of important surroundings, the neighborhoods are surrounded by a large variety of typologies. In the north, there is the hospital, as well as some old churches. In the east, the site is bordered by the Dommel and TU/e campus. In the south, the neighborhood connects to the train station and city center. And finally, in the west is the Kruisstraat.

7.2.2 GREEN STRUCTURES

The large green wedge coming into the city center via the Dommel borders the redevelopment site. This can be seen in Figure 55 on the next page. In addition to this, there is some presence of trees along one of the arterial roads, but this is met with lower amounts of ground-bound greenery. The Dommel is by far the most important green element.

7.2.3 MOBILITY ANALYSIS

Finally, in terms of mobility, the neighborhoods are in good condition. This was perhaps to be expected, as both neighborhoods scored very well on car-reduced potential.

There is the close proximity of the central train station, providing frequent connections by train to large cities in the Netherlands. Furthermore, there is a HOV bus line cutting right through the center of both neighborhoods. This provides adequate access to the bus network. In any case, the location of the neighborhood within the city allows for smooth travel by bicycle. There are plenty of cycling lanes in and around the site, but that does not mean the network does not need to be extended. The results of the mobility analysis can be found in Figure 56.

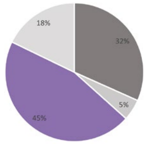
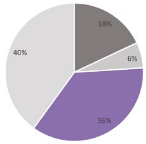
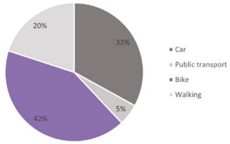
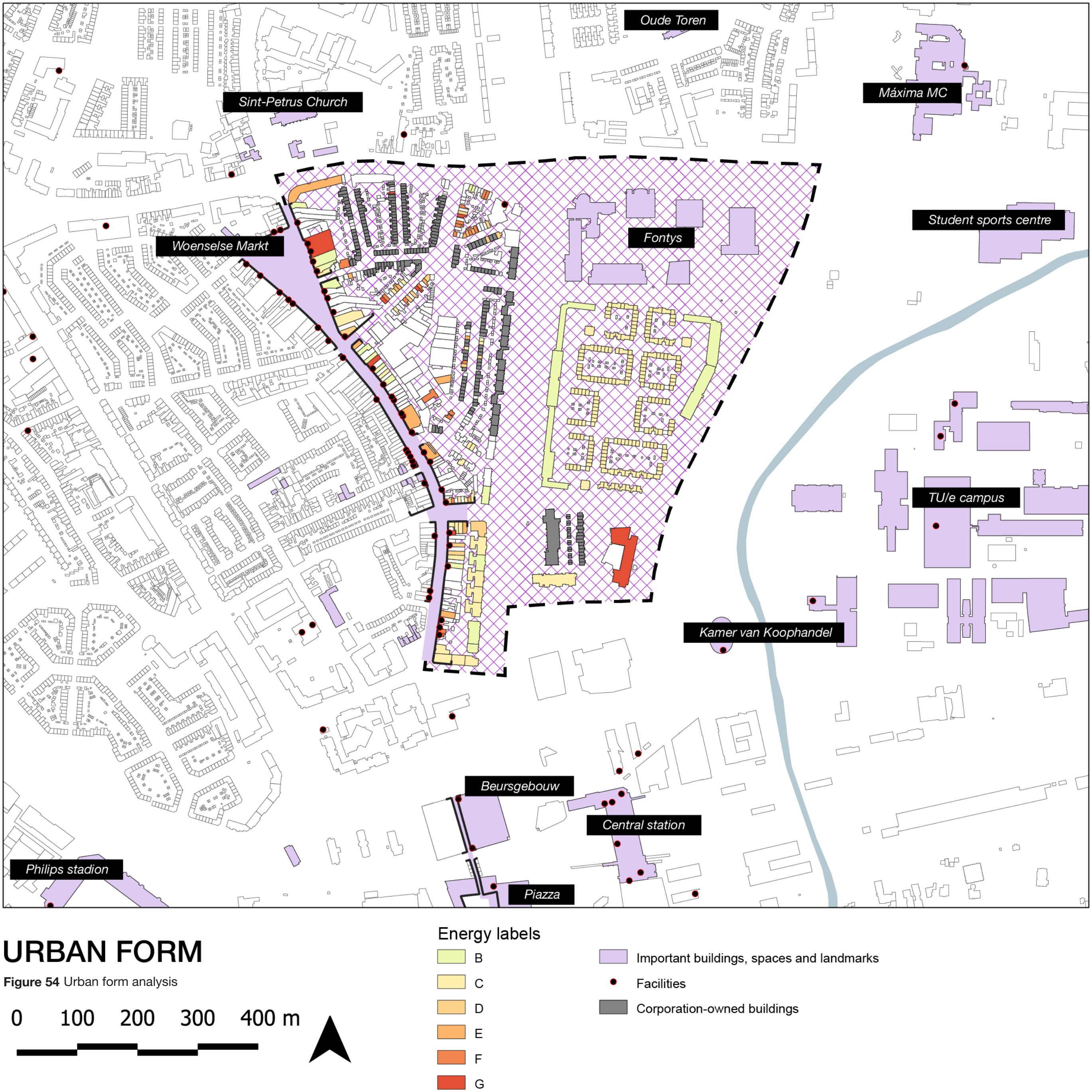
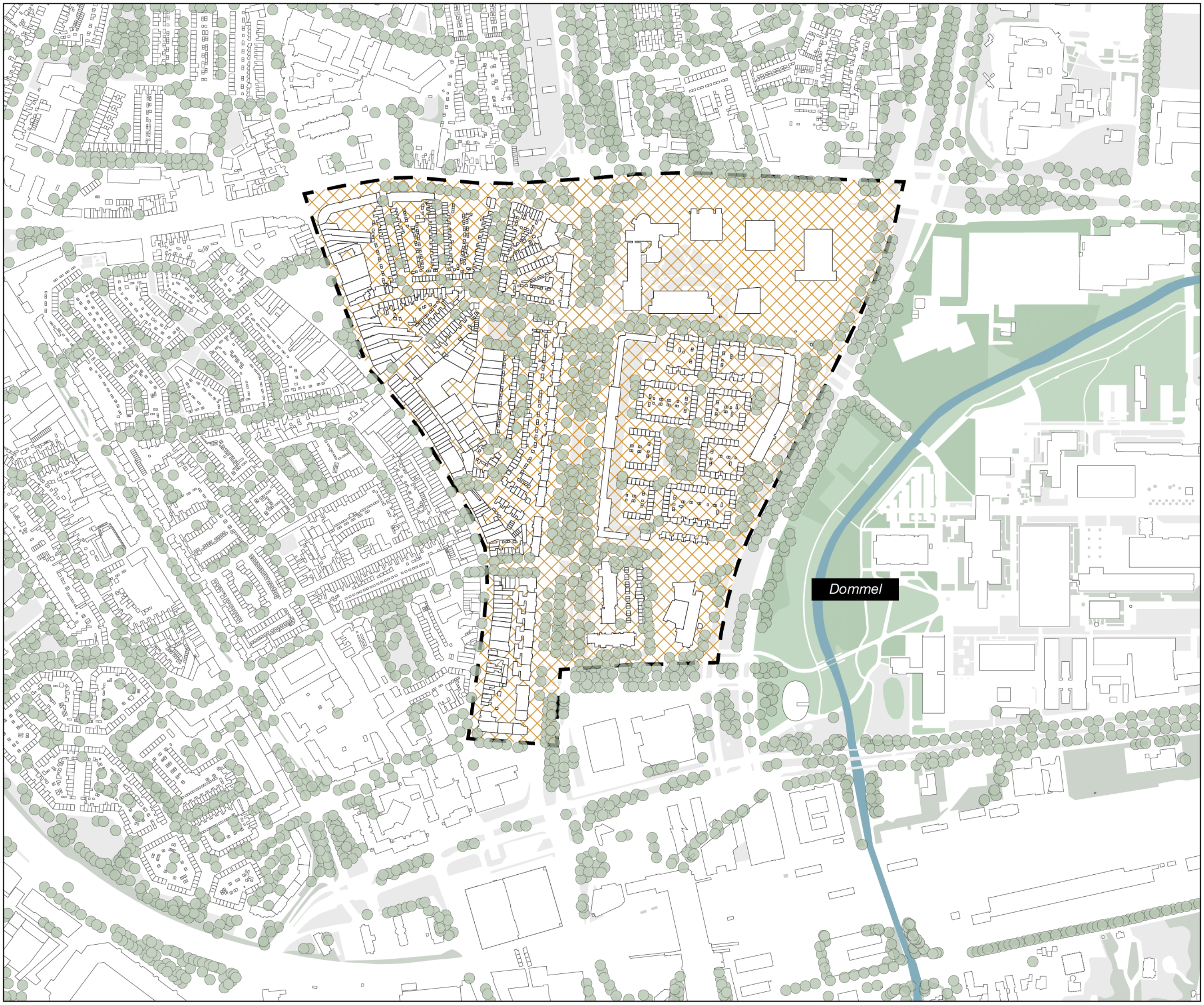
	Woenselse Watermolen	Gildebuurt	Eindhoven total
Modal split			
Amount of vehicles	397	530	106337
Parking place coverage	5%	7,3%	3,2%

Figure 53 Continuation of the data overview



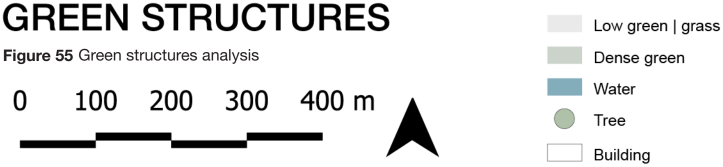
URBAN FORM

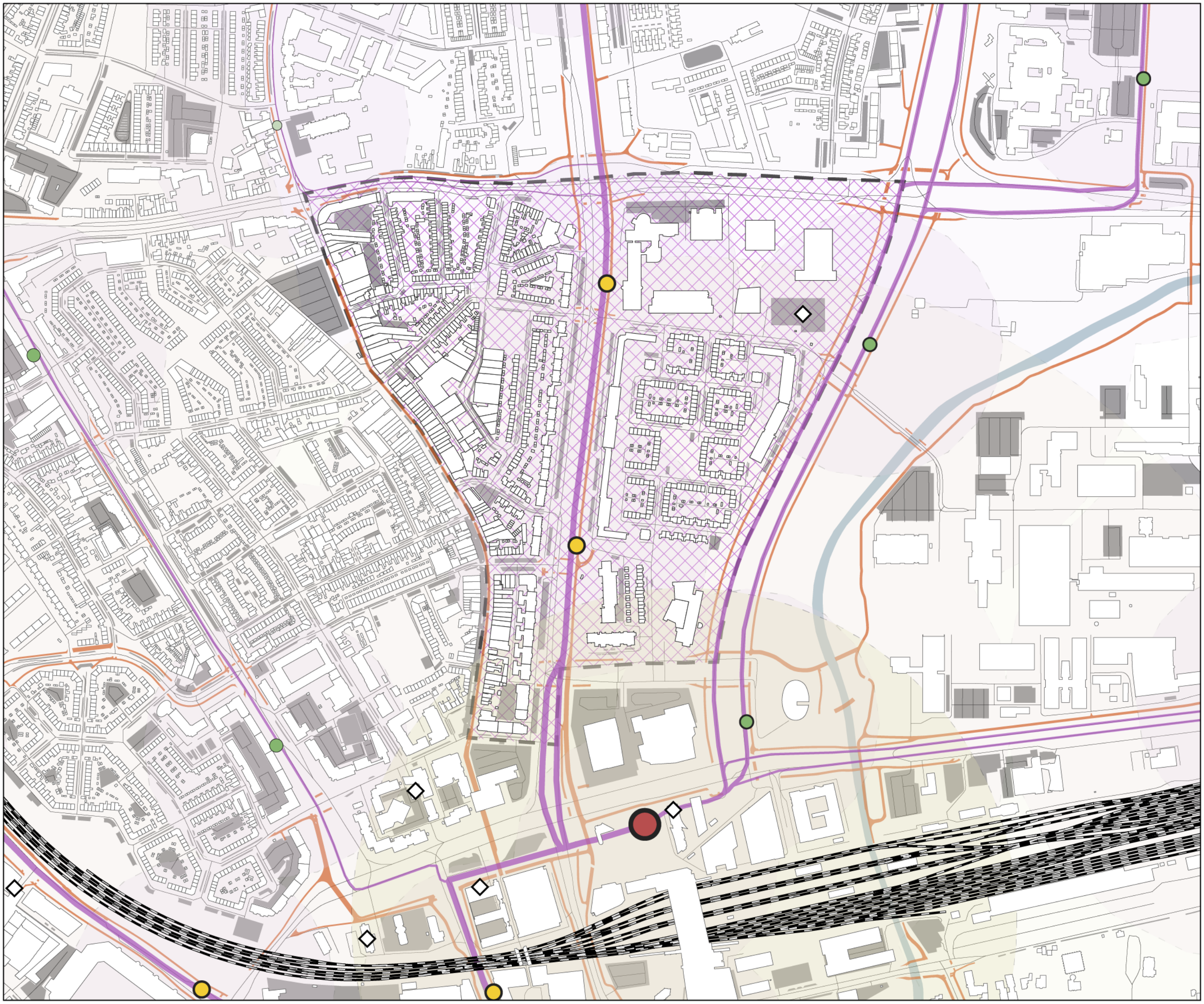
Figure 54 Urban form analysis



GREEN STRUCTURES

Figure 55 Green structures analysis





MOBILITY

Figure 56 Mobility analysis

0 100 200 300 400 m

- HOV line
- 3+ lines
- 2 lines
- 1 line
- Railway
- Parking garage
- Neckerspoel station
- Buildings
- Parking lot
- Cycling lane
- Road

7.3 CONCEPT DESIGN

7.3.1 MOBILITY

As a result of the analysis on mobility, the public transit in the neighborhood is of adequate level. To establish a mobility concept, further adapatations are made in favor of car-reduced development. In Figures 58 to 60, different topics concerning the neighborhood are visible in wider context. This strengthens the mobility analysis, by adding a larger context to the in-depth mobility analysis.

In terms of conceptualization, the active transport network is extended, aiming to strengthen the connections between the east and west parts of the site. Within the site, there is an increase in attractive walking environments, to encourage the use of active transport modes.

The car is limited in access to the city ring, and can only enter the neighborhood via the use of a loop running in one direction through the neighborhood. The public transit bus axis cuts right through the heart, just as before, connecting to the central train station.

The final mobility concept can be observed in Figure 57.

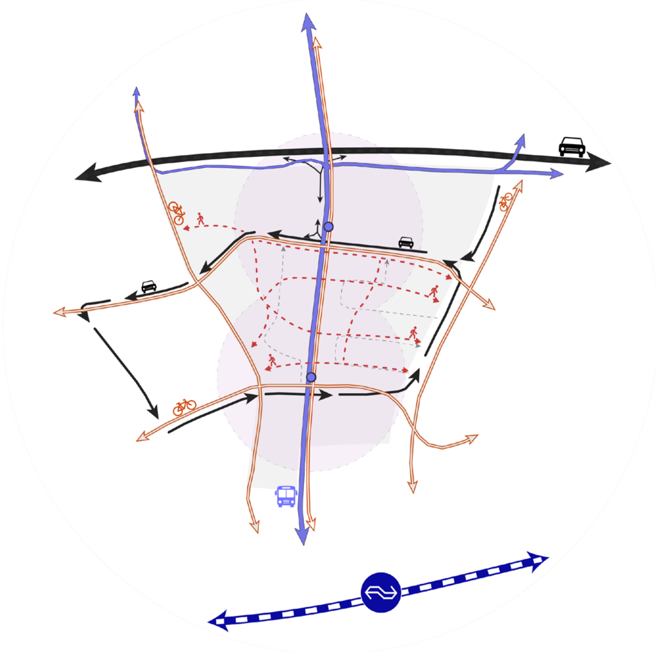


Figure 57 Mobility concept

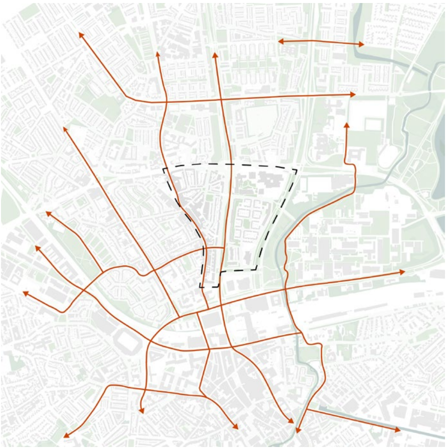


Figure 58 Cycling network

Figure 59 Public transport network

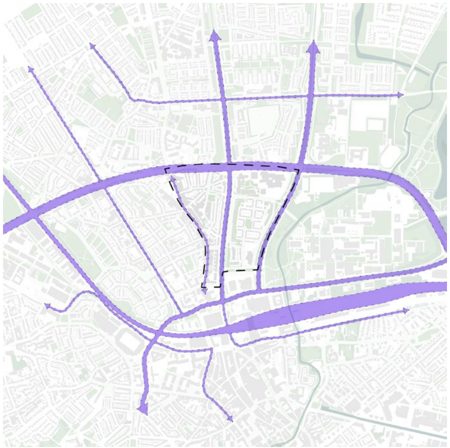


Figure 60 Neighborhood connectivity

7.3.2 GREENERY AND FACILITIES

Similar to the mobility analysis, the in-depth analysis is strengthened by including a wider context.

The main objective for the site is to connect the abundance in greenery in the east of the site, with the abundance of facilities in the west of the site. As can be seen in Figures 62 to 64, there is an imbalance that can potentially be bridged, strengthening both sides of the neighborhood.

In the concept, visible in Figure 61, an attempt is made by creating a plethora of green passages from west to east. These passages decrease in size, the further they go west. Along the passages, smaller pockets of greenery arise which can be filled by playgrounds or gardens. In terms of functions, the liveliness of the Kruisstraat is drawn towards the east, however in a modest manner. The extension of the greenery is dominant over the extension of functions, in order to not make the entire neigborhood similar to the Kruisstraat.

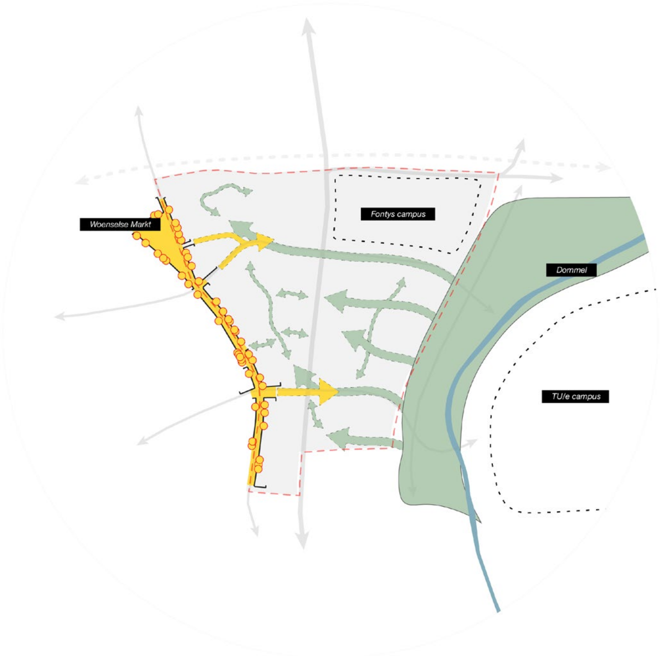


Figure 61 Greenery and facility concept

Figure 62 Green network

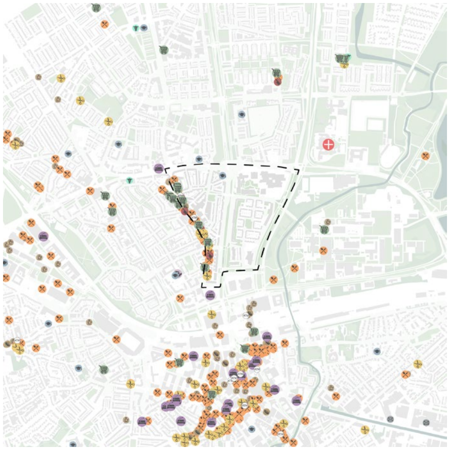


Figure 63 Network of facilities

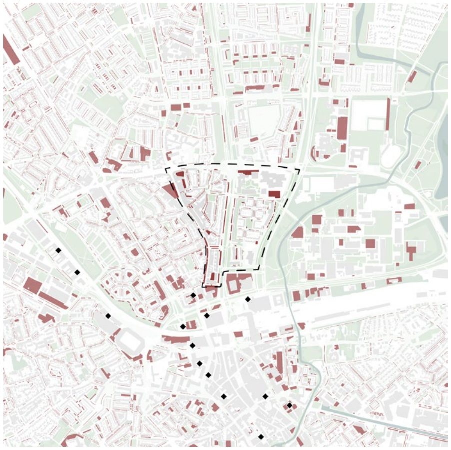


Figure 64 Parking spaces and garages

7.3.3 DENSIFICATION

Lastly, the densification concept is formed. Similar to the previous two concepts, a wider context is added to the in-depth analysis prior to forming the final concept. This can be seen in Figures 66 to 69.

In terms of density, the city center has higher, desired density. There is a pocket of high density elderly homes located north of the site, it could be valuable to densificy along a pattern that connects these two zones of higher density. This is complemented by the homes owned by building corportations, as these follow a similar pattern.

Additionally, the change in mobility creates new densification opportunities. Along the eastern part of the site, as well as the connections formed from east to west can be used to densify. This creates a pattern of densification axis. This results in the final densification concept, visible in Figure 65.

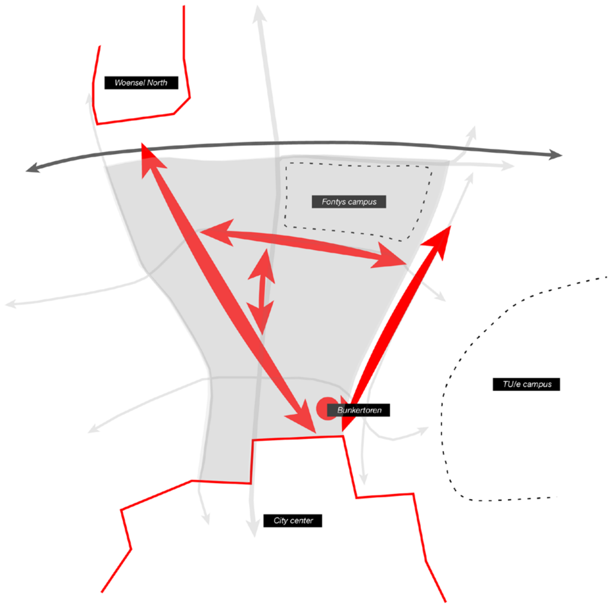


Figure 65 Densification concept

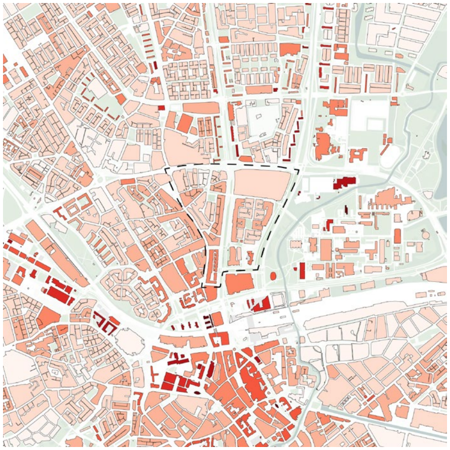


Figure 66 Floor space index

Figure 67 Energy labels

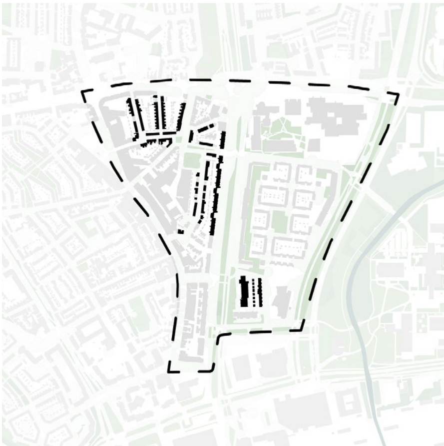


Figure 68 Corporation-owned buildings


WoensXL
Ring road
Fontys
Woenselse Markt
HUB
P
Kruisstraat
Dommel
TU/e campus
Park
Bunker
Strijp-S
City center
Central station

7.4 FRAMEWORK PLAN

After establishing the concepts for the site, a framework plan is formed. This framework plan is a more detailed version of the concepts established in the report. The framework plan aims to establish rough plots and directions, which can later be filled with more specific solutions. This then serves as a foundation for the detailed masterplan of the area.

The framework plan is visible in Figure 69. A wide color scheme is used to make distinctions within the framework plan. The layers of Mobility, Greenery & Facilities, and lastly Densification all appear in the framework plan, and will be briefly explained.

Mobility

In terms of mobility, distinction can be made between four types of intervention categories. There are interventions to improve walking, cycling, car sharing and car access limitations. In tems of walking, stronger connections between the east and west are created by forming direct connections along pathways were other modes of transport are not, or hardly allowed. Along the routes for walking, there are various pockets of greenery and facilities that can further strengthen the perception of traveling through the neighborhood on foot.

Figure 69 Framework plan

Framework plan legend

Project area

Infrastructure

- Bike connection
- Bus line
- Car slow lane
- City ring road
- Subterranean parking garages
- Parking pockets
- Multi-modal mobility location

Zoning

- Mixed-use; retail & residential
- High-density residential
- Low-density residential
- HUB area
- Communal function
- Primary public space: Green squares
- Greenery / park
- Playground
- Water
- Education

Links and connections

- Pedestrian connection
- Bicycle connection
- Green connection
- Green connector; traffic calming
- Main activity hotspot

For cycling, the emphasis of existing cycling routes is increased. Stronger east-west connections are formed, by creating more direct routing, and safer routing. In these east-west connections, the cyclists will have priority. The car loop, which will be discussed hereafter, consists partly of sections which are ‘fietsstraat‘. This means that car users and cyclists share the same street, but the cyclists have to be respected.

The largest sum of interventions considers car infrastructure. Two major car arteries will be removed, or renovated. Firstly, the large arterial road currently parallel to the bus lane will be removed. In line with the city strategy, traffic within the city ring is limited, and rerouted via the city ring. This opens up possibilities for reducing these arterial roads. The other arterial road that is changed runs parallel to the park and Dommel. Here, part of the former road will be changed to a shared road for bikes and cars. The new road will form the eastern part of the loop through the neighborhood, allowing cars to only travel in one direction. This helps to discourage the use of private cars to travel within the city ring. Along this loop, multiple shared mobility hubs are situated, as well as small roads which allow for vehicles to still reach front doors of most buildings. This creates a system where car use is discouraged, but not impossible.

Greenery & Facilities

The interventions for greenery and facilities aim to solidify the presence of both greenery and facilities in the parts of the neighborhood where they are now lacking. For greenery, this is drawing the park towards the west, and for facilities, this is expanding the facility cluster a bit towards the east of the site.

The park is provided more room to enter the neighborhood, and can do so along the ‘fietsstraat‘ parts of the loop. The expansion of the park is met with green pockets spread throughout the neighborhood, decreasing in size the further away from the park. The bridging of facilities is also along the ‘fietsstraat‘ part of the car loop, ending in squares which act as entrances to the Kruisstraat.

Density

The change in infrastructure allows for multiple opportunities to densify. Firstly, the connection between the denser city center and the elderly homes in the north is formed. The envisioned plots differ based on their proximity to either the park, or the Kruisstraat. More plots for densification are located along the ‘fietsstraat‘ next to the Fontys, and in the location of the former arterial road parallel to the park.

Figure 70 Mobility extracted from masterplan

Figure 71 Greenery extracted from masterplan

Figure 72 Building blocks extracted from masterplan

7.5 MASTERPLAN

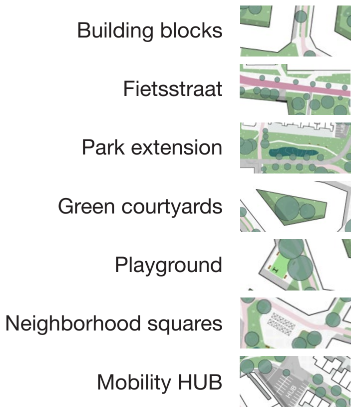
The masterplan shows the detailed proposal for the high-density development of the Gildebuurt and Woenselse Watermolen. The base of the masterplan is shaped by interventions regarding mobility, forming the foundation for a car-reduced neighborhood. Interventions include the creation of a one-way road system for cars, the expansion of walking and cycling routes, and the introduction of mobility hubs. These hubs are spread throughout the neighborhood, allowing inhabitants access to shared cars if they need it. Within the neighborhood, car use is discouraged.

Space created by this change in form of mobility is used to densify. Additional densification is achieved by renovating large parts of the former neighborhood. Densification is done by creating a mixture of blocks with private and public courtyards of various building heights. Most of the buildings have a hight of around 4 floors, since this is neither too low density, nor does it alienate the upper floors.

Lastly, the connection from the neighborhood towards the Dommel is strengthened by drawing the park inwards. In terms of facilities, the neighborhood is strengthened by allowing for better access to the expanded Kruisstraat and Woenselse Markt.

Figure 73 Masterplan

1:5000




HUB
HUB
HUB
HUB
HUB
HUB

7.5.1 DISSECTION OF MASTERPLAN

The interventions taken have resulted in the final masterplan, visible on the previous page. In this short section, the results of the masterplan will be dissected. Additionally, the changes in numbers for performance indicators will be provided.

In terms of mobility and infrastructure, the different modes of transport are visualized in isometric view in Figure 75. The routing in and around the neighborhood can be observed as a hierarchy. The changes in infrastructure have been visualized in Figure 74. The decrease in road surface is significant, and can be linked to the reduction of presence of the large arterial roads. Additionally, more than half of the space formerly functioning as parking space has been removed.

Contrary to the reduction of road surface, there is an increase in surface for cycling, both cyling lanes and fietsstraat surface increase compared to the situation before intervening.

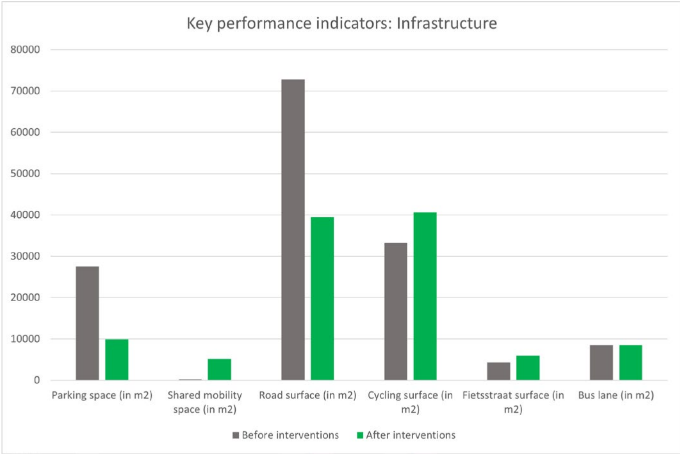


Figure 74 Key performance indicators: infrastructure

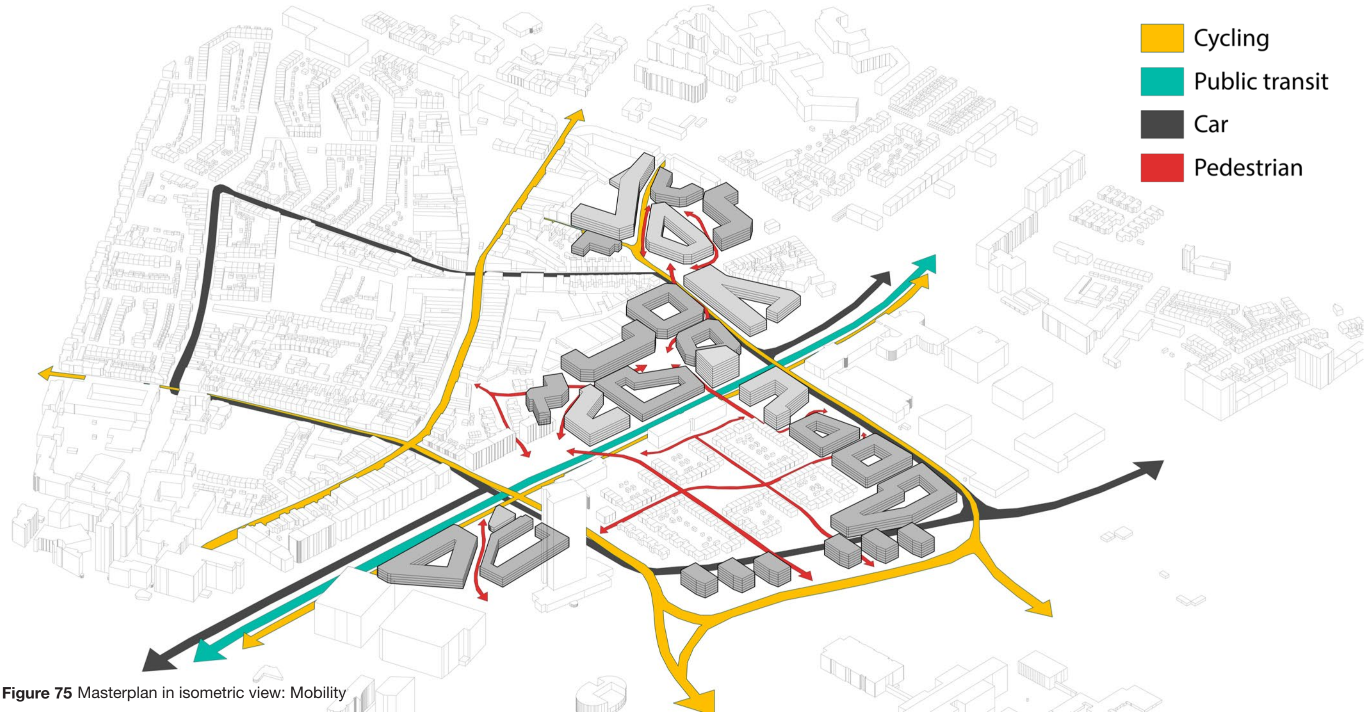


Figure 75 Masterplan in isometric view: Mobility

The decrease in infrastructure opens up space, which can be filled in many ways. One of the objectives of the neighborhoods was to bridge the green in the east to the functions of the west, the concept regarding greenery and facilities.

The results of interventions on the topics of greenery and facilities can be seen in isometric view in Figure 77. Especially the extension of the park is visible, made possible by the removal of a large part of the John F Kennedylaan. On the western part of the site, the presence of the greenery lowers, but is spread throughout the wandering environment and in private courtyards.

In terms of functions, the large share of functions from the Kruisstraat is slightly extended into the neighborhood. This creates places where the green extension from the park, and the extension from the Kruisstraat meet. At these locations, vibrant squares can be formed.

In total, the public space considering greenery has increased significantly, by nearly 10%.

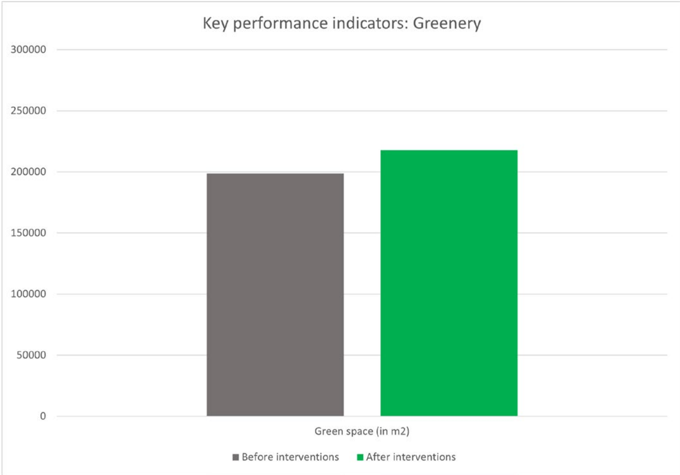


Figure 76 Key performance indicators: greenery

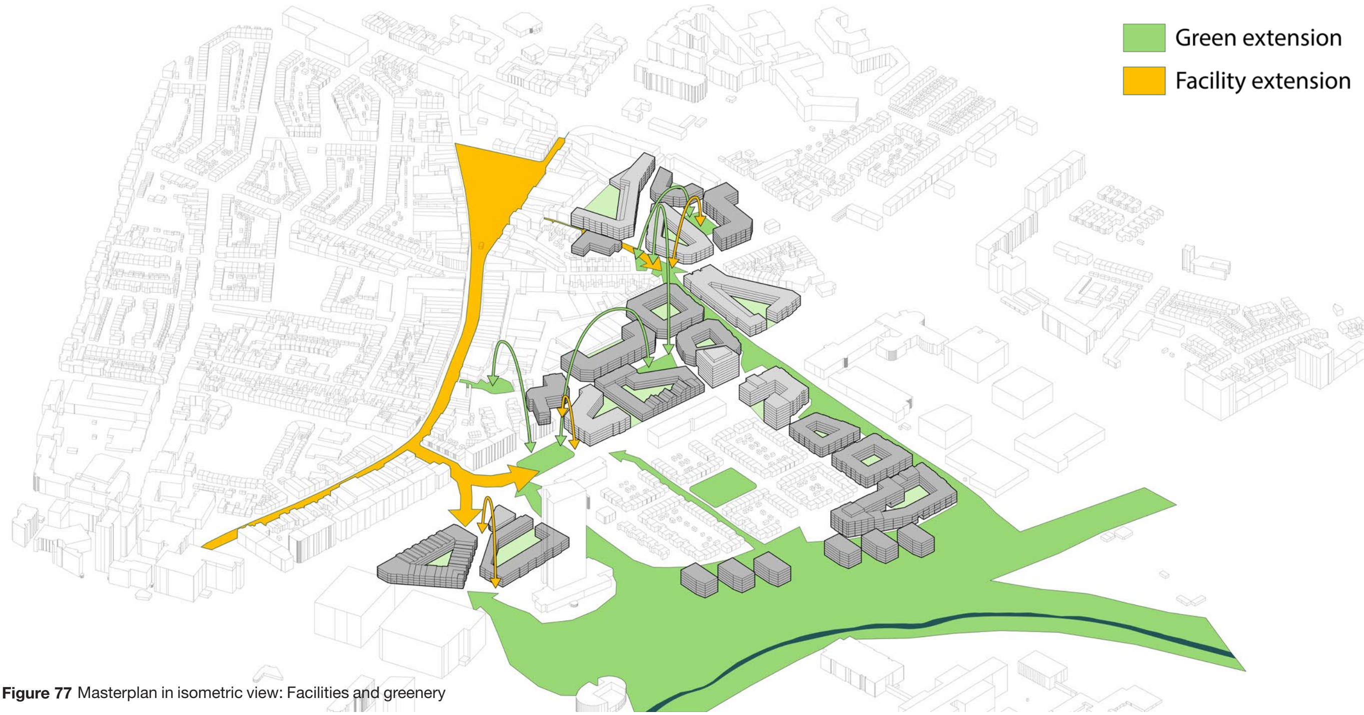


Figure 77 Masterplan in isometric view: Facilities and greenery

In terms of dwelling types and target groups for the site, the aim is to make the neighborhood a place for population groups who have a lower reliance on cars by lifestyle. These population groups mostly include students and elderly, as was found in the literature review. Redeveloping the neighborhood with these target groups in mind is favorable, as the Fontys campus and TU/e campus are both very nearby, as well as the high-density elderly homes discussed during the densification concept phase.

In Figure 79, the proposed division of rent types and target groups can be seen. The locations are chosen specifically per target group. Most elderly homes are concentrated towards the Woenselse Markt, at walking distance. This is also close to the other elderly homes opposite of the ring road.

Most student homes are concentrated towards the campuses, while the remainder of added buildings is not aimed towards a specific target group. The results of added dwellings per demographic group can be seen in Figure 78.

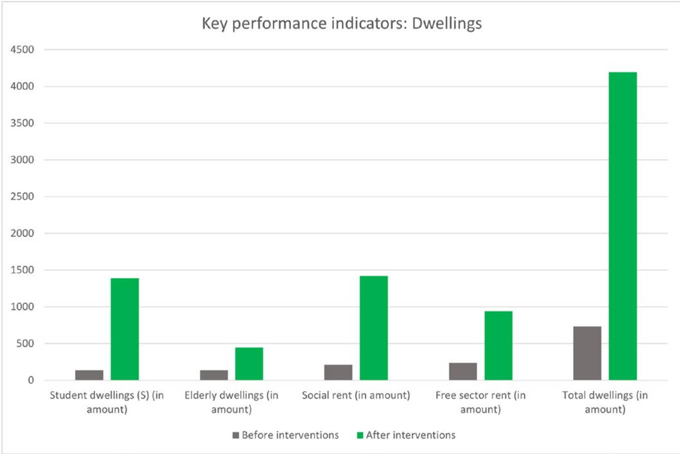


Figure 78 Key performance indicators: dwellings

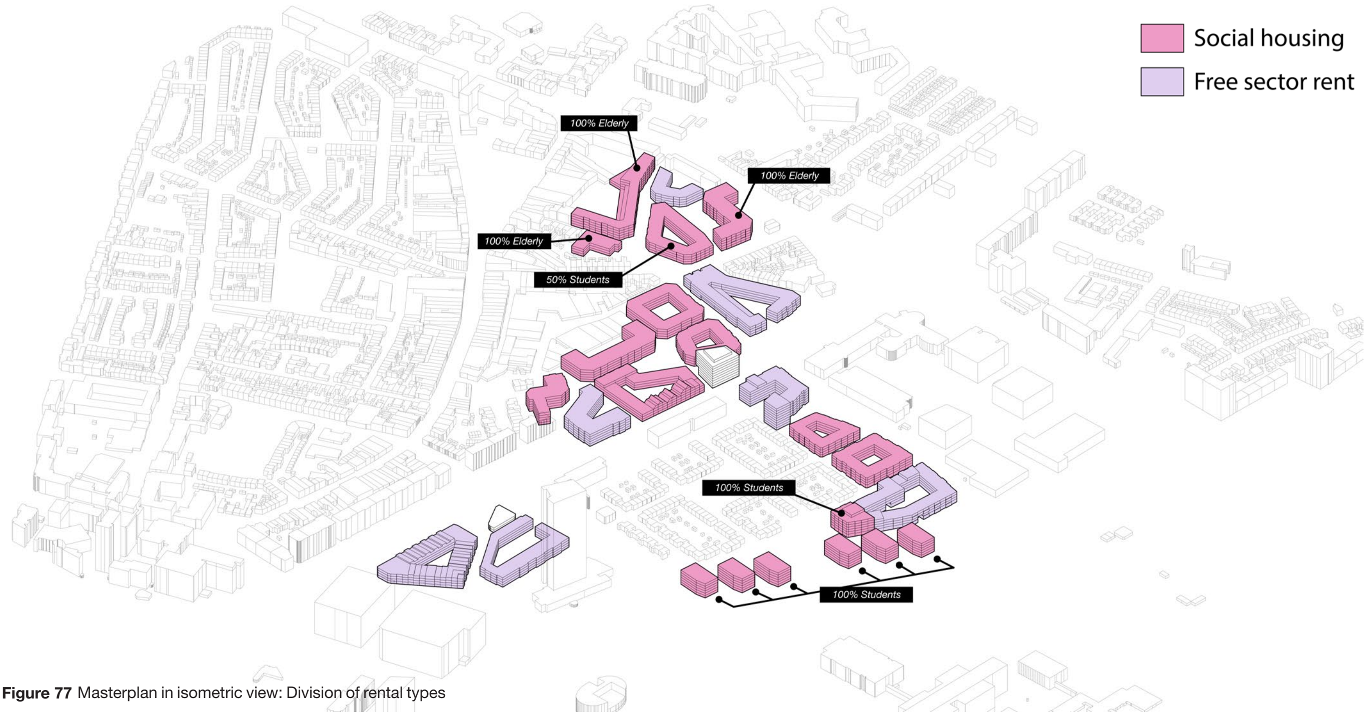


Figure 77 Masterplan in isometric view: Division of rental types

Lastly, the expansion of facilities in the neighborhood is discussed. By adding a lot of dwellings, the demand for facilities will increase. Due to the presence of the Kruisstraat in very close proximity, a large addition of functions is not necessary. With the additions made to make the Kruisstraat more accessible, the addtion of a few functions is proposed.

Most functions, like a gym, do not yet appear on the Kruisstraat. Additionally, supermarkets and pharmacies are necessary to match the future growth of residents. The addition of functions can be observed in Figure 81. Finally, the addition of function space is compared to the total addition of building surface. This can be seen in Figure 80. Only a very small portion of added building space is reserved for new facilities.

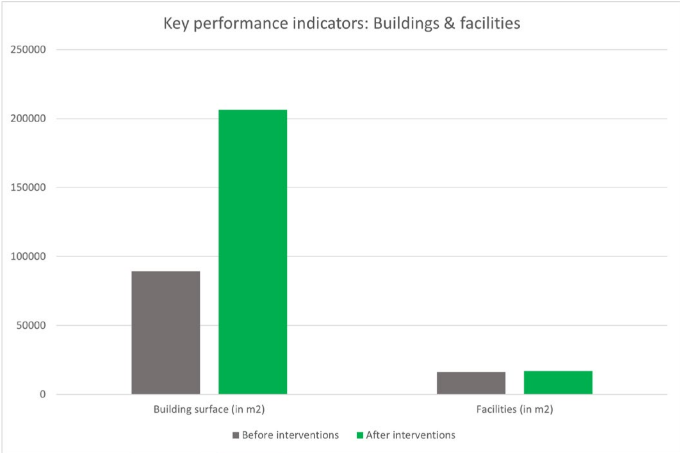


Figure 80 Key performance indicators: buildings & facilities

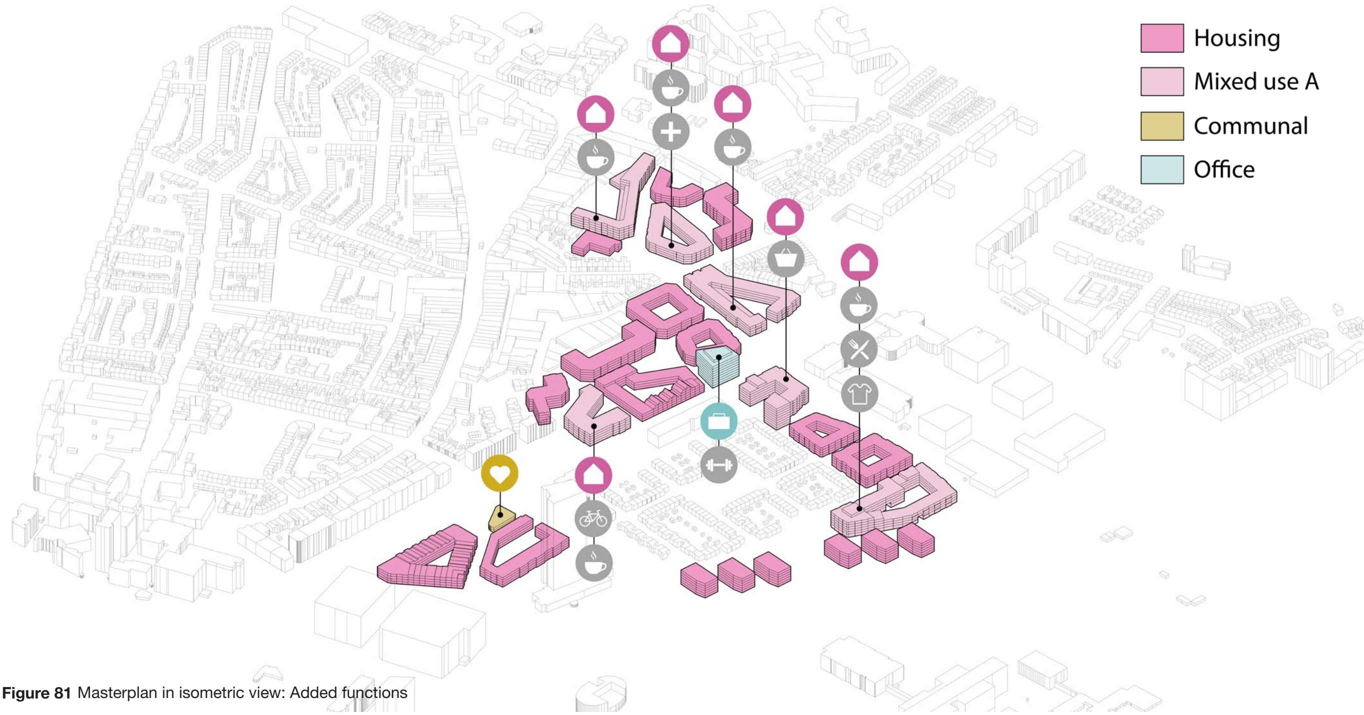


Figure 81 Masterplan in isometric view: Added functions

Figure 82 Position of urban sections in project area

7.6 URBAN SECTIONS

To provide a better overview of the impact of the proposed densification, three urban sections are provided. The sections have been cut in such a say to show the various forms of densification, and the resulting relationships between the height of the added volumes, and the public space in-between.

Section A covers the area between the added elderly homes and the dommelpark. Section B covers the area between the new high density area besides the Bunker tower and the Fontys campus. Lastly, section C shows the densification along the street connecting the park and the Kruisstraat.

Especially section C shows the impact of the new volumes, while sections A and B mostly show the new density compared to the older, unchanged Woenselse Watermolen density.

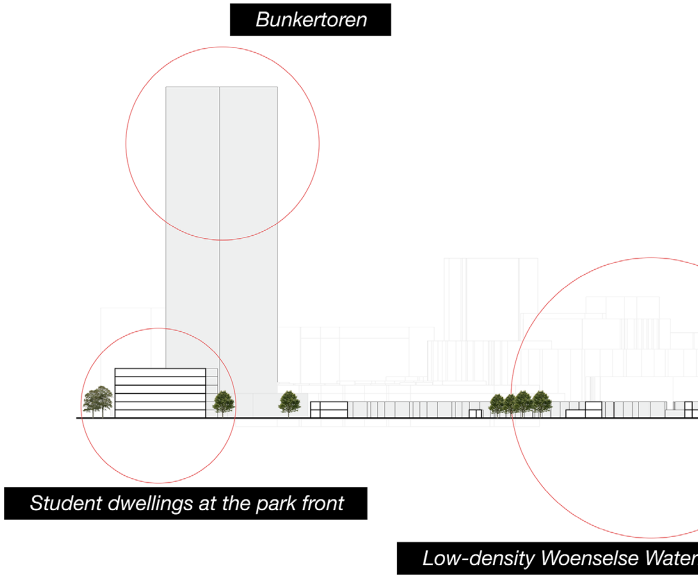


Figure 83 Urban section A

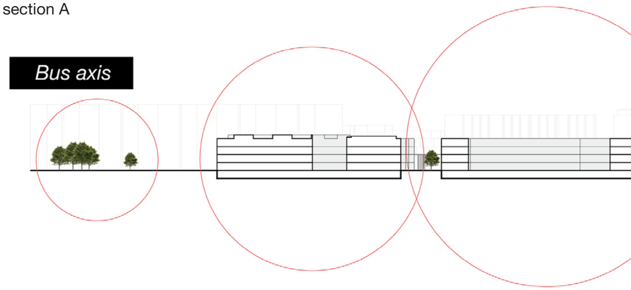
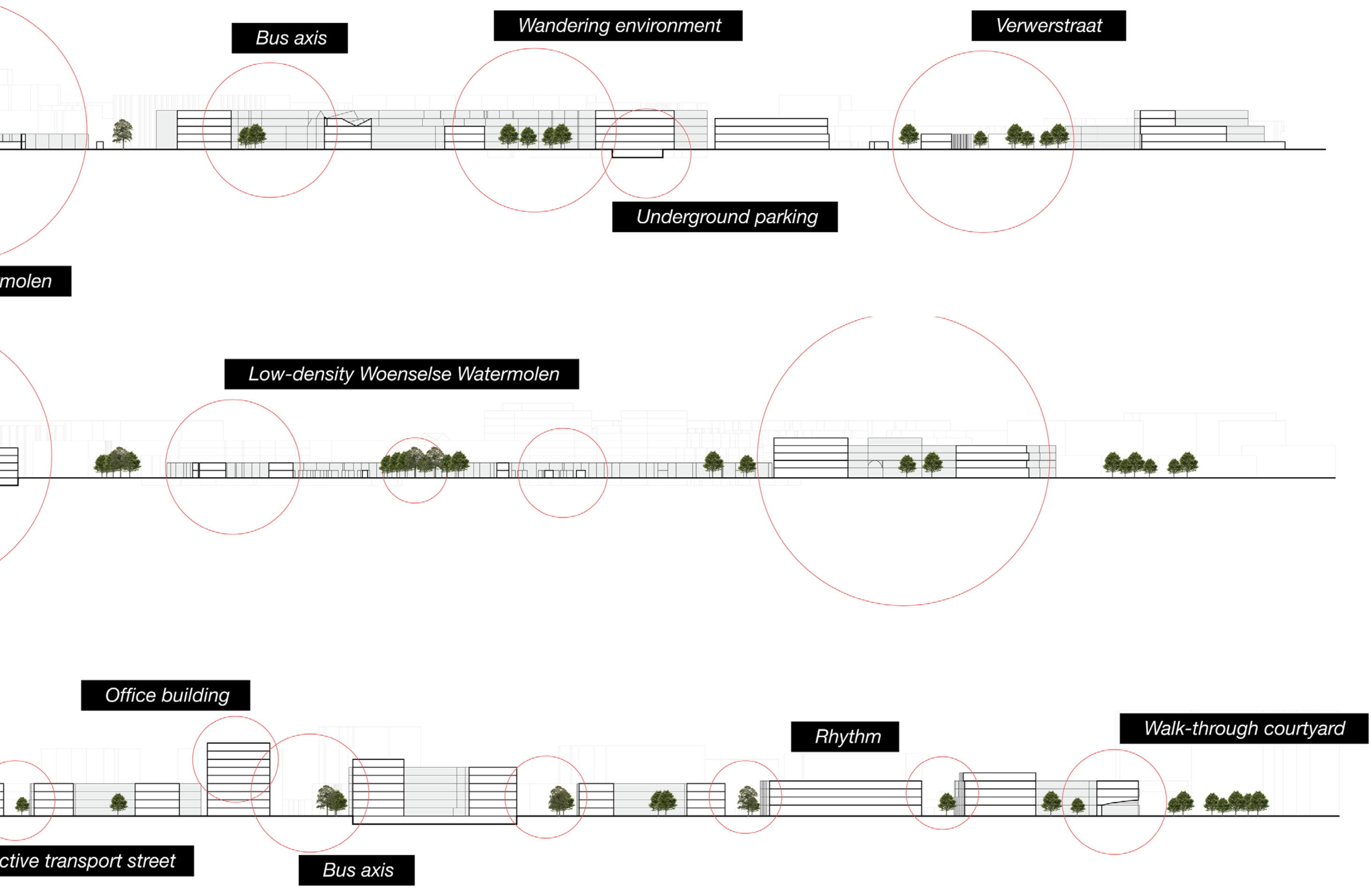


Figure 84 Urban section B

Figure 85 Urban section C


Bus axis
Wandering environment
Verwerstraat
Underground parking
molen
Low-density Woenselse Watermolen
Office building
Rhythm
Walk-through courtyard
ctive transport street
Bus axis

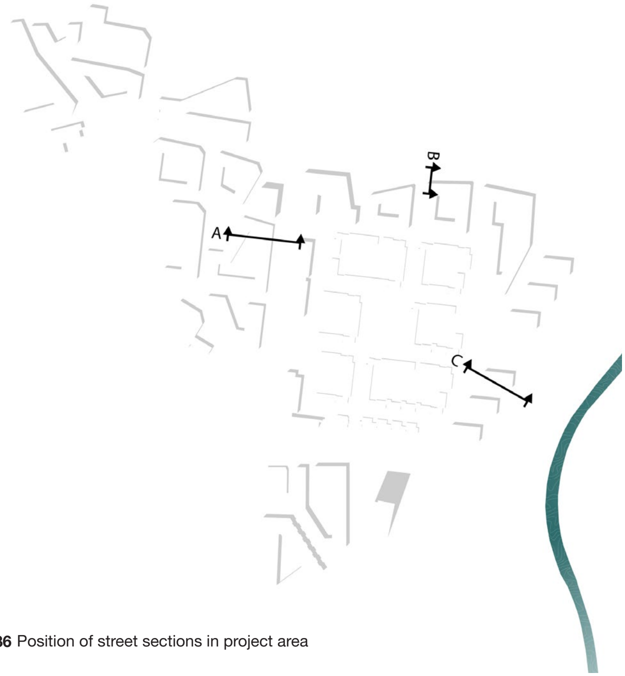


Figure 86 Position of street sections in project area

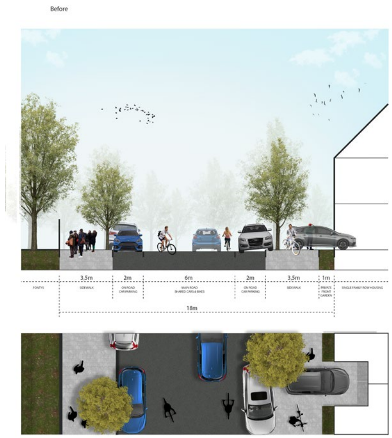


Figure 87 Street section B before interventions

7.7 STREET SECTIONS

To compliment the urban sections, a series of street sections is also created. These street sections are made with more detail, and show a before, and after situation. This is done to show the impact of interventions in a more detailed manner.

Each section shows a different street, renovated in a different way. For section A, this means depicting the added densification after reducing the presence of the Montgomerylaan.

Section B shows the change in the street between the Fontys campus and the Woenselse Watermolen neighborhood. Here, the transformation of the road towards a fietsstraat, in combination with more space for greenery is visible.

Lastly, section C shows the transformation of the John F Kennedylaan, running parallel to the Dommel. Here, the wide roads are offered for a smaller, single-directional road, and remaining space is used to densifiy and open up the park.

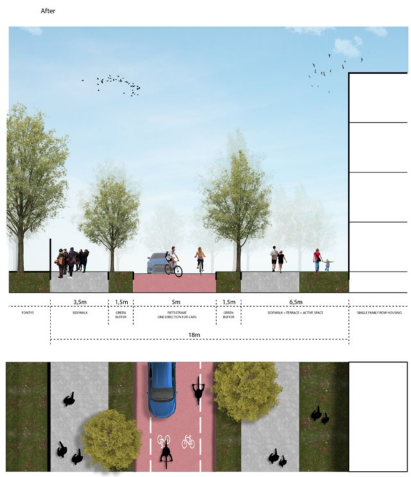


Figure 88 Street section B after interventions

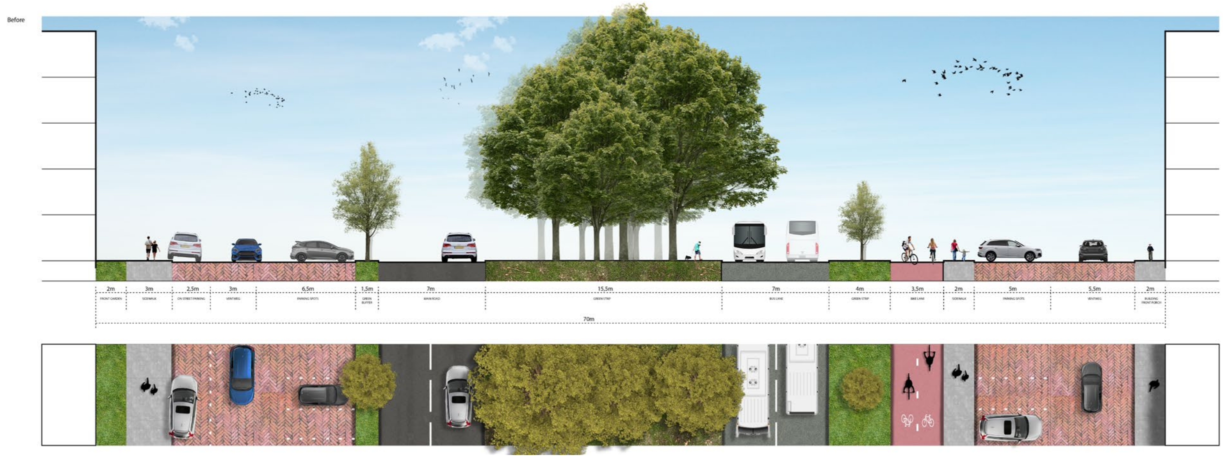


Figure 89 Street section A before interventions

Figure 90 Street section A after interventions

Figure 91 Street section C before interventions

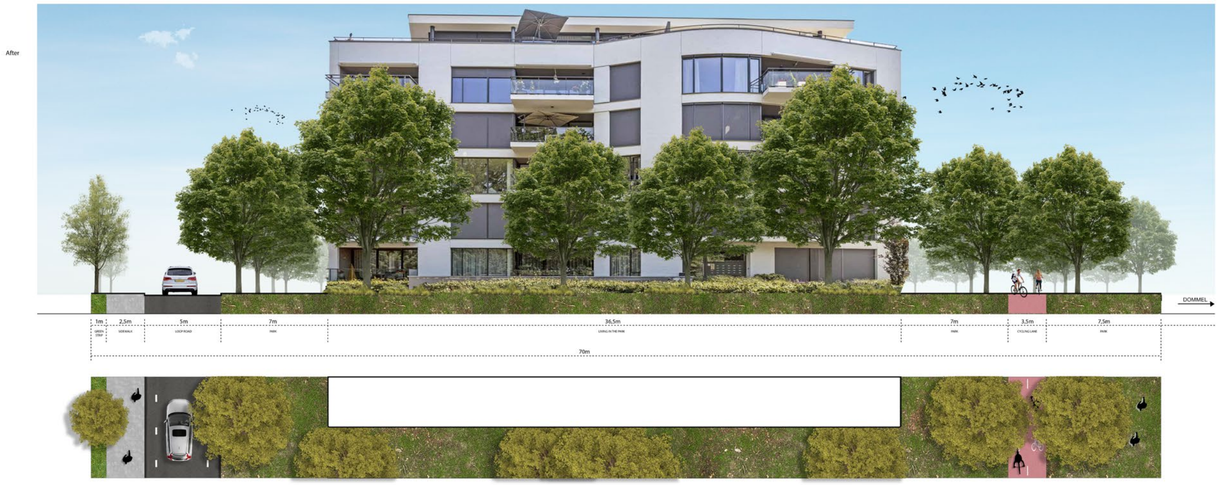


Figure 92 Street section C after interventions

7.8 PUBLIC SPACE

After all interventions, the balance of the public space is reconsidered. Before intervening, 55% of public space was reserved for greenery. After intervening, this has increased up to 63%.

Additionally, the introduction of shared mobility space can be found after interventions. This can be explained by the introduction of the hubs throughout the neighborhood. On the other hand, the parking area reduction is also substantial, changing from 8% to 3% of total public space.

The reduction in road surface is also strongly visible in the public space overview, as can be seen in Figures 93 and 94. Considering all public space, the road surface almost halves, after formerly occupying 20% of the area.

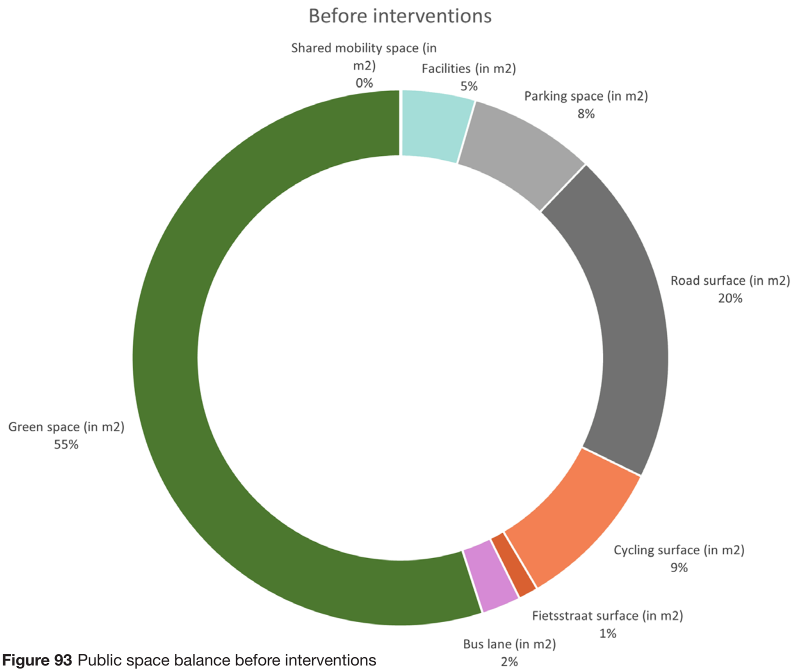


Figure 93 Public space balance before interventions

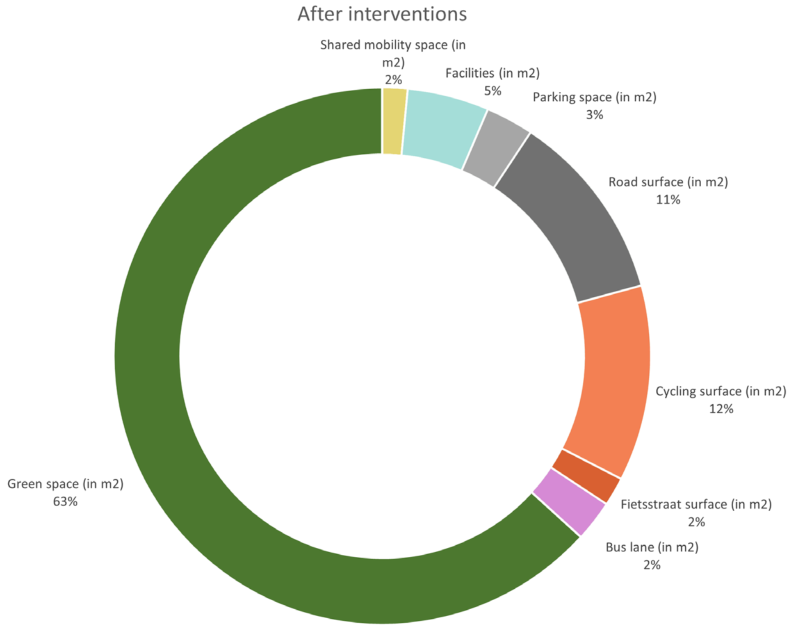
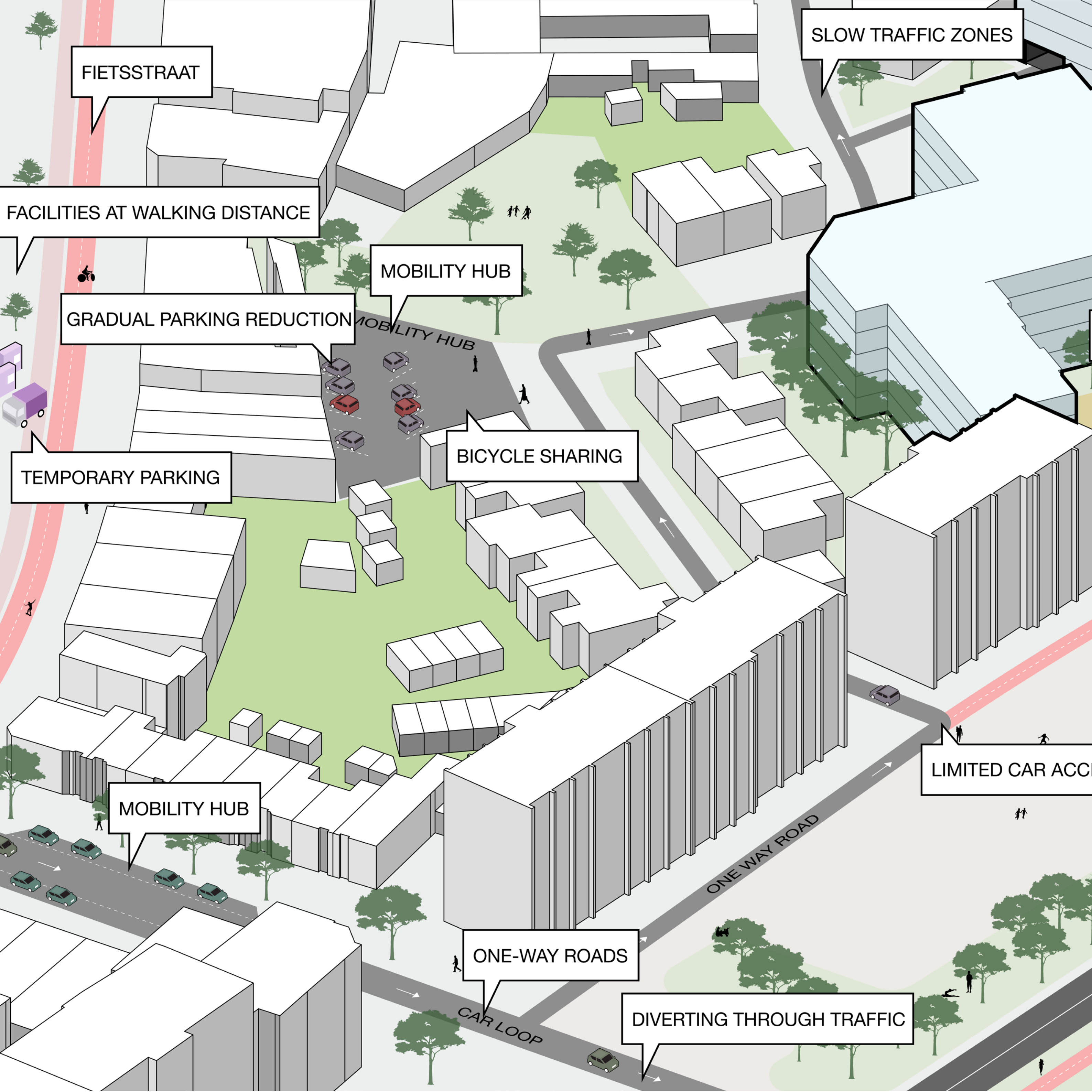


Figure 94 Public space balance after interventions



FIETSSTRAAT
SLOW TRAFFIC ZONES
FACILITIES AT WALKING DISTANCE
MOBILITY HUB
GRADUAL PARKING REDUCTION
MOBILITY HUB
BICYCLE SHARING
TEMPORARY PARKING
LIMITED CAR ACC
MOBILITY HUB
ONE WAY ROAD
ONE-WAY ROADS
CAR LOOP
DIVERTING THROUGH TRAFFIC

7.9 CONCLUSION

All in all, the goal of the design phase was to create a comprehensive strategy at various scales, ranging from regional to neighborhood. The strategy was accompanied by interventions. These interventions were applied on a strategical level in the bigger scale levels. In the neighborhood scale, the interventions were applied into a detailed design.

The strategy, together with the applied interventions, were based on literature and mapping analysis. This provided the design phase with a strong foundation. In the end, two neighborhoods were redeveloped within the context of a regional and city-scale strategy, all with the goal to reduce the reliance on private vehicles, with the goal to densify the city in the future.

After redevelopment, the neighborhoods Gildebuurt and Woenselse Watermolen were densified by 130,98%. Besides drastically increasing the density of both neighborhoods, more space for greenery was provided. This has strengthened the neighborhoods in their relationship to their surroundings. The green wedge of the Dommel river was solidified into the neighborhood, and the wide range of functions of the nearby Kruisstraat were made more accessible.

This redevelopment project has achieved to convey what is possible if mobility is approached from an other perspective, rather than the conventional car-centric perspective. By redeveloping cities with minimized attention to private vehicles, a lot of space opens up for people. This can open cities up and create better places to live. A necessity is offering plenty of alternatives to fulfill the mobility needs of inhabitants, aiding the mental shift away from the car towards sustainable, space-efficient modes of transport.

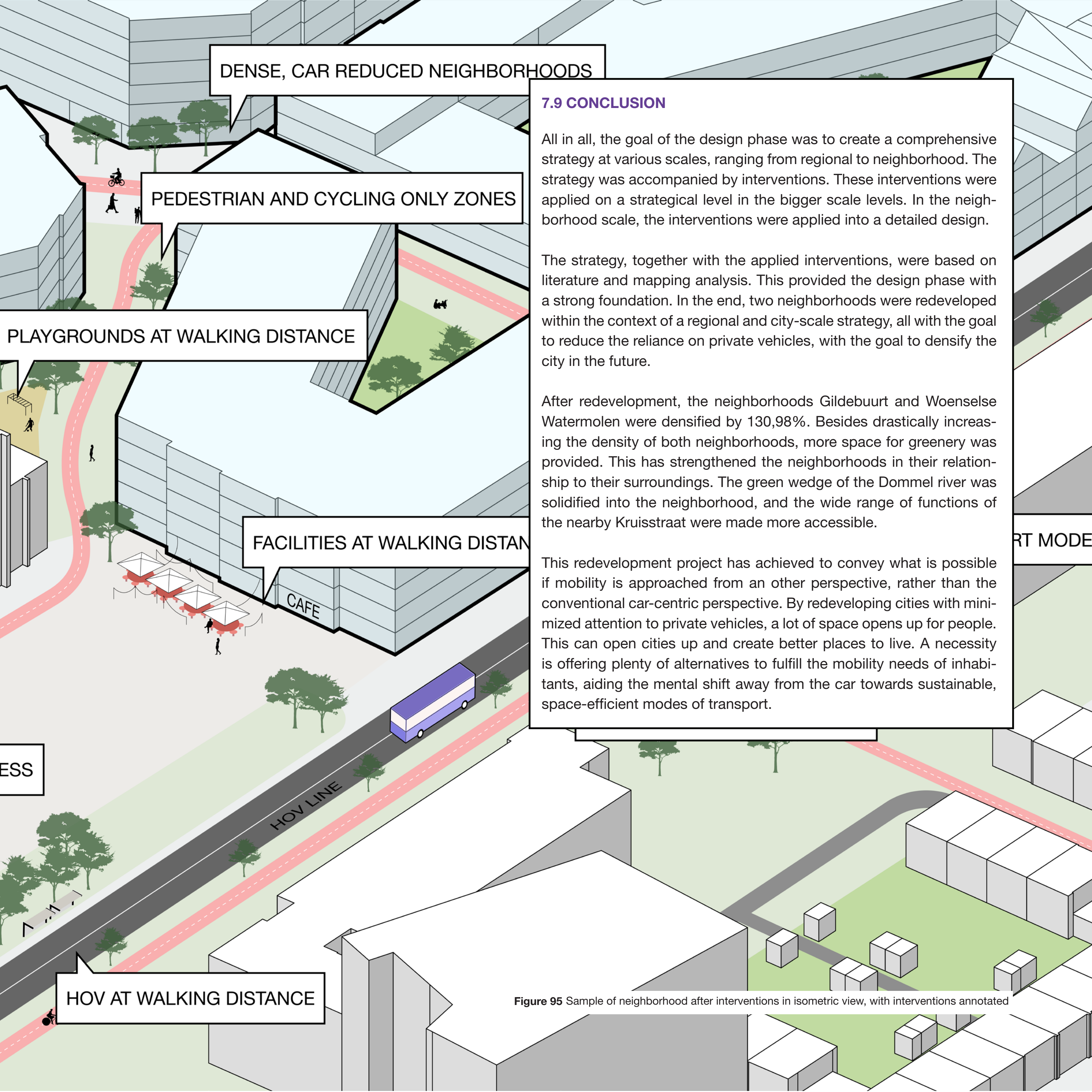


Figure 95 Sample of neighborhood after interventions in isometric view, with interventions annotated

Figure 96 Collage impression of a mobility hub in the redeveloped neighborhood


GO
Lime

Figure 97 Collage impression of the one-way loop road in the redeveloped neighborhood

Critical reflection

All in all, the objective of this thesis was to answer the main research question, with both a strategy and a design.

To what extent can the various neighborhoods of Eindhoven become car-reduced, and how can car-reducing interventions be applied within the context of densification?

Through the use of a systematic literature review, a list of neighborhood characteristics was set up, which provided an overview of qualities to look for in cities who aspire to reduce citizens' reliance on private vehicles. Additionally, a stakeholder overview and a list of interventions was derived, which could help during the design phase of the project.

The information on neighborhood characteristics was used to conduct a mapping analysis on the city of Eindhoven, which concluded with insights in the neighborhoods with the highest potential to become car-reduced. Based on the steps taken up until this point in the project, a location for redevelopment was chosen.

This chosen location consists of the neighborhoods Woenselse Watermolen and Gildebuurt, which are locted next to each other. In the design phase of the project, these two neighborhoods were transformed and densified, while maintaining a similar residential function. Through the applied interventions and subsequent design, the neighborhoods were densified by 130,98%. In terms of target groups, dwellings for specifically elderly and students were added in locations relevant to the demands of each demographic group.

Although this project has succeeded in answering the research question, and succeeded in densifying through design, certain parts need more explanation and critical analysis.

Firstly, the destiction between traveling for leisurous activities as compared to traveling for work is not explored to a detailed level. Demanding a shift in mobility mode choice is more simple when earning money to live is not affected. This is also a consequence of many years of car-centric development, and a reason why breaking car-dependency is difficult. Further research and design interventions specifically tailored for work related mobility and car-dependency is recommended. Options for overhauling work related travel should not be made by only workers, but also by the companies they are working for. For this, more flexibility is demanded.

Secondly, the neighborhood characteristics and interventions found are a mixture between different types of urbanism from places troughout the world. These different contexts bring in characteristics and interventions which can not be universally applied to equal standards. Therefore, it is advised to consider local context very carefully when applying interventions.

Thirdly, during the mapping analysis, many sources were used. Some sources were used to compliment each other, like for instance in terms of parking area data. This means that not all data from one dataset has been compared in similar ways, and could thus have caused some discrepancies in the results. This is however not solvable, unless all data is verified by one source, instead of spread over various sources with different parameters.

Fourthly, in terms of deciding on locations for densification and car reduced potential, some arguments could be made for more indicators. Due to limiting the size of the mapping analysis, some neighborhoods with average scores for redevelopment have not been chosen. Inner city neighborhoods and neighborhoods at the edge of cities function-differently, at least in the context of Eindhoven. It is thus not entirely fair to rate them by the same standards. Further research could implement a way to differently score neighborhoods with different systems.

All in all, this thesis has shown that there still is plenty of potential to densify the city of Eindhoven. In addition to the potential to densify, the city can strenthgen its green wedge structure and bridge gaps to facility hotspots, if it is willing to change its system of mobility. If current levels of car use are kept, this will be more difficult.

End

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Appendix

KEY PERFORMANCE INDICATOR TABLES

Table 11 Key performance indicator total data overview

KPI	*Before interventions*	*After interventions*	*Absolute change*	*Percentage change*
Total floor surface	*89.385m^2*	*206.461m^2*	*+117.076m^2*	*+130,98%*
Facility surface	*16.093m^2*	*16.929m^2*	*+836m^2*	*+5,20%*
Road surface	*72.808m^2*	*39.420m^2*	*-33.388m^2*	*-45,86%*
Bus lane surface	*8.503m^2*	*8.503m^2*	*0m^2*	*0,0%*
Fietsstraat surface	*4.320m^2*	*5.958m^2*	*+1.638m^2*	*+37,91%*
Cycling lane surface	*33.315m^2*	*40.610m^2*	*+7.295m^2*	*+21,90%*
Total biking infrastructure surface	*37.635m^2*	*46.568m^2*	*+8.933m^2*	*+23,73%*
Parking space	*27.568m^2*	*9.923m^2*	*-17645m^2*	*-64,00%*
Shared mobility space	*250m^2*	*5.218m^2*	*+4.968m^2*	*+1987,00%*
Green space	*198.735m^2*	*217.793m^2*	*+19.058m^2*	*+9,59%*
Amount of trees	*1.448*	*1.465*	*+17*	*+1,17%*
Total public space	*582.273m^2*	*582.626m^2*	*+353m^2*	*+0,06%*
Total private space	*245.810m^2*	*245.457m^2*	*-353m^2*	*-0,14%*

KPI	Before interventions	After interventions	Absolute change	Percentage change
Student dwellings	140	1.390	+1.250	+892,86%
Elderly homes	140	444	+304	+217,14%
Social rent	213	1.420	+1.207	+566,67%
Free-sector rent	238	940	+702	+294,96%
Total dwellings	731	4.194	+3.463	+473,73%

Table 12 Target group housing shortage shrink

KPI	Absolute change	Shortage in Eindhoven	New shortage	Shortage shrink
Student dwellings	+1.250	1.500	250	-83,33%
Elderly homes	+304	590	286	-51,53%
Social rent	+1.207	3.000	1.793	-40,23%
Free-sector rent	+702	unknown	unknown	unknown

LITERATURE REVIEW DESIGN CONSIDERATIONS

Table 13 Design considerations from the literature review

Neighborhood characteristic	***Literature mentions***	***Explanation***
Amount of parking spaces	*9*	*The amount of available parking space plays an enormous role in the feasibility of car use. Parking spaces in the neighborhood influence the accesibility of the car itself. The more car parking space available in the neighborhood, the bigger the negative effect on car-free mode choice.*
Public transport proximity	*9*	*Perhaps the most important characteristic of a neighborhood in increasing the effect of car-free mobe share is the accesability of other modes. The proximity of public transport stops is very important for this category, since it lowers the barrier of mobility without having to use a car.*
Amount of different services and resi-dences		*A city or neighborhood composed of a large mix of services and residential buildings shortens travel distances for inhabitants. Shorter travel distances are easier to cover via alternative transport modes to the car. Thus, a higher mixture of services and resi-dences has a very positive impact on car-free mode choice feasibility.*
Parking norms	*6*	*Parking norms are the cause for the available parking spaces, and indirectly also for parking demand. The influence of parking is signigicant in terms of mode choice. Lenient parking norms up the availability and demand, a stricter norm results in lower availability and demand.*
Neighborhood acces-sibility from outside	*6*	*Although it is important for the inhabintants of the neighborhood to reach destinations, it is also important people from outside the neighborhood can reach destinations in the neighborhood. If accessibility is high, especially via other transport modes than the car, the potential car-free mode choice in the neighborhood can result in a positive effect.*
Car ownership rates	*6*	*Car ownership rates provide an indication to the citizens that are able to use a car effectively. If more people own a car, usage will (usually) also be higher. Higher car ownership rates have a negative effect on car-free mode choice.*
Parking demand	*6*	*Free parking is often seen as a right, even moreso in a car-dependent neighborhood. A mixture of mobility attitude and parking availability influences demand. Parking demand is also dependent on the availability and accessibility of other transportation modes. A high parking demand is often a symptom of a neighborhood that lacks alternative transport modes. Thus, a high parking demand has a negative effect on car-free mode choice.*
Age	*5*	*Car-free neighborhoods are favorable places to raise children. Considering age groups, young families are most likely to favor living in a car-free neighborhood. If age groups corresponding with young families are overrepresented, this positively impacts car-free mode choice.*
Amount of inhabitants per area unit	*5*	*A close connection with the amount of dwellings, a neighborhood with higher density of citizens is favorable for car-free development, and thus also positively impacts car-free mode choice feasibility.*
Total amount of ser-vices and residences	*4*	*This topic is a mixture of the amount of different services and the total amount of buildings, thus variety and density. Both of these factors have a large positive effect on car-free mode choice.*

Neighborhood characteristic	***Literature mentions***	***Explanation***
Fuel and charging stations	*4*	*In neighborhoods tailored to car users, plenty of car infrastructure will theoretically re-sult in more comfortable driving. Neighborhoods close to highway entrances and other important traffic structures will negatively impact the mode choice towards car use.*
Parking costs	*4*	*The economic aspect of parking also affects car-use. Car parking costs can come in the form of a charge for parking temporarily, or in the form of paying for an unlimited private parking spot. Parking costs affect the costs of using a car for mobility. Higher costs can cause exclusivity, but will have a positive effect on car-free mode choice.*
Greenery & Street ornaments	*4*	*In similar terms to speed limits, neighborhood characteristics that positively influence other transport modes than car use will have a positive effect on car-free mode choice. Plenty of greenery and street ornaments aimed towards pedestrians, cyclists and bus riders will increase comfort and affect mode choice positively.*
Amount of dwellings	*3*	*A concentrated or compact city structure in terms of residential locations is creates a favorable condition for introducing car-free development. A higher density positively impacts car-free mode choice feasibility.*
Speed limits	*3*	*Neighborhoods with low speed limits are more likely to have a positive effect on car-free mode choice. When cars are present, the slower they drive, the safer other modes of transport become, this increases comfort for other modes.*
(protected) bike lanes	*3*	*The availability of a widespread bicycle network consisting of comfortable to use and protected bike lanes will cause more comfort using a bicycle to commute. A greater level of bicycle infrastructure in a neighborhood will positively affect car-free mode choice.*
(protected) sidewalks	*3*	*Similar to the availability of bike lanes, a good sidewalk network allows people to get around on foot in comfort and safety. The increases the appeal to walk instead of opt-ing for the car. Sidewalks, just like bike lanes, positively affect car-free mode choice.*
Commuting distances	*3*	*A topic that ties in with density of dwellings and services, as well as distance to public transport. The topic is about proximity, at higher proximity levels, people will be less likely to use the car. A city with a high level of proximity will thus be favorable in terms of car-free neighborhoods. High proximity has a positive effect on car-free mode choice.*
Air pollution	*2*	*Car-free neighborhoods can severely reduce air and noise pollution. Pollution can pro-vide authorities with a reason to intervene in certain locations where pollution is high. It is less comfortable to walk or cycle outside when there is lots of pollution from cars around. More pollution has a negative effect on car-free mode choice.*
Noise pollution	*2*	*Similar to air pollution.*
Urban heat island effect	*2*	*A larger paved area in the neighborhood causes health nuisances for people outside of air-conditioned cars. A larger portion of paved area in neighborhoods negatively effects car-free mode choice, since it lowers the comfort of walking or cycling.*

Neighborhood characteristic	***Literature mentions***	***Explanation***
Distance to services	*2*	*The distance to services or shops is similar to the amount of different shops and services present in the neighborhood. However, if a neighborhood is close to an external service cluster, this changes the potential of car-free mobility. Closer distance positively effects car-free mode choice.*
Bike parking	*2*	*To facilitate the needs of cyclists, providing ample bike parking infrastructure is necessary. Bike parking takes up lower amounts of space than car parking does. Bike parking has a positive effect on car-free mode choice.*
Trip cost	*2*	*Trip costs play an important role in mode choice. If alternative modes to car use are cheaper and remain feasible, more people will make use of those other modes. If car use is the cheapest mode, more people will use the car.*
Car use costs	*2*	*Similar to parking costs, higher expenses for car-use will result in lower usage. Vehicle taxes are not regulated on neighborhood scale, but can play a role in larger areas. Higher vehicle taxes will have a positive effect on car-free mode choice.*
Income	*2*	*Income levels have a marginal effect on car use. A higher income allows for easier car purchase and other costs like fuel and parking. Higher income levels negatively impact car-free mode choice.*
Employment	*2*	*Highly educated workers are more likely to live in car-free environments. Additionally, jobs that are more easily done remotely are favorable for car-free mode choices. A high share of workers with service vehicles and equipment negatively impact car-free mode choice.*
Level of maintanence	*2*	*Maintaining the neighborhood in terms of physical appearance and social structures can strenghten car-free modal choice. Strong social structures can reduce commuting distances and car-free role models can influence neighborhoods. A high level of maintanence has a positive effect on car-free modal choice.*
Different housing typologies	*1*	*Different housing typologies may have a marginal effect. It is mostly important that the housing typologies have no built-in place to store vehicles, as this will increase convenience of using the car. Typologies with garages or dedicated parking space are to be avoided.*
Car restricted areas	*1*	*Car-restricted neighborhoods cannot exist on their own, they need an accompanied city strategy. Neighborhoods with already car-restricted areas have a positive effect on car-free modal choice.*
Road infrastructure spending	*1*	*Spending on road infrastructure is often many times more than public transport funding. The balance between the two can indicate the state and priority of both transport modes. More spending towards public transport has a positive effect on car-free mode choice.*
Obesity & Health	*1*	*Car infrastructure allows vehicles tailored to people with disabilities to travel through the city. In car-free environments, disabled people might face obstacles. Therefore, it is important that these people are still able to reach their destinations without car dependency. Since this is not always the case, higher levels of health problems have a negative effect on car-free mode choice.*