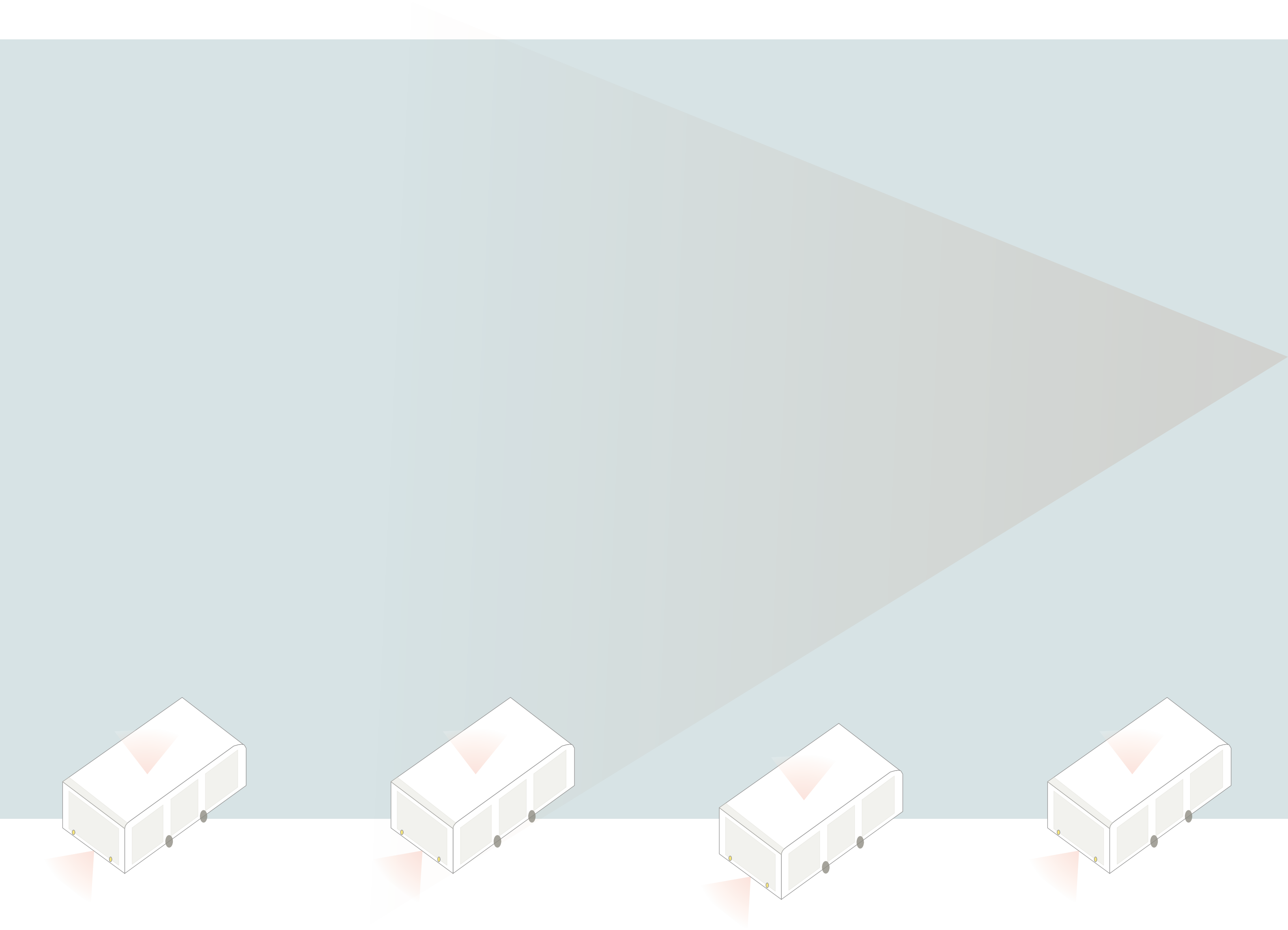
THE CITY-FRIENDLY CAR?

URBAN DEVELOPMENT IN A NEW MOBILITY AGE

- SOPHIA HAAS -



Chalmers University of Technology
Department of Architecture and Civil Engineering

Supervisor: Jorge Gil
Examiner: Meta Berghauser Pont

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ABSTRACT

The progress of industry towards autonomous cars will change our cities in similar ways as when the car was introduced on a large scale 70 years ago. Cities must understand the impact of the introduction of autonomous cars and **consider the long-term effects for its citizen**, if we want to steer this transition towards the city-friendly car. Industry is moving forward fast and has already reached the second stage of advanced driver assistance systems of cars, that provide safer journeys for the car driver, and **prototypes are testing full automation**.

Are municipalities able to take advantage of this development **to adjust urban planning towards a healthy and sustainable living environment**? Does the change towards autonomous cars allow a transformation of street space that can be used for **more greenery**, as well as for more **pedestrian- and cyclist-friendly solutions**?

This thesis explores potential impacts of autonomous cars on greenery and walkability in cities. Implemented by the **development and assessment of scenarios** that translate current visions and trends of industry and policy into a tangible design of the future city, using the case of Gothenburg.

To get a broader perspective, the thesis includes a **review of the 1960s, which reveals the motivations and impacts of this mobility transition** that led to the current car-friendly city. Further, an **online survey** is conducted that shows how the car, formerly as a symbol of freedom, has lost its status, especially for the younger generation. This knowledge, combined with current visions and trends introducing autonomous driving, are used to develop two scenarios: 1. "***The Door-To-Door Society***" and 2. "**The Ride-Sharing Society**". In both scenarios, it is assumed that full automation takes place, but in scenario 1, the **car remains privatized**, while in scenario 2 it is a **common good**. With a spatial design approach, scenarios are designed and then assessed in how well they perform in terms of greenery and walkability.

The outcome of this thesis shows that both scenarios perform very different. **The concept of sharing is a more important parameter, than the transition toward automation**. The thesis concludes that the change from the car-friendly city to the city-friendly car is within reach, but that it is highly **depends on mobility behaviour and the willingness to share**.

Keywords: autonomous vehicle, greenery, walkability, the car-friendly city, future urban development, scenario-based approach, the city-friendly car, ride-sharing.

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Then a big thanks go to **Erik**, who supported me mentally during this phase. I also want to thank all **my friends and my family**, with whom I could discuss this work and who also sent me interesting reports. In addition, I thank all those who have **participated in my survey**!

You all made this work possible!

Tack så mycket! Vielen Dank!

READING INSTRUCTIONS

The thesis starts with an introduction, in which the motivation for this work is described and the problem is formulated. The chapter also presents the research question and the methodology with its delimitations, that are used to answer the questions. The work response to the questions in a chronological way following different steps.

Step 1 describes the background, in which the scenario-based approach and regulations of greenery and walkability (liveability) are presented. **Step 2** provides a historical insight into the car-friendly city. A special focus is on the handling of liveability in cities, that guide through the whole work. **Step 3** describes today's trends and visions of different representatives about autonomous driving. **Step 4** develops the scenarios, in different scales. **Step 5** then evaluates the scenarios on their liveability. These steps are followed by the synopsis which reflects the work.

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1. INTRODUCTION

1.1 MOTIVATION

The idea of the Master`s Thesis has developed during the Master`s Thesis Preparation Course. I have a degree in landscape architecture, in which I have carried out different projects. Nevertheless, my interest has always been in **urban mobility and its impact on the urban development**. “*What effect does motorised traffic have on other road users and how does it shape the city? Or is it the city that shapes the traffic*?” These were open questions for me, which I wanted to pursue in the form of a Master’s Thesis.

Since controversial debates are increasingly discussing the the change of mobility towards **autonomous driving**, it quickly became clear to me that the effects on cities would not be examined under “*normal*” cars, but under autonomous vehicles.

The effects of the petrol-driven cars are well known, if one dare to look back in history. “*The Car-friendly City*” in the second half of the 20^{th} century, describes exactly these effects (Maurer, Gerdes, Lenz, & Winner, 2015). Also then, **people were on the threshold of a new form of a revolutionary mobility**.

That’s why I wanted to draw the arc in my work and venture such a retrospective view of the history in order **to understand the motives for a car-friendly city and its visions**. These can help to understand structural changes in urban planning and the people`s mindset. With this as background information, it is interesting to also explore the **visions and trends towards autonomous driving today**.

Since I come from landscape architecture, I wanted to put an additional focus in my work. This includes **greenery and walkability** in cities. What impact do autonomous cars have on the urban environment and how do these changes affect the distribution of greenery and walkability?

The work follows the motivation to answer these open questions to get a broader understanding of the **relation between mobility and urban environment**.

1.2 PROBLEM STATEMENT

Controversial discussions about the future of the car can be pursued daily in the news. Above all, the German car industry is involved in a **scandal over fake waste gas values in diesel vehicles**. Although the required CO_2 values are maintained on the test block, they are exceeded on city roads. The industry promised customers to buy an environmentally friendly and clean car when buying a diesel. Consequently, **consumers have been deceived and fooled**, what damaged the image and the credibility of the diesel and the car industry sustainably. In the United States, Volkswagen had to buy back the affected cars and in Germany high financial penalties had to be paid (Hulverschneidt, 2016). What cannot be bought back, is the **lost trust of consumers** who have consciously decided for a supposedly environmentally friendly car.

The whole fraud additionally enhanced the **debate about polluted air in cities**. Increasing dissatisfaction with an excess of fine dust in inner cities, forced local communities in Germany to block roads specifically for older diesels, that are not corresponding the European Norm 5 (Matthies, 2018). **The one who actually pays for the whole scandal, are the betrayed consumers**.

The movement "***Fridays For Future***", developed under the activist Greta Thunberg, mobilises students around the world every week, to fight for the climate and the future of the earth. Climate change is immediate and the **pressure on the car industry to switch to e-mobility and autonomous driving** is increasing, with every day. Due to the pressure of society and the competition among themselves, companies are already developing **prototypes of autonomous vehicles (AVs)**.

But before these new forms of mobility will enter the cities, many questions need to be answered. First, what form of autonomous driving will be introduced to cities? Will they remain as a **private good**, as the petrol-driven car today, or will the paradigm of mobility change towards an **on-demand society using ride-sharing services**? And how will this new form of mobility affect the urban life in cities?

That the car has an impact on urban development has not been a secret since the car was introduced in the second half of the last century. The new mobile freedom overshadowed other forms of mobility, structured inner cities, and city growth in their favour (Maurer et al., 2015). This development towards the **car-friendly city, partly dominates and shapes the configuration of cities until today**. Pedestrians often remain subordinate to traffic. The result is long waiting times at traffic lights, crossing dark underpasses, or exhausting bridges. Green is often seen as just accompanying roads but has to gain a stronger position in the cities in terms of the coming challenges of advancing climate change.

Even autonomous cars will have an **impact on the urban environment**. A tightly timed and connected driving style not only makes roads safer but also increases their capacity. Both roads, and parking areas can be used more effectively through the autonomation. Excessive street space could thus be returned to the city and public life (NiMo e.V., 2017). But, how might the street space look like, where the urban environment is highly connected with autonomous vehicles? **Is there place for greenery, pedestrians and cyclists on these roads**?

1.3 RESEARCH GOAL AND QUESTIONS

The aim of the work is to find out **how different forms of autonomous driving affect the urban environment**. For this, trends and visions of the car industry and politics are researched and transferred into scenarios. **Spatial effects on greenery, cyclists and pedestrians** are then visible and can be assessed and evaluated in the further process.

The development of scenarios is proceeded by a **Research by Design** approach that examines the effects of different autonomous vehicle models on the urban structure. The scenarios are developed on the example of **Gothenburg** in three different scales in order to gain the **greatest possible insight**. Depending on the scale, the detail and focus of **different influence criteria**, that are examined for their structural change, differ. The two scenarios are based on a previous literature review, that provides a foundation for criteria selection and gives the thesis an academic degree.

The following **main research question** serves for the scenario development and literature selection and is answered by relating sub-questions.

HOW MIGHT THE CHANGE TOWARDS AUTONOMOUS VEHICLES IMPACT THE LIVEABILITY OF CITIES IN THE FUTURE?

1. What are the existing strategies and regulations of greenery and walkability?

   By exploring important regulations at global, national and regional level, important characteristics of greenery and walkability are acquired, which serve as criteria in both, the scenario design and the following assessment.

2. What can we learn from the mobility transitions and the city development of the past?

   Important motivations of the mobility turn are recognised and their effects on greenery and walkability. Conclusions about possible complications can be drawn.

3. What are the visions of the industry and the policy?

   The visions serve as a starting point for the scenario development and at the same time limit the selection of technologies for autonomous driving.

4. What are possible spatial effects of autonomous vehicles on the city structure?

   The visualisation of scenarios under different kinds of autonomous vehicles, illustrates spatial changes in different scales.

5. What could the liveability of future cities look like?

   Direct effects on greenery and walkability can be recognised in the scenarios.

Working with scenarios makes it possible to visualise **extreme situations** and to exhaust possible future changes to the utmost. In doing so, **positive effects of autonomous driving** on the urban structures can be recognised, but also **negative influences, complications** and possibly even dangers, which would result from a certain scenario. Additionally, not only experienced planners and architects but also the layman is able to recognise and understand the effects through their **visual capacity**.

1.4. METHODOLOGY

In order to be able to explore and present the possible future urban changes through the introduction of autonomous vehicles, it is important to become acquainted with the subject in literature (Figure 01). It examines the **trends and visions of society, industry and politics on autonomous vehicles**, that form the basis of the scenario development. In addition, a historical approach is included to understand the **motivations for the redesign of urban structures towards the car-friendly city**. The thesis includes a special focus on greenery and walkability. The **goals of the *United Nations* and *The Urban Agenda*** additionally provide the legal framework and ideas for the city of tomorrow.

With this background, **Research by Design** with a **scenario-based approach** aim to translate the theoretical foundations into spatial representations. Both positive and negative conclusions of the effects of autonomous vehicles on the urban structure and sustainability can then be worked out. Scenarios can serve as a "*warning system*" if potential restrictions and complications are to be expected in the future.

STEP 1: Background

Step 1 provides an overview of **theory and principles** that serve as a theoretical background and as a basis for the development of the thesis. Research papers from different universities, journals and books about **scenario-based approaches, the construction of visualisations and alternative futures**, give examples of how to develop scenarios with the help of a participatory processes. These provide important questions and a variety of methods to successfully develop future scenarios.

The background additionally, explores **urban qualities (greenery & walkability)**, that contribute to a sustainable urban development. On the one hand, the investigation takes place on the **global level**, where guidelines of *The United Nations* and *The Urban Agenda* for greenery and walkability are selected. Depending on the location of the case study, national and regional legislations must be consulted. For the **national level**, the thesis examines the Swedish' criteria for greenery and walkability. Strategies of the *City of Gothenburg* deliver the **regional objectives** for the handling and implementation of the qualities in urban space. A summary of the elaborated urban quality criteria **serves to design the scenarios, as well as for the subsequent assessment**.

STEP 2: "Drivers of the past" - A historical approach

Each scenario-based approach includes a **literary review into historical events**. Actions of the past can then be reflected in order to derive possibilities, or to avoid possible negative influences and risk in the present. The thesis examines the work of **Per Lundin**, about the introduction of the car into society and cities in the second half of the 20th century. The motives towards the car-friendly city and the influences of the car on urban structures in Germany, Sweden and the United States are presented. The handling with **greenery and walkability** is additionally examined and supported by **photos** of the time. A summary helps to shows the results of the quality factors, that can later be compared with the future scenarios of autonomous driving.

STEP 3: "Drivers of the present" - today`s understanding of mobility

Step 3 examines the motivations of the present toward autonomous driving, in **politics, research and in the car industry**. The goal is to find out in what level of autonomous driving the technology is today. In addition, expert assessments are reflected on **how full automation could affect society, urban structures and urban qualities** (focus: greenery & walkability). This provides important insights into technology and possible effects of autonomous driving on the urban environment. On the one hand, it serves as a **direction choice and as a limitation** of possible technical developments, on the other hand, it sets the **starting point for the scenarios**.

In order to find out relevant information, the *Press and Information Office of the Federal Government of Germany* was examined for autonomous driving and possible legislative changes. Academic news, statements of company leaders, videos from "*Drive Sweden*" and the car industry, research studies, and reports serve as sources that explore **future mobility under technical, spatial, legal, and social aspects**.

To strengthen chapter 4 "*Today`s understanding of mobility and future visions*" an **online survey** has been included. Usually, in a scenario-based approach it is necessary to implement a workshop to get to know the participant`s opinions and demands on their future. Regarding the limited worktime of a master`s thesis, it is not possible to build up such an extensive participatory step. To compensate this, the online survey collects in a short time **important information about the mobility habits of the population**. A broad age range is an advantage in order to experience the wishes and demands of different generations. The summary and assessment of this survey gives a conclusion about how the future urban environment should look like and what the role of the car might be. It also demonstrates a self-assessment of the road users and their willingness to adapt to new forms of mobility. Out of this survey, **commuters** derived, that are introduced in step 4 and help to assess the scenarios in step 5.

STEP 4: Scenarios

In this work, **two opposing scenarios** are considered, that both deal with the topic of autonomous driving. The form of autonomous driving has been defined in step 3. **Commuters**, that developed out of the survey, additionally represent their mobility behaviour today.

The first scenario of "***The Door-To-Door Society***" assumes that individuals, as today, will own their own autonomous car. In the second scenario of "***The Ride-Sharing Society***", private cars are replaced by an autonomous taxi fleet based on the demand principle.

The scenarios are designed in **three different scales** (Metropolitan 1:75.000/ District 1:10.000/ Axonometry). QGIS with Open-Street-Maps (OSM) defines layers that represent the **criteria of greenery and walkability**. Each map illustrates a selection of layers, depending on its scale. Depending on the scenario, **layers can change in its spatial habit or in its attributes** to show the effects of autonomous driving on the urban environment. The **metropolitan map** visualises a large scale, that focuses on urban density, different types of green, public transport and parking situation. It gives an overview of the whole region of Gothenburg. The **district map** illustrates in an abstract way the street hierarchy, that sets the terms for the distribution of greenery and walkability. The **axonometries** are hand-drawn to allow the viewer to emotionally experience the impact of autonomous vehicles on the urban environment. It gives space for own imaginations, discussions and reflections.

The scenarios therefore represent **two completely controversial situations** that might both be possible in the distant future. Each of them will influence the urban configuration, greenery and walkability in its own way. In the end, it is possible to draw conclusions about the chosen form of mobility, to better understand and to assess its impact on the urban context.

STEP 5: Assessment of Scenarios

Step 5 assesses the scenarios in a **quantitative way**, to calculate direct impacts on the street system, the distribution and area size of greenery and the overall length of the pedestrian area. With these calculations, the **spatially recognizable changes get a concrete number**, which varies depending on the scenario. The effects of the two modes of autonomous driving and the differences between the two scenarios are clearly visible. All calculations are done in **QGIS** (geographic information system) by using different measurement tools of the "*Vector*"-tab. The **results are summarized in tables and diagrams and compared with the situation today**. The deviation of the scenarios from the current situation is given as a percentage.

Additionally, a **qualitative assessment of the commuters** is performed. In this step, it is important to be able to understand the demands of commuters, demonstrated by feelings, limitations and problems. The **commuters** help to better imagine, how the urban transformation of each scenario affect their life.

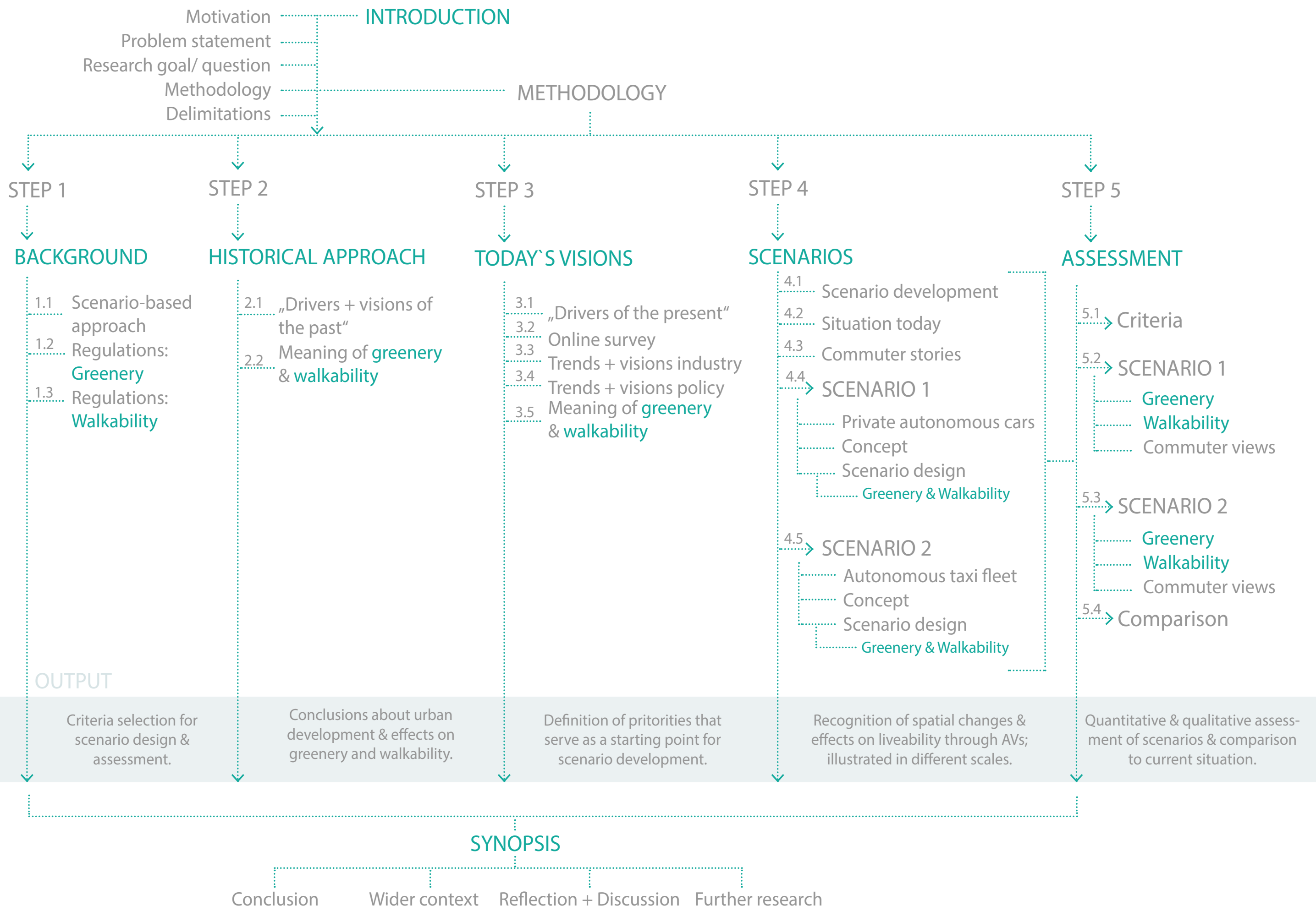


Figure 01 *Structure of the work*

1.5 DELIMITATIONS

Due to the limited time of the master`s thesis, it was important to narrow down the scope of the work. The **choice of urban qualities** is the first limitation. Sustainability in cities can be measured by different qualities, including the fields of ecology, economy, participation and social culture. It would have been exciting, in addition to greenery and walkability, to also explore **public spaces and its social factors**, that promote a healthy and inclusive city. A deeper assessment of the scenarios would then have been possible to also recognise **social impacts of autonomous driving** on the population. Social aspects are **partly explored by commuter stories**, but a deeper insight would have been interesting. The thesis touches other qualities of a sustainable city development, but they cannot be further developed.

Cyclists were partially involved in the work, if they can contribute to the **improvement of green qualities**, for example if they also serve as green corridors. The focus of the work is on walkability and greenery, and other important aspects that could be used to improve and expand cycle paths are neglected.

The second limitation is the **selection of technology** in the scenario design. The thesis discusses two scenarios, both dealing with full automation. However, it could have also been interesting to design scenarios, where the automation would not have been progressed so far. For example, where citizen would have switched to **car-sharing or ride-sharing models under petrol-driven cars**. Or, where a **mix between self-driving cars and petrol-driven cars** would exist in the same time. The selection of the full automation makes it possible to explore **totally contractionary scenarios** in order to gain the greatest possible insight into possible urban changes. The choice of the technology, as well as the quality factors were determined by the level of own interest.

2. BACKGROUND

2.1 A SCENARIO-BASED APPROACH IN (LANDSCAPE-) ARCHITECTURE

"*The mind is continually creating scenarios*" (Lindgren & Bandhold, 2003,p.22). With this quote, Lindgren and Bandhold (2003) are describing how important it is for humans to be able to imagine and discuss their own future. **Our brain is a scenario-machine**, which "*thinks ahead and processes information about what is to come*" (Lindgren & Bandhold, 2003, p.22). As Schwartz (1996) explains, scenarios are "***a tool for ordering one`s perceptions about alternative future environments in which one`s decisions might be played out***" (p.4) (compare Lindgren & Bandhold, 2003, p.21). This automatically realized future visions enables people to recognize and weigh their future and possible uncertainties. Different scenarios and their effects can be compared in this way. **A literary review additionally supports future visions by understanding and reflecting how we acted in the past**. Through this reasoning visions can be developed in the present to **detect negative influences and risks at an early stage** (Sztuka Achim, 2019).

Today, we are living in a "*fast-moving environment*" (Lindgren & Bandhold, 2003, pp.4-5) where quantitative forecasting techniques are insufficient, if predictions about the future are made out from the past (Sztuka Achim, 2019). **If a quantitative approach is not enough to develop future visions**, then according to Stiens (as cited in Hoffmann, 2016,p.45), **scenarios should be applied**. With the use of scenarios as a qualitative method, the "*discovery*" as a cognitive function got a higher priority than the "*explaining*" (Hoffmann, 2016, p.45). Scenarios are primarily used in planning processes that have to expect different future perspectives. This includes the field of urban morphology, that works out tools for morphological studies that are used to strengthen the design process (Ståhle, 2008).

In this case scenarios are used to deal with complex planning contexts, which needs to take spatial, and temporal aspects into account (Mertens, 2010, p.158). Scenarios often visualize extremes, which are showing possible consequences of the future development. Thereby, scenarios are no prognoses, they are not predictions of the future. The advantage of using scenarios as a method is, that they are showing a spectrum of **possible alternative futures** (Hagemeier-Klose, Albers, Richter, & Deppisch, 2013,p.422). For the critical reflection of the strategies and measures not only the contemporary most "*likely*" or most "*desired*" futures are considered, but different development types are taken into account (Figure 02)(Hagemeier-Klose et al.,2013,p.414). Hypothetical pictures of the future are serving for the identification of decisions and courses of actions, to extrapolate suitable strategies (Hagemeier-Klose et al.,2013,p.422).

According to Fürst (2005, p.23) this visualization technology plays also an important role in participation. **The translation and location of realistic or extreme trends or values into a tangible spatial design enables to make the future vision understandable for laypeo-**

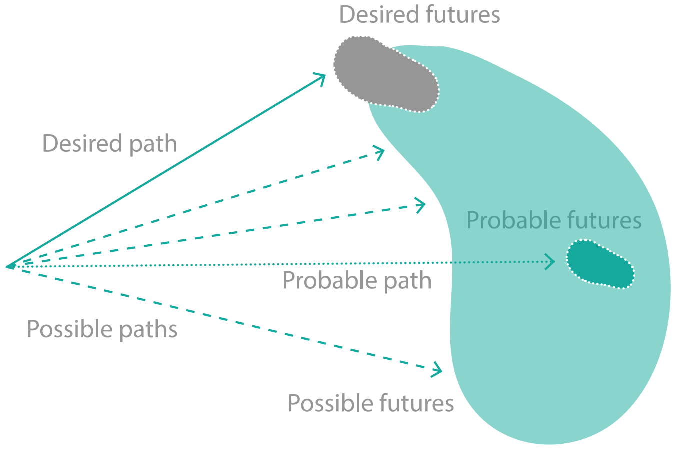


Figure 02 *The relation between probable, possible and desired futures (Lindgren & Bandhold, 2003, p.23) / own figure*

ple (Mertens, 2010, p.158). This increases the acceptance of planning and incorporates with the inhabitants to work actively on the future design of their cities. Through the graphical communication of the effects on the urban environment more affected people can be reached, than through administrative actions and political discussions (Mertens, 2010,p.178).

> *"a tool for ordering one`s* ***perception*** *about* ***alternative future environments*** *in which one`s* ***decision*** *might be played out" (Schwartz,1996)*

When using scenarios in landscape architecture, it is necessary to relate a fundamental theoretical background with the practice. "***Scenario techniques [...] connect generative design theory and analytical knowledge on morphology***" (Ståhle, 2008). The theory hereby, delivers the process of viewing, considering and pondering, before an action (the practice — designing and building) can be made (Berr, 2018). As Berr stated in 2018, the theory as the basis of the practice allows then, with the help of thought models the view of later actions and makes predictions and recommendations possible (p.74).

A well-built participatory process gathers information about the future liveability of cities and creates a high-quality vision (Ortegon-Sanchez & Tyler, 2016) (Pollastri et al., 2017). The construction of different future visions through a literary background goes beyond the "*all-too-common 'political wish list'*" (Ortegon-Sanchez & Tyler, 2016). To start scenarios, **workshops with residents or experts can be organized**. These workshops can be performed in different ways to get durable outlooks of alternative future visions. Many papers are describing different techniques to reach and work with the participants. Most of the design processes are performed in an "***explorative***" way, to answer the question "*What can happen in the future, if...*" (Pollastri et al., 2017). **Apart from the possible urban future, negative scenarios, or the weakest possible future urban development can be explored**. A 2x2 matrix additionally can help to locate different possible mobility forms, to test low or a high impact on future cities (LID, 2015) (Figure 03).

Regarding Willis (2014), the overall challenge in scenario planning and design is to work across different scales. Current trends are playing a role, as well as the user groups. Scenarios can also be "***reactive***" by asking "*what might happen*" (Willis, 2014) in the future. Another form is described by "***proactive***" scenarios. "*What might be possible*" (Willis, 2014) in the future. This question reflects **how the future conditions could be divergent from today**. An interaction between reactive and proactive allows to create scenarios in an arranged way "***of connecting the present with distant futures, of imagining, narrating and picturing how large-scale trends could play out and affect everyday life***" (Willis, 2014). Therefore, landscape architecture is much more than just technical-functional and aesthetically representative green in cities (Berr, 2018). We as "***[d]esigners are people who are paid to produce visions of better futures and make those futures happen***" (Willis, 2014).

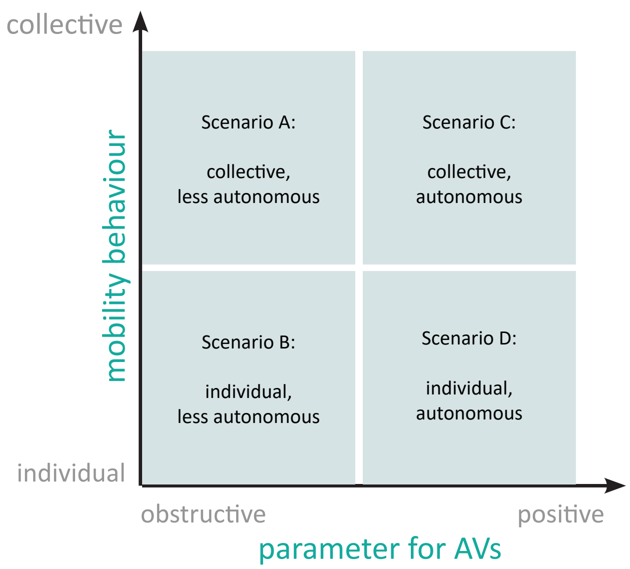


Figure 03 *2x2 matrix for future mobility models, based on (Gertz & Dörnemann, 2016)/ own figure*

2.2 STRATEGIES AND REGULATIONS: GREENERY IN CITIES

"En stad blir inte hållbar förrän människor trivs. För att nå dit måste vi sätta människor båda först och i centrum"
(von Schmalensee, 2018,p.2)

"Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more" (United Nations, n.d.-b, Goal 11). With this statement the United Nations are introducing the eleventh development goal for sustainable cities and societies. **Until today cities are often configurated by "*car-centred urban models*"** (UN-Habitat, 2012b), **which have big influences on the distribution of urban spaces**. Further, the UN-Habitat stated in 2012 (b), that many governments are not aware of the importance and the impacts of public spaces on the city quality, social development and other parts of humans well-being (UN-Habitat, 2012b).

The Nature-based Urban Innovation (NATURVATION), which is supported by 14 institutions across Europe and founded by the European Commission, strengthen the statements of the UN-Habitat. Sustainability is "***no longer a 'nice to have' addition to development-as-usual […] [it] is now central to response to climate change and in enabling growth, security and social well-being***" (NATURVATION, 2019b). Wetzel and Mu (2012) conclude that urban spaces and green cities are crucial, if we want to achieve a sustainable future for the next generation. Greenery provides a cooling effect in cities "*between 0,5 and 7°C, with an average of 1°C*" (Bockarjova, Uu, & Iii, 2017,p.4) and improves the "*resilience of cities to high temperatures*" (Ministery of the Environment and Energy, 2018,p.4). To build a healthy living environment and sustainability in cities a **connection between different green areas** must be developed. **Multifunctional ecosystems** enhance not only the city climate and living habitats for species, but they can "*act as a nature-based solution to tackle societal, economic, and environmental challenges*" (ICLEI, n.d.).

Although the political awareness of greener cities exists, UN-Habitat (2012b) stated that the main obstacles to sustainable urban planning are the **lack of laws and parameter at governmental and sub-governmental levels**. Therefore, The Urban Agenda 2016 adopted regulations, which should be followed and implemented by national governments and local authorities. According to greener cities the '*Declaration On Sustainable Cities And Human Settlements*' contains, that there is a need on multifunctional garden and parks for "***social interaction and inclusion, human health and well-being, economic exchange and cultural expression***" (United Nations, 2017, p.13). Furthermore, the UN-Habitat (2012) postulates, that open spaces are not only upgrading the character of a city, they are rather enhancing the overall "*functionality*" (UN-Habitat, 2012b).

> " [it is] *no longer a 'nice to have' addition to development-as-usual […] [it] is now* ***central to response to climate change*** *and in enabling* ***growth, security and social well-being***" *(NATURVATION, 2019b).*

To improve the restistivity of cities regarding climatic changes, flooding risks, dryness risks and waves of heat, paragraph 67 of the Quito Declaration highlights the importance of "***well-connected and well-distributed***" (United Nations, 2017, p.19) **green and public spaces**. These spaces have to be "*open, multipurpose, safe, inclusive, [and] accessible*" (United Nations, 2017, p.19). If these characteristics of public spaces are implemented, then additionally the **corpoal and cognitive health of the inhabitants, a better microclimate and the attraction of cities will be achieved** (United Nations, 2017, p.19). Another task for public spaces, as stated in The Urban Agenda § 100, is that they are "*free from crime and violence*" (United Nations, 2017, p.25). The Sustainable Development Goals (SDG) of the United Nation and The Urban Agenda 2016 are demonstrating the overall goals, regulations and framework for the nations. Nevertheless, it is additionally important to go deeper into detail, and focus on the strategies of the individual nation.

For the thesis the Swedish regulations about the handling of green spaces are important. To achieve and implement the SDG in Sweden, the Ministry of Culture developed a policy for the shaped living environment. This document addresses not only the governments task, but also the importance to include urban planners into planning processes, to encourage a sophisticated planning from day one. "*[F]eelings of pride both in those who plan, build and manage [the urban environment] […] and also in those who will reside, work and* *live there, now and in the future*" (Ministery of Culture, 2018,p.6), describes the vision in achieving a quality life in Swedish cities. The Government appeals to a **long view planning with multiple dimensions of sustainability** (von Schmalensee, 2018,p.12). In Sweden urban qualities are described by "*konst och kultur i de offentliga rummen, liksom hur upplevelsen av friytor, gaturum och andra gestaltade livsmiljöer värderas*" (art and culture in urban spaces, as well as how the experience of free spaces, street space and other shaped habitats is valued) (von Schmalensee, 2018,p.12). The Government of Sweden demands, that by 2025 "*the majority of the municipalities must make use of and integrate urban green spaces and ecosystem services in urban environments in the planning, building and managing of cities and towns*" (Ministery of the Environment and Energy, 2018,p.4). Green areas are not only necessary to provide a place for recreation. Furthermore, **they are part of ecosystems, which have the power to "*clean air, lower temperatures, take care of surface water and offer [...] healthy environments*"** (Ministery of the Environment and Energy, 2018,p.3). A sustainable city development therefore, creates a robust and safe living environment where people come together in attractive public spaces and where new ideas arise (Ministery of the Environment and Energy, 2018,p.4-9). As the SDG number 11.7 of the United Nations describes, "***universal access to safe, inclusive and accessible, green and public spaces***" (United Nations, n.d.-b) **should be achieved by 2030** (United Nations, 2017).

To achieve the Sustainable Development Goals, the **City of Gothenburg** developed a strategy plan which needs to be fulfilled in 2035. The "*Transport Strategy for a Close-Knit City*" describes, that the River City Gothburg aims to be "*inclusive, green and dynamic*" until then (Hellberg, Bergström Jonsson, Jäderberg, Sunnemar, & Arby, 2014). The objectives on the social level

> "***konst och kultur*** *i de offentliga rummen, liksom hur* ***upplevelsen*** *av friytor, gaturum och andra gestaltade livsmiljöer värderas*" (von Schmalensee, 2018,p.12)

are to create "*en tät och grön stad där de offentliga platserna bidrar till ett rikt och hälsosamt stadsliv*" (Park och naturnämnden, 2014,p.26). The ecological aim provides a **green city with a variety of plants and animals, where the ecosystem services are going to be used**. To achieve an attractive urban environment, a mix of meeting places and pedestrian zones with different cultural offerings are necessary.

Göteborgs Stad published different strategies to come closer to their aims. One strategy describes the **challenge of the availability of space in the urban context**. "*Space is a limited resource in urban environments*" (Hellberg et al., 2014,p.44), and therefore, it is important to **rethink the distribution of space which is occupied by infrastructures**. Oversized traffic routes can be turned into city streets, which can be used for people and urban life. Another **strategy deals with the identity of the city**. "*Identitet kan ha två innebörder, dels en miljös karaktär och dels människans identitet kopplat till miljön*" (Park och naturnämnden, 2014). Therefore, the aim of the city is to **create small and big sized parks and nature areas, that are equally distributed in the whole city**. Every citizen should be able to identify himself with the new public spaces.

GREENERY	EXPECTED CONDITIONS + DEMANDS	IMPACT ON URBAN ENVIRONMENT + IMPROVEMENTS	NEGATIVE ISSUES + SUGGESTIONS FOR IMPROVEMENT
ECOSYSTEM	• Green, diverse (plants and animals) • Productive ecosystem services • Corridors + patches for migration	• Healthy life + using ecosystem services • Conservation	
NATURE AREA	• Connected, multifunctional • Living habitat for species, animals • Small + big size recreational + nature areas • Parks, connected in a network • Corridors	• Climate change, cooling effect, resilience, clean air, water management, indoor climate, fire risk protection	• Limitations in urban growth and form
PUBLIC SPACE	• Open, accessible • Multifarious + sustainable + green • Well-connected, well-distributed • Multifunctional • Inclusive, interactive • Free from crime + violence • Culture, art, attractive + innovative	• Flooding risk, drought risk, heat waves, better microclimate, long-term qualities	• Limited resources in the urban environment • → rethink the distribution of space that is occupied by infrastructure • Use it as green areas/ open space for people/ nature + animals

Table 01 *Legal claims and regulations for greenery*

Figure 04 *Summary: Statements about greenery - based on The Urban Agenda & United Nations & national regulations*

The whole green structure should be connected in a network, close to the people. The range goes from small city parks to big nature and recreational areas. **They are providing fresh air in the city, a feeling of solidarity and are fulfilling important tasks of a sustainable water management** (Park och naturnämnden, 2014). Corridors and green spaces close to buildings are not only creating an attractive townscape, they rather enhance the indoor climate, decrease fire risks and soak in rain water (Svensson, 2010). Therefore, the Swedish' Government adopted a new planning and building law in 2009, which determines to build green areas close to housing areas as of 2011 (Svensson, 2010). **Gothenburg is therefore already dealing with the topic and has concrete suggestions on how the SDGs can be integrated into future urban planning**. All requirements for a sustainable development in the future are given.

2.3 STRATEGIES AND REGULATIONS: WALKABILITY

"1.3 million drivers, passenger and pedestrians dying each year on the world`s roads"
(United Nations, 2018).

The Deputy Secretary-General Amina Mohammed proclaims, that *"we have a chance to save the lives of million people around the world [if we are acting now]"* (United Nations, 2018). Therefore, **it is necessary to put more money into infrastructure and proper pedestrian and cycle paths**. This is not only saving lives, but also reducing CO_2 emissions (UN News Centre, 2016). To achieve the claims the United Nation developed goal number 11.2, which requests to provide a *"safe, affordable, accessible and sustainable transport systems for all, [to] improv[e] road safety [by 2030]"* (United Nations, n.d.-b). Additionally, the New Urban Agenda supports the SDG and takes pedestrians and cyclist into the focus. **The safety of non-motorised transport (NMT), including pedestrians and cyclists, has to be "*actively protected*"** (United Nations, 2017,paragraph 113) (UN Environment, 2016). This can be made by legislations and policies where, as stated in paragraph 114 (a), **cyclists and pedestrians should be arranged over private car traffic** (United Nations, 2017,p.29). Traffic jams and air contamination will be reduced by this measurements while the living conditions in cities gains more *"efficiency, connectivity, [and] accessibility"* (United Nations, 2017,p.30). The car traffic accounts 23 per cent of global CO_2 emissions. Furthermore, it also increases greenhouse gases faster than other industries (UN News Centre, 2016).

To achieve the goals of better connected and protected cycle and pedestrian paths in cities, it is important to promote a **compact city planning**. This would have positive impacts on the infrastructure development, by providing shorter distances between start and destination and to get a better connectivity in general (Aldon et al., 2015,p.5). **It is important to create visions about the future city we want to live in, where questions about the implementation of NMT can be asked**. How good is the city connected to public services, such as hospitals, educational institutions, tram and bus system, and how safe is it to walk there also in the darkness? By developing and acting on a vision about a better connected and safe urban environment, the SDG and the '*Quito Declaration On Sustainable Cities And Human Settlement*' can be achieved (United Nations, 2019).

*"**safe, affordable, accessible** and sustainable transport for all [to] improv[e] **road safety** [by 2030]"*
(United Nations, 2019)

In the case of Sweden, the Government decided to enlarge the financial framework (from 2017) to support cities in expanding their infrastructure for bicycles (Ministery of Culture, 2018,p.11). **The overall objective is to increase the use of sustainable transport systems, such as public transport, bicycles and pedestrians, to at least 25% by 2025** (Ministery of the Environment and Energy, 2018,p.4). The Government's '*Strategy for liveable cities*' also includes, that the locomotion in cities has to be effortless, secure and independently. Public institutions and other facilities for the daily life, must be in a walkable distance. **Street space additionally is to count as important public spaces** with cafés, stores and other facilities to achieve dynamic cities (Ministery of the Environment and Energy, 2018,p.3. **No citizen should be dependent on a private car while moving through the city**. By making cities more compact, they can be more easily accessed by residents. As a result,

people have an active role and the ability to make environmental alternatives in their daily lives (Ministery of the Environment and Energy, 2018,p.3). Another big aim of the Swedish Government is to have a zero-net emission of greenhouse gases in Sweden by 2045. This can be achieved by **upgrading environmental structures that provide possibilities for walking and cycling**. Furthermore, an extension of electric vehicles is important. For this reason, the Government provided subventions for electric vehicles, to make it easier for singular persons to afford them. "***Through better mixed-use of urban areas and improved accessibility through walking, cycling and public transport, [...] and other vehicles with low emissions, [...] wellbeing in cities can increase while the negative effects on health and the environment decrease***" (Ministery of the Environment and Energy, 2018,pp.5,6).

Also, in terms of mobility, Gothenburg wants to become a pioneer in the world`s society. Under the statement: "*Walking is also travelling*" (Hellberg et al., 2014), **the city wants to get more people to do their shopping on foot**. On this point Gothenburg raises the goal of the Ministry of the Environment and Energy. The Ministry suggests an increase in mobility by pedestrians, cyclists and public transport at least 25% by 2025. In contrast, Gothenburg is aiming for 35% of all paths to be carried out by physical effort by 2035. The rate in the River City amounts already 26% today (Hellberg et al., 2014). By the reason, that "*antalet resor till fots idag är mycket högre än antalet cykleresor*" (Mars AAT, 2015), the **municipality sees a big potential in enhancing the quality and availability of cycle paths**. To fulfil this aim, pedestrians and cyclist should be given the priority in the city. If motor vehicles and bicycles have to share the same road, then the **motorised vehicles have to adapt the speed of the bikes**. Further, the city plans to create a good constructed bicycle network, which is easily accessible from the whole city. Another important aim to enhance the quality of a pedestrian and bicycle friendly city is to provide safe transport systems. **Public transport has to be connected to pedestrian and cycle routes, so that all groups of people can use the system independently** (Hellberg et al., 2014). To allocate more space for cyclist and pedestrians, the city proposes to relocate cars from the street to a covered car park (*Climate Programme for Gothenburg*, 2014). These measures provide a vibrant urban life. The closeness to "***good public transport as well as green areas, retail facilities and other service facilities would benefit pedestrians and cyclists***" (*Climate Programme for Gothenburg*, 2014).

WALKABILITY	EXPECTED CONDITIONS + DEMANDS	IMPACT ON URBAN ENVIRONMENT + IMPROVEMENTS	NEGATIVE ISSUES + SUGGESTIONS FOR IMPROVEMENT
NMT	• Actively protected by legislations and policy • Prioritised over private motorised transport • Well-connected, easy, safe, independent • No dependency on private cars	• Less congestion + pollution • More efficient quality of life	
TRANSPORT	• Safe, accessible, affordable • No dependence on private cars • Electrical vehicles • Connection to cycle + pedestrian paths	• Improvement of road safety • Free mobility decision	• Few investments
COMPACT CITY	• Facilities in walking distance to living area • Relocation of cars in covered car park to use new space for cyclists + pedestrians	• More space for cyclists + pedestrians • Safety + attractivity + urban quality	• Often car-friendly urban models • Influence of cars on distribution of urban spaces + cycle + pedestrian paths
STREET SPACE	• Pedestrian zones with attractions • Mix of meeting places • Art and culture	• Attractive urban environment	• Oversized traffic routes and infrastructure barriers • → turning into city streets that can be used for people + urban life

Table 02 *Legal claims and regulation for walkability - based on The Urban Agenda & United Nations*

WALKABILITY

Regulations & Strategies

„Safe, affordable, accessible and sustainable transport for all"
(United Nations, 2019)

„1.3 million drivers, passengers dying each year on the world`s roads"
(United Nations, 2018)

THE URBAN AGENDA & UNITED NATIONS

More investments into infrastructure + proper pedestrian + cycle paths
(United Nations, 2018)

§ 113 — *Active protection for pedestrian safety + cycling mobility*
THE URBAN AGENDA

§ 114 (A) — *Prioritize cyclists + pedestrians over private motorized transportations*
THE URBAN AGENDA

§ 118 (A) — *Improvement of the efficiency, connectivity, accessibility of health + quality of life*
THE URBAN AGENDA

11.2 SDG — *Safe, affordable, accessible + sustainable transport for all*
UNITED NATIONS

By 2025: 25% of all transportation should be made by walking, cycling + public transport
(Ministery of the Environment and Energy, 2018)

Bigger financial framework for municipalities to expand NMT solutions
(Ministery of Culture, 2018)

Safe, easy + independent locomotion through the city without a need of private cars
(Ministery of the Environment and Energy, 2018)

Compact cities: walking distance of public institutions, shops, other services
(Ministery of the Environment and Energy, 2018)

Mixed-use urban areas
(Ministery of the Environment and Energy, 2018)

well-being
dynamic cities
environmental choices
accessibility
reduction of congestions and pollutions
safety
sustainable future
reduction of global warming
life quality

Figure 05 *Summary: Statements about walkability - based on The Urban Agenda & United Nations & national regulations*

2.4 CONCLUSION

Green and pedestrian-friendly cities are becoming important to increase quality life in cities. Chapter 2 has shown the regulations at national, regional and local levels and their objectives, from a sustainable, social, accessible and safe city. In doing so, strategies were mentioned that serve to realize the goals. It can be summarized that **in the future a denser city structure with a diverse land-use is of importance**. Distances in the cities are shortened, what enables pedestrians and cyclists to easily reach their destinations. The increased emission levels in cities require a **rethink that will replace motorized traffic with sustainable non-motorized transport (NMT)**.

That's why cities are facing new challenges. Pedestrian-friendly path systems need to be expanded and the street space has to deliver more than just be used for locomotion. **It develops new public spaces in which an active and vibrant life can be happen**. Green areas in the form of small parks, corridors, water infiltration pits and large natural areas becoming additionally, more important. **They provide a balanced ecosystem and protect plants and animals**. In addition, they guarantee a pleasant microclimate in cities. **Access for residents to the green areas should be ensured in order to promote a healthy society**.

Selected points of these strategies have been summarized in the arrows below. They serve to assess the scenarios later in this work. **By integrating these design measures into urban planning, the sustainability of cities can be improved**.

Greenery

- Well-connected and distributed green areas in different sizes + public spaces
- Universal access to safe + inclusive green and public spaces
- Variety of plants and animals
- Transformation of oversized roads into city streets

Walkability

- Active protection of the safety of NMT: pedestrians + cyclists
- Compact city planning with shorter distances to facilities- diverse land-use
- Street space counted as public spaces (cafès, shops)
- Prioritizing pedestrians + cyclists over motorized transport: speed adaption
- Relocation of on-street parking to covered car parks
- Better connection between public transport and cyclists/pedestrians

3. HISTORICAL APPROACH

3.1 "DRIVERS AND VISIONS OF THE PAST"

The importance of the motorized vehicle as a symbol of modernity could not be overlooked after the end of the World War II. Various models about possible city structures were discussed during this time, which should guide the urban development in a positive, forward-looking direction. But most of them have never been applied and remained stuck as normative drafts in the ideas (Schlicht, 2017,p.6). The United States, as the liberator of Europe "*had become a positive model of postwar Europe, both culturally and nationally*"(Lundin, 2008b,p.260). The **urban development in America proceed in line with the introduction of cars**. Therefore, it was possible to create cities with a car-friendly shape. Particularly Los Angeles was seen as a prototype for the new urban development, where **forty per cent of the city was used for parking possibilities**. Larger shopping areas with oversized parking places, were built in the outskirt of cities, connected by motorways with a width of fifty to sixty metres (Lundin, 2008b,p.257).

> *"one of the best means for expressing* ***individual liberty*** *and one of the* ***greatest factors in the development of human personality"*** *(Lundin, 2008b).*

Europe was impressed by the progress the United States made. With **America as a pioneer, the cultural and public importance of the car evolved in Europe** (Lundin, 2008b). Finally, the "***car-friendly city***" ("*die autogerechte Stadt*") and the **functionalized city** (Le Corbusier), were introduced as models for the reconstruction of cities after the Second World War (Schlicht, 2017,p.6). Bernhard Reichow was the founder of "*the car-friendly city*" in 1959. With the eponymous book ("*Die autogerechte Stadt*"), Reichow wanted to set guidelines to support the cities with the handling of these new epoch (Schlicht, 2017,pp.6-7).

In war-damaged Germany, the vision was the **modern development of cities**, that takes precedence over old traditions (Stambolis, 1996). The inhabitants were asked to command all the needed courage to say goodbye to many things. **A one-by-one reconstruction of the old walls would not have been possible**, due to the psychological damage caused by the war (Stambolis, 1996). "*[T]o embrace the future became a favored survival strategy [of Germany]*" (Lundin, 2008b,p.259). With the argument, that the city centre represents more than just a place to live – **inner cities were reconstructed to be more accessible for the "*rhythm of traffic*"**. The city centre should symbolize a home, an identity and values (Stambolis, 1996). The concept intended to **flood the inner cities with traffic, so that they are not going to die in the future**. An efficient traffic system, therefore, had a fundamental meaning for the economic reconstruction of German cities (Gall, 2001).

Not only Germany, but the **whole of Europe dismissed old traditions and the past** (Proff et al., 2012). Only a few cities persisted on old urban structures of the past. Budapest, Warsaw, and Nuremberg were duplicated identically (Lundin, 2008b,p.259). At the same time, the **cars became political important in Europe**. They demonstrated "*the most visible aspect of the democratization*" (Lundin, 2008b,p.262). The United Nations Economic Commission for Europe (UNECE) (Schreurs & Steuwer, 2015) decided in 1950 to build a Europe-wide motorway system. The aim was to **overcome antiquated mindsets, cultural and governmental barriers and to unify a liberal Europe**. Until 1990, 40.000 kilometres has already been constructed (Lundin, 2008b,p.261). Also in Sweden, the Government and urban planners worked closely together. **Consolidation, modernization and the mechanization of the industry were symbols of the new epoch**. Buildings could no longer represent density (Lundin, 2008b,pp.257,259).

"*[R]ekordåren*" (Lundin, 2008b), revived the mass modernization of the car sector. The number of cars only in Germany quadrupled in the Fifties (Harlander, 1998). Sweden had with one million cars the utmost per head car quantity in Europe. The car-society had an enjoyable "***drive-in mentality***" (Lundin, 2008b,pp.261,258). Every spot should relate to a proper street network. The dream of material wealth and better living conditions were big. For Sweden, as for the rest of Europe was clear, that the cars are an "*irresistible development*" (Lundin, 2008b,p.273), to which the **cities have to adapt**. **Public transport lost its weight in the cities**. The Stockholm delegation determined in 1956, that the public transport had to align to the road traffic. The deputy Berglund had a stronger opinion on public transport and argued that it was only there to transport "*the carless proletariat*" (Lundin, 2008b,p.273). The boom in the car industry made it possible for the general public to benefit from the economic miracle. While the petrol-driven car in the 1930s was an indication of the middle class including the prosperous society, **regular people could afford a car as a result of the economic boom in the 1950s** (Lundin, 2008b,p.261). Thereby, a new way of investments was opened. Additionally, to single-family homes, there was also the opportunity to put money into motorized vehicles (Staub, 2017). **The car expressed modernity, a new epoch within a new society – the car-society**. Roland Barthes (as cited in Lundin, 2008b,p.260) defined the motorized vehicle as "*the supreme creation of an era*" (Lundin, 2008b,p.260).

Gender equality was promoted by the car. Advertising specifically targeted women and promised them independency from their husband if they owned a car (Figure 06). "*Endlich hast Du mir die Freiheit geschenkt. Endlich brauche ich Dich nicht mehr nach dem Autoschlüssel zu fragen*" [Finally you have given me the freedom. Finally I do not need to ask you for the car key anymore] (Bohn, n.d.). This advertisement of the BMW Isetta in a newspaper with the slogan "*Die Befreiung*" [the liberation] shows a woman in an open cage, with a car in the background (Bohn, n.d.). Therefore, the car was "*one of the best means for expressing individual liberty and one of the greatest factors in the development of human personality*" (Lundin, 2008b,p.261).

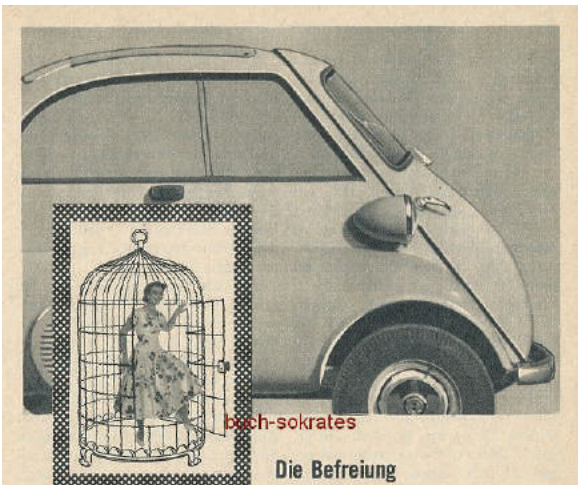


Figure 06 *Advertisement BMW Isetta ("Reklame BMW Isetta," 2017)*

DIMENSION	DRIVERS OF TRANSFORMATION TOWARDS THE CAR-FRIENDLY CITY	OUTCOMES
PEOPLE	• Affordability of automobiles [1] • Modernity [1] • Life in another speed level	• Freedom, independence [1] • Material prosperity, status symbol [1] • Emancipation [6]
CITY	• Reconstruction of destroyed inner cities after the war [1] • Modernization, automation [1] • Dream of single-family houses in green areas/ suburbs [7] • Door-to-door connectivity [1]	• Separation of functions + different types of traffic [1] • Urban sprawl [1] • Car „traffic set the terms for pedestrian traffic" [1] • Sub-urban areas: Car-free islands [1]
ECONOMIC	• Economic miracle [1] • Industrial development [8]	• Automobile as a consumer [7] • --> Participation in the economic miracle - modernity
POLITICAL	• Unified Europe [1] • Democracy [1]	• Breaking down ideological, cultural and political boundaries [1]
ENVIRONMENT	• Desire of life in the countryside [7] • Single-family house with garden [7]	• Escape the stress of inner cities [1] • Accessibility of nature areas [1]
(CAR) INDUSTRY	• Demonstration of the post-war modernization concept [1] • Basis of sustainable economic development [8]	• Tax benefits [8] • Decentralized industrial bodies + citizens [8] → Increase competitiveness [8]

Table 03 *Drivers of transformation towards the car-friendly city*

3.2 MEANING OF GREENERY AND WALKABILITY

The possibility to take **vacations and to spend time with the family in nature areas outside the city was the quality in owning a car**. As larger shopping areas moved into the outskirts, former attractive and vibrant city centres became empty ghost towns (Lundin, 2008b). Traffic jams and accidents were on the agenda. By the reason, that there was no proper speed control at the time, the number of deaths from traffic accidents in Germany counted 17,000 in the mid-1960s (SWR, 2017). The roads allowed a speed of 60km/h (SWR, 2017). To enable large streets, plot boundaries, that earlier contributed to an attractive townscape, have been moved backwards, to enlarge the street spaces (Stambolis, 1996). **In the time during 1963 and 1973, 100.000 buildings were destroyed in Swedish' inner cities** (Lundin, 2008b,p.277).

The new built roads dominated the urban image and made it for pedestrians and cyclists more dangerous and difficult to overcome them. Therefore, new problems arose between the different road users. **Pedestrians and car traffic obstructed each other and made street crossings unsafe**. Pedestrian crossings and underpasses were built to overcome and not affect the traffic flow (Staub, 2017). Reichow, additionally proposed a **city without intersections, for a pleasant and safe ride** (Der Spiegel, 1957). At dangerous traffic junctions, roundabouts where planned. A bit later the request about **zebra crossings** has been made, to ensure safety for pedestrians (Der Spiegel, 1952).

Congested streets in the inner city affected, that many **people moved into suburban areas**, where they started a new life. These areas were often built in an organic shape with a strong infrastructure network and car parks surrounding the whole quarter (Figure 07). **The suburbs can be characterised by their easy accessibility by car**. No where in the city to the parked cars was further than 250 meters. The inner area of the neighbourhood was designed exclusively for pedestrians and was divided into different zones depending on the function (Lundin, 2008b). **Pedestrians were therefore also important road users in the car-society, whose locomotion had to be planned**. People were not able to walk from the suburbs to the inner city, but in their neighbourhood all facilities were easy to reach by foot.

To maintain the vehicle traffic and the pedestrians, **Scaft 1968** developed a guideline book (Lundin, 2008a). One of these proposals to solve danger zones was to **separate different types of traffic in space and time**. Each type of **traffic should be determined according to its function**, so that the traffic flow could proceed homogeneously. The traffic routes should be designed to be **simple and manageable**, so that no moments of surprise will appear. The **pavement should be abolished and a separate and individual footpath off the road should arise**. If roads and pavements intersect, then they must be continued by a **hierarchy** of each other through transitions and underpasses. All facilities, such as schools, shops, bus stops and houses must be connected to the pedestrian network (Lundin, 2008a, chapter 7). In inner cities, some selected streets were transformed into **pedestrian zones**, such as the Sergelgatan in Stockholm (Lundin, 2008b,p.274).

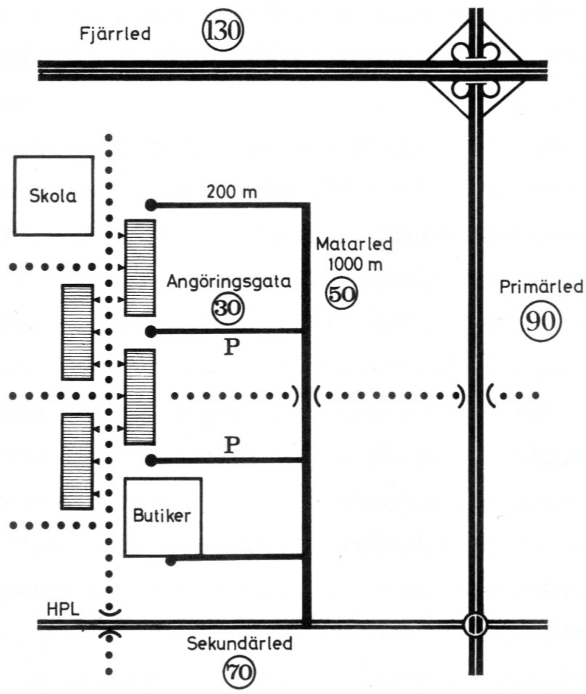


Figure 07 *SCAFT - division of traffic (Lundin, 2008a)*

3.3 CONCLUSION

The **generalisation of the urban environment**, under the introduction of the car has taken place on an international level. Many countries acted in the same way to prepare cities for cars. The historical development provides an indication of the state were cities are today and why the urban environment looks like it is today. The focus of urban planning under this era was on **integrating the car into existing or rebuilt cities**. The development of **recreational areas in the cities played a minor role** at that time. Nature areas should serve as a balance at the weekend, or on holidays, and were only reachable by car outside the city. In addition, the parallel existence of **various road users posed new challenges** that the car-friendly city had to cope with. Due to the **desire of unrestricted driving, pedestrians and cyclists had to be "*redirected*" or "*separated*", to not interfere with car traffic**. When the roads intersected, **bridges or tunnels** were built. Otherwise, a different design of the pavement determined, which road user had to use which path. In addition to the unrestricted flow of traffic, these measures also ensured **safety for non-motorised traffic**. The ideal also supported **car-free neighbourhoods** with a diverse land-use, where different **functions could be reached by foot**. Although the focus of the urban planning was on integrating the car into cities, we can learn from the design features of non-motorised transport, that ensured safety for all road users.

Gothenburg - Hjällbo (2018)

Figure 08 *(own figure) - car-free (green) pedestrian island surrounded by traffic and parking places*

Basel - Rosshof area (1975)

Figure 09 *(Spirgi, 2015) - parking places instead of public spaces/ green areas or denser cities*

Leipzig - Friedrich-Engels-Platz (1971)

Figure 10 *(Raphael (married Grubitzsch), 2009) picture: 183-W0512-0316 - bridges for pedestrians*

Leipzig - Separation of road users (1973)

Figure 11 *(Raphael (married Grubitzsch), 2009) picture: 183-M0828-0009 - bridges for pedestrians*

Greenery

+	Green suburbs; quality of green space
+	Bigger recreational areas outside the city
-	Green areas suffered under the pressure of parking places
-	Focus on traffic planning instead urban planning
-	Artificially created green instead of natural green

Walkability

+	Car-free neighbourhoods
+	Delivering safety by separating road users
+	Diverse land-use of suburban neighbourhoods
-	Tunnels & bridges to overcome traffic
-	Subordinated NMT + lower reachability + long walking distances
-	Lack of connection between public transport and NMT

\+ positive outcomes

\- negative outcomes

4. TODAY`S UNDERSTANDING OF MOBILITY IN CITIES AND FUTURE VISIONS

4.1 „DRIVERS OF THE PRESENT“

Today we are living in a “*mobile risk society*” (Kesselring, 2008), that is **facing an unsteady and uncertain change of modernity**. This new form of modernity is shaped by “*constant changes, motion and transit*” (Freudendal-Pedersen & Kesselring, 2016). Mobility change in the future is still uncertain, but technical advances are discussing many possibilities. Even today, other forms of mobility have been established beside the car. Nevertheless, the car in cities is still the dominating transport vehicle and is expected to grow by 25% until 2030 (Hellberg et al., 2014). **Cities, inhabitants and the car drivers themselves, are suffering under congestions**. In London a car driver spends 227 hours in congestions annually (INRIX, 2019). Traffic obstructions are also produced by commuters (Gruber, 2018). This is not only time-consuming and expensive for the car drivers, but also **responsible for 27% of Europe’s total CO2 emission** (Transport & Environment, 2018) (INRIX, 2019).

Rising running costs of private cars and a variety of other consumer goods are changing the meaning of cars as a status symbol especially by the younger generation (Proff et al., 2012). The **decline of the importance of private cars** can be seen in many aspects. On the one hand, less people are obtaining their driving licence. In Germany the number of applications between 2000 and 2008 shrank from 90,6% to 75,5% (Proff et al., 2012). **The young generation today demonstrates a weak consumer group of the car industry**. In comparison with 1999, where the disposal of cars on customers under 30 years amounted 17%, declined in 2009 by 10% (Proff et al., 2012). These numbers are also reflected by the survey. **40% of the participants do not own a private car.** The overall **status of public transport and bicycles as an alternative means of transportation increased** in the same time. The passenger kilometres (pkm) by using **railways in Germany** increased from 61 billion pkm in 1990 to 95,8 billion pkm in 2016. Also in Sweden an enhancement of 93,94% has been registered (European Commission, 2018). Main drivers for the society towards autonomous vehicles are the **demand for safer streets**. 25.651 persons were killed monthly by road accidents in Europe in 2016 (European Commission, 2018). With more efficient assistance systems and new techniques in vehicles the number of fatalities can be reduced. In the same time, it would be possible to use the travel time in autonomous vehicles for other purposes than by controlling the car. Bratzel & Thömmes (2018) are describing this turn in time management as the “*mobility time revolution*”. Traveling by autonomous vehicles increases therefore the **pleasure and the cosiness of the passengers** (DianGe et al., 2018). In addition, **all groups of society, including those without a licence and older people, can use the means of transport independently** (ADAC, 2018).

To solve the problem of air contamination and congestions, cities already started to **colour cars regarding their cleanliness** (Umwelt-Plakette.de, 2018). Other cities are reacting with traffic bans for selected vehicles concerning their licence plates (Szarata, Nosal, Duda-Wiertel, & Franek, 2017). **Car-sharing pools** promote to switch from private cars towards public provided cars. With this measures the city also reacts on the occupation of space by parked cars. Due to different studies a city fleet consisting out of **autonomous cars can function by only using 10-30% of the today`s vehicle stock** (Bratzel & Thömmes, 2018). Additionally, it would optimize the stream of the traffic (Bratzel & Thömmes, 2018). Prescribed in regulations is a **CO2 reduction of 37,5% by 2030** (Schulz, 2018). Therefore, it is important to update the transport sector with high-quality technologies. **The political actions are motivated by technological progresses realized by the car industry** (Schreurs & Steuwer, 2015). Europe motivation is to be the **world pioneer in safety and protection of transport systems** in all modes of transportation (Maurer et al., 2015) (Schreurs & Steuwer, 2015). This aim should **improve the competitive ability of the European industry** and enhancing the solidarity of all member states. Further, an **increase of the social welfare** is expected (Schreurs & Steuwer, 2015).

The demand of the European Union is to establish a new market for the car industry. **Competitive readiness within the car industry motivates to collaborate with new players of the computer industry to develop the software for e-vehicles and autonomous cars**

(ADAC, 2018). Communication technologies and information systems demonstrating an important part of autonomous vehicles. For the economy the development towards autonomous driving symbolizes a "*stronger cross-fertilisation between the transport modes*" (Schreurs & Steuwer, 2015). By a **higher amount of autonomous cars with a more efficient technique, the cumulative costs will shrink from a long-term perspective** (Bratzel & Thömmes, 2018). It will also protect endless resources like petrol by 10% (ADAC, 2018). The general goal is to enhance the efficiency in transport systems to enable a **safe and intermodal passenger transport** (Schreurs & Steuwer, 2015).

The **outcomes for the environment are not totally explored yet**. The development of the autonomous car is still unknown and therefore, the environmental impacts are dependent on, if the car remains to be privatised, or available as a common good. Regarding different scenarios, which will be tested in chapter 6, it could also be possible that a traffic relocation will take place. Consequences of this development would be, that **passenger prefer to travel by comfort autonomous vehicles, instead of using public transport or bicycles**. This scenario would exacerbate already existing environmental problems (Bratzel & Thömmes, 2018).

The drivers of the environment for the transformation towards the autonomous car are anyway the threats of **climate changes and the limited availability of resources.** A sustainable development and a reduction in the car ownership and the amount of traffic made by private cars, are requested (Schreurs & Steuwer, 2015) (Bratzel & Thömmes, 2018). Another motivation is the **reduction of greenhouse gas emissions by 60% until 2050**. The transport sector should be decarbonized and a higher complexity of mobility should be achieved (Schreurs & Steuwer, 2015). The overall trend is going towards **renewable energies**, that can be used to drive autonomous cars (Bratzel & Thömmes, 2018). The whole debate about another form of mobility also pushes the **research of green technologies and material substitution** (Schreurs & Steuwer, 2015).

DIMENSION	DRIVERS FOR TRANSFORMATION TOWARDS AUTONOMOUS CARS	OUTCOMES
PEOPLE SOCIETY	• Variety of consumer goods [4] • High running costs: private cars [4], reduction of mobility costs [19]	• Change + application of other means of transportation [17] • Increased convenience + comfort [20]
CITY	• Close spatial oriented system [4] • Autonomous city fleet: Reduction of vehicle stock by 70-90% [19] • Citizen focused mobility planning [13]	• Remove traffic fatalities and injuries by 2050 [18] • Minimize congestion: parking search: 30% of congestion [19] • Minimize occupied space by parking spaces [19]
ECONOMIC	• Petrol saving by 10% [17] • Optimisation of traffic stream [17]	• Fast deployment of automated technologies [18] • Lower cumulative costs [19]
POLITICAL	• EU guideline: CO2 reduction – 37,5% by 2030 [15] • EU goal: pioneer in safety of transport [18] + technology [21] • High value-quality, innovative transport technologies [18] • Orientation and coordination of national policies [18]	• Increase of social welfare [18] • Innovations: efficiency, clean energy usage, safety through communication systems [18] • Competitiveness of local industries [18]
ENVIRONMENT	• Climate change + limited resources + sustainable development [18] • Reduction of greenhouse gas emissions by 60% until 2050 [18] • Decarbonisation of the transport sector [18] • Trend towards regenerative + renewable energy [19]	• Outcomes on the climate depending on different aspects: ○ Traffic relocation ○ Urban sprawl – longer distances ○ Ownership of common good [19]
(CAR) INDUSTRY	• Competitiveness of car industries in Europe [17] • Ambition of speed: driver of new technologies [20] • Cooperation between IT and car industry [18]	• Level of automation today: 2 of 5 [19] • Rising efficiency: assistance systems + transport system [18] • Seamless, highly interconnected mobility chain [19]

Table 04 *Drivers for transformation towards autonomous cars*

4.2 ONLINE SURVEY

A scenario-based approach receives its depth by implementing a participatory process. This method helps to look outside the box and integrate the participant's opinion as a tangible tool additionally to the literary research. The introduced online survey "*Car use today & Future demands*" was implemented on the 13th of February 2019 with the help of Smart Survey ("Smart-Survey," 2019). The survey includes **15 multiple-choice questions**, where mainly one answer could be given. Only on some, more specific questions, it was possible to tick multiple answers. The exact wording and construction of the questionnaire can be found in the appendix of this work. **The aim of the survey was to get people's opinion about the role of the car in their daily lives**. Furthermore, it was to be found out which other forms of mobility are preferred for moving around the city. **The survey represents a self-assessment of the participats about their mobility behaviour**.

To reach a broader population, the survey was distributed via social media, as well as by email. It was also asked to share the questionnaire with family members and relatives in order to get different age insights. Due to this distribution, a participant number of 100 has been reached. Nevertheless, the focus was on the age distribution among **21 to 29-year-old**. This distribution can be attributed to the fact that the use of social networks is mainly claimed by the younger generation. According to the statistics portal "*Statista*", the main user group is between 25 and 34 years old (statista, 2019). By the request, to send the survey to family members and relatives, it was nevertheless, possible to receive answers of **40% that are older than 30 years**. Another peak in the age distribution demonstrates the **generation between 50 and 59 years**. This can be explained by the fact that the parent generation has played an important role in participation.

The division of private-owned cars is almost balanced, with a divergence of 2%, between the members, what makes the result about the future development of the urban environment exciting. In addition to the question about the private car, it was asked if parents with children are among the respondents. This question is very important, as it **could be concluded that parents may have a higher demand for cars**. An easy availability of the car could be beneficial to meet the needs of children - recreational activities, school trips, excursions, etc. By analyzing the usage of the car, the **groceries with almost 55%** demonstrate the main purpose of mobility. The second largest use is for leisure purposes. There is a lot of room for interpretation in this result, because it cannot be compared whether it was mainly the parents who ticked this point. That would mean that they use the car for the recreation of their children. But this statement is purely speculative. This would require an expanding question. The third field is represented by **commuters (42,42%)**, who are dependent on their car to drive to work or by doing business trips.

Although many participants use the car as a means of mobility, the **value as a status symbol decreases**. 86% of the members shared this opinion. Many papers are describing, that the car is parked and unused in 95% of its whole life (Bratzel & Thömmes, 2018). This number is represented by the survey which asked the usage time of the private owned cars per week. **43% stated to use the car less than one hour per week.** Here again, it would be necessary to know, who made the statement. The participants, who own a car, or the car-less responders. Nevertheless, the second larges answer with **20% is using the car one to two hours a week**. In conclusion it can be assumed, that the car is only used for short-term activities.

To get a better understanding in the general movement of the participants a question illustrating different forms of mobility has been asked. Hereby, multiple answers could be crossed. 66% argued to use public transport. This number is followed by **60% traveling by bike**. Another preferred mode of transport is **pedestrian traffic with 54%**, closely followed by the private car with 44%. This is in line with the figures of the city of Gothenburg, where already today **26% of all movements are covered by physical effort** (Hellberg et al., 2014). Therefore, for the future development, it can be assumed that the **trend is slowly moving away from the private car and being replaced by other forms of mobility**. The use of car-pools is represented with 8%. This result is certainly still expandable in the future. But it can be explained by the fact that the participants without a car are used to travel by public transport or physically. The participants with private cars have no need to rent a car in addition.

To go deeper into the 60% of the cyclists, an additional question about the **time on the bike per week** was questioned. The answers are reflecting, that most of the participants are using **bikes for short-term activities**. 35,11% using the bike around ten to twenty minutes. Then it is remarkable, that the second peak with 22,34% are using the bike **two to four hours**. This could represent, that the bike is an important vehicle to reach destinations, as well as to keep fit.

To go deeper into this topic a question about the **willing bicycle distance** for reaching destinations, was asked. 25,51% stated, that **three to five kilometres** per way would be achievable. The difference in the distribution of the votes between three to five, five to seven, and seven to ten kilometres, is only by 3%. **This means, that the majority is willing to cycle up to ten kilometres each way to reach the destination**. This is in line with the statement of the Federal Environment Agency in Germany. They estimate that every second car route up to 10 km in length can be displaced by bikes (Winkler, Kugele, Laberer, & Niedemeier, 2016).

In comparison to the bike, the next question was asking about the **willing walking distance.** 32% of the people can imagine to reach their destination in a distance of one to **1.5 kilometres**. 18% prefer to walk a distance between 1.5 to two kilometres. And even for 8% it would be manageable to walk up to three kilometres. This corresponds to a 40-minute walk.

After the questions about the mobility behaviour it was important for the survey to find out, what the participates expect from the **future city**. For this the questionnaire asked about the **demands on the future city** by giving proposed answers and additionally, the possibility to write own suggestions in an extra field. It was possible to give multiple answers, as well. The majority (79,8%) claims for a better connected and distributed **public transport network.** Furthermore, 76,77% are requesting **more green areas and public places** in cities. The cyclists envision with 68,69% a **better bicycle network** in the future city. Beside of this 52,53 argue for a mix of function, that is accessible by foot and additionally, they prefer **traffic calmed areas** (53,54%). Only 6,06% favour a better street networks for cars and more parking places in the future city (21,21%).

In the open field the participants mentioned:

Climate-neutral public transport; taxis as e-vehicles; free usage of public transport; fees for driving in the cities with private cars; intelligent routing (smart cities); Vision zero: no traffic fatalities + no pollution made by traffic; city should belong to the people and not to the car; new means of public transport - drones, etc.; a social city: focus on social equality; hydrogen cars; renewable energy usage.

The survey concluded with the question, if the participant could live without a private car in the future. **58% agreed**, and 36% neglected this question. The rest preferred not to decide themselves.

66% are seeing the city of the future car-free.

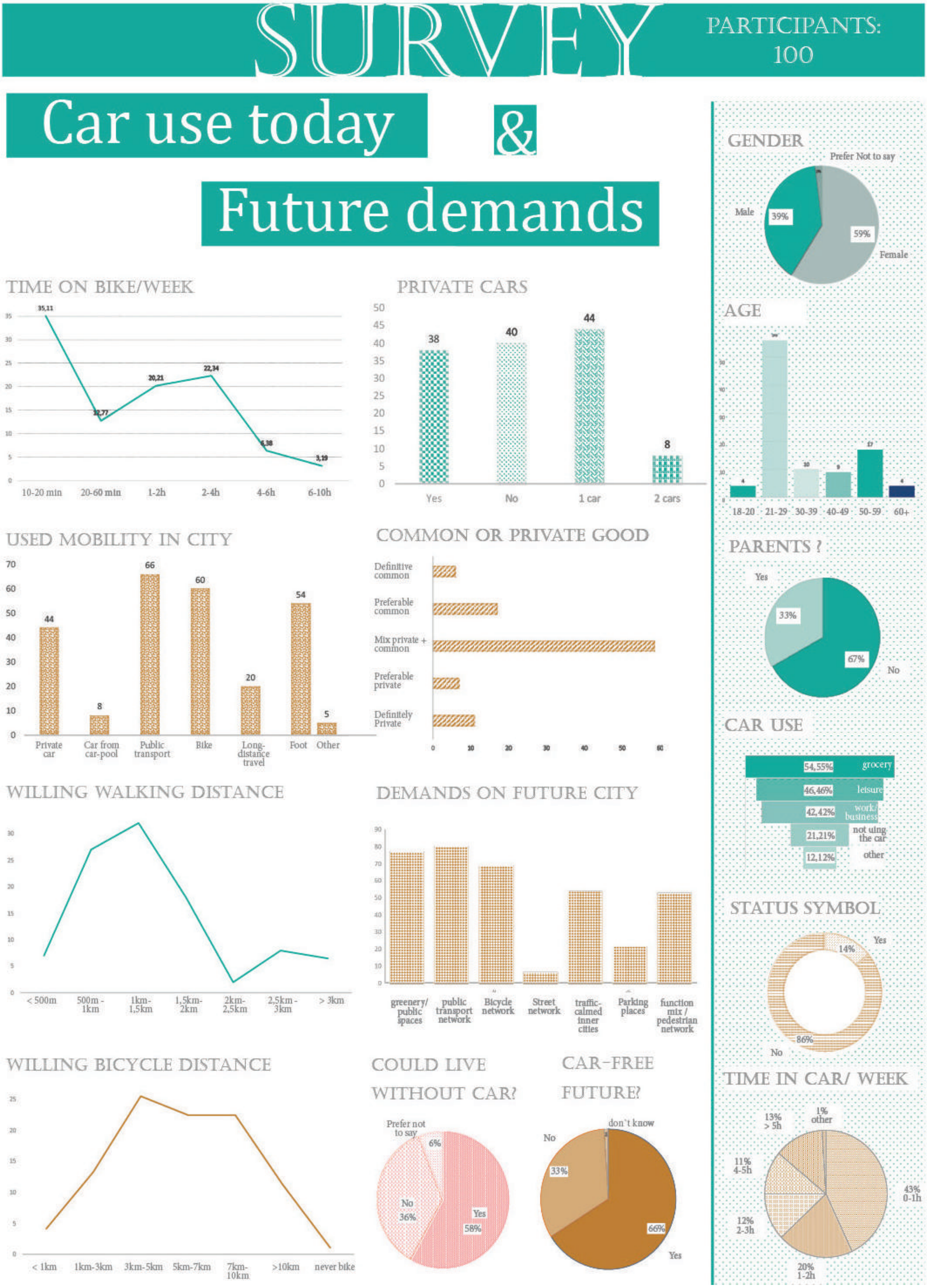


Figure 12 *Evaluation of the survey*

4.3 VISIONS AND TRENDS OF THE INDUSTRY

The car industry is already today working on **smart solutions for advanced driver assistant systems** (ADAS). Driven by road safety and the reduction of fatalities from traffic accidents, a new market has opened in cooperation with the information technology. The competitiveness is additionally driven by EU regulations to reduce CO2 emissions and greenhouse gases and to decarbonize the transport sector (Schreurs & Steuwer, 2015). Many cities are increasingly targeting the volume of traffic in the cities and are suing the automotive industry for excessive emissions. The technology towards autonomous driving is still proceeding and divided into **five levels** (BMW, 2019) (Gertz & Dörnemann, 2016).

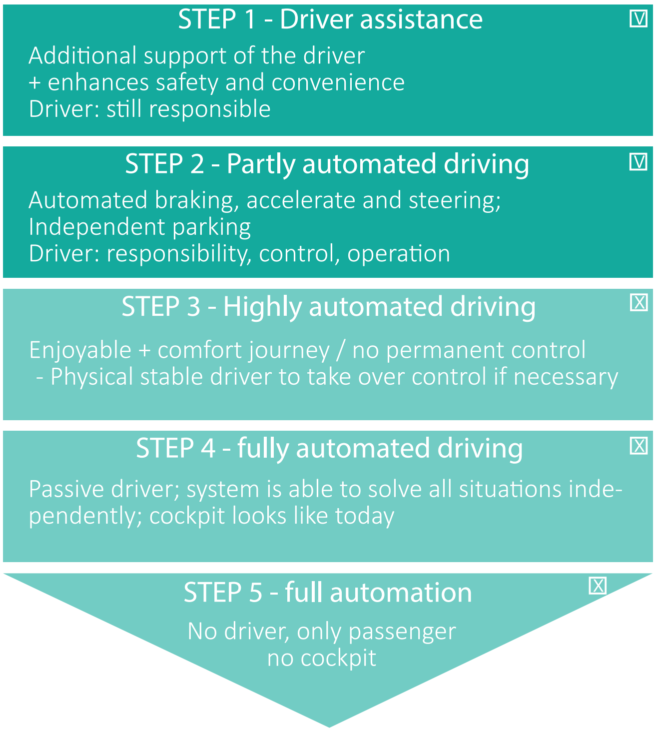


Figure 13 *Development steps (BMW, 2019)/ own figure*

That autonomous driving is coming in the future is no question anymore. The slogan of Volvo arguments that intelligent security is their way of **giving relaxation and a calm feeling in everyday life** (Volvo Car, 2019). Nevertheless, Mercedes-Benz confirms, that it is important to put the "***human first***" in the new technology. Many people are uncertain and fascinated in the same time about future technologies. As Jasmin Eicher, Head of Research Future Technologies at Daimler AG stated:

> *"[a] digital transformation can only be designed successfully if it is deeply anchored within society.* ***Humans and access to data must be at the heart of a digital transformation****. [...] That is why we are also working on solutions in the field of digitalisation which place the* ***freedom, decision-making autonomy and individuality*** *of human beings at their centre. We aim to create a balance between humans and technology. The approach we are following here is '****Human first****'"*
>
> *(Mercedes-Benz, 2018).*

Beside mobility solutions, the industry is also focusing on its implementation into the urban context. BMW (2019) explains some of its urban scenarios for the future, which focus not only on the car, but on mobility in general and the targeted integration of green structures.

One scenario describes the city in a cycle in which housing, mobility, agriculture and energy production are interconnected. **Cyclists and pedestrians generate energy through friction**, which can be used for electric vehicles. Even children contribute to energy while slipping on the playground.

Another scenario describes living in a high-rise characterized by digitization and connectivity. Due to the high availability of all functions, mobility becomes secondary. The **roof can be used for urban farming**.

The scenario of smart mobility is probably the most unusual. Mobility is increasingly taking place in the vertical space by drones and cable cars. In addition, **urban and rural borders are merged through urban farming and urban gardening** (BMW, 2019).

It is only a question of time, when full automated vehicles will take over the streets. But the **car industry is already testing and improving different prototypes of autonomous vehicles**. Also at Chalmers a self-driving bus has been tested as part of the government`s co-operative program "*The next generation`s travel and transport*"(Chalmers, 2018). The technology is in place for the vision of a **smart city** that has already been tested in model cities- including Santander in Spain (BMW, 2019).

4.4 VISIONS AND TRENDS OF THE POLICY + RESEARCH

Not only the industry is preparing for the adaption of autonomous cars in cities. The policy has an important part that provides the framework for the implementation of smart cities with new forms of mobility. The Federal Chancellor of Germany, Angela Merkel, announced in 2016: ***"Das Thema autonomes Fahren wird jetzt auch sehr schnell zu Rechtsveränderungen führen, sodass das autonome Fahren als gleichberechtigtes Fahren auch in alle Gesetze hineingenommen werden kann, zum Beispiel in die Straßenverkehrsordnung."*** [The topic of autonomous driving will now very quickly lead to legal changes, so that autonomous driving as equal driving can also be included in all laws, for example in the Highway Code] (Presse- und Informationsamt der Bundesregierung, 2016). That means, that the policy has an **active part in implementing autonomous cars into our society**. Prognoses indicate, that the **acceptance of the society for a new form of mobility is growing in the near future**. This is related to a change of the individual behaviour and economic profits (Schreurs & Steuwer, 2015,p.226). The car will not only be used as a means of transport, it will increasingly become a mobile habitat in the future (Sommer, 2017).

"Drive Sweden" (Figure 14) produced a video that demonstrates **urban and social changes** through the introduction of a autonomous taxi fleet in cities. The car is no longer a private property but serves for social purposes. The **continual collection and drop off of commuters means that parking is no longer needed in the cities**. Ride sharing also reduces the number of cars needed in the cities, which in turn has a positive impact on the design of the street space. The **width of the roads can be reduced by the improved flow**. The **freed-up street space can be used for social purposes, for recreation and leisure activities**. In addition, there are no more street signs, which makes the townscape more pleasant (Drive Sweden, 2015) (Figure 14).

Due to different research paper, a change towards AV is likely. **But its implementation and consequences on the city is still uncertain**. The book "*Autonomous Driving – Technical, Legal and Social Aspects*" written by Maurer et al. in 2015, deals with autonomous cars as a component of the road traffic in the future. To explore the transition of AVs and their impact on the city configuration, Maurer describes different future scenarios. Two of them **serve as a starting point for the scenario development in this work and are implemented spatially using the example of Gothenburg.**

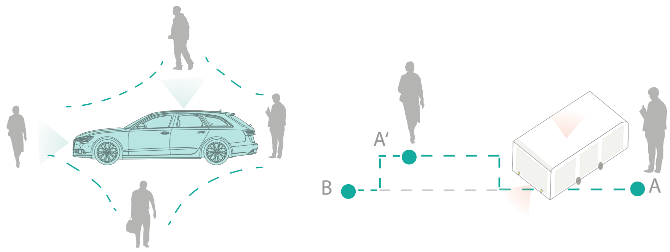


Figure 15 *Car sharing and ride sharing*

The Regenerative City" by Maurer (2015):

In this scenario, it is assumed that **autonomous vehicles are still privately owned**. In addition, full-scale automation is not yet complete. Energy supply and use in "*The Regenerative City*" is sustained and produced locally by renewable energy sources. The environmental awareness of the society is pronounced and the desire for a **healthy and high-quality city life** is great. Public transport supports multimodality in cities. The **density of inner cities and pedestrians and cyclists as environ-**

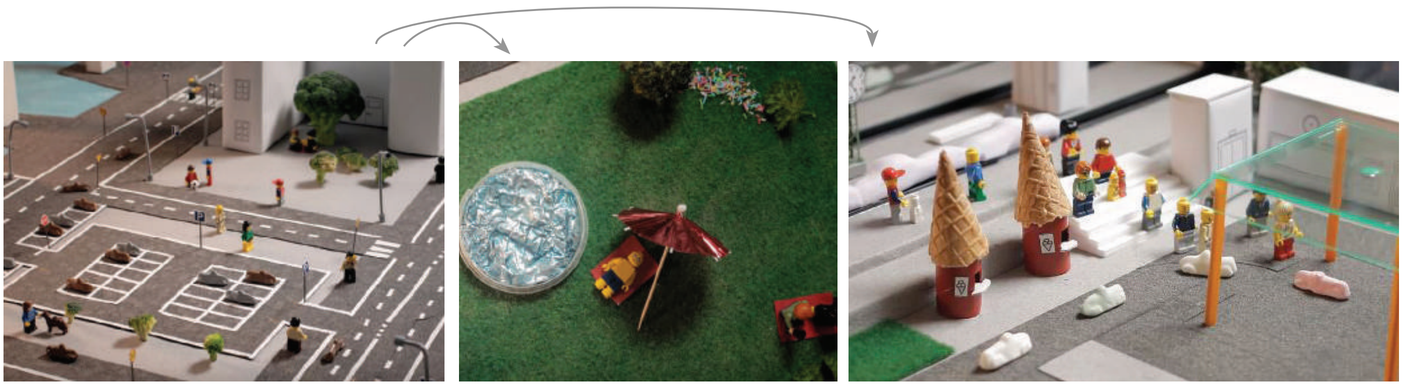


Figure 14 *Drive Sweden - Change of the urban configuration by AVs (Drive Sweden, 2015).*

mentally friendly road users is increasing. Distributed hubs support the intermodality and create polycentric city structures. As cars continue to be privatized, a modernization and restructuring of parking systems is expected to **save urban space** (Maurer, Gerdes, Lenz, & Winner, 2015, chapter 11)

“*The Hypermobile City*” by Maurer (2015):

“*The Hypermobile City*” is expected to be developed by 2055. **Cars are fully automated and working as a common good**, driven by public providers. Even if the Government restrain people to move to the suburbs, the more comfortable travel mode makes it easier to drive long distances (Isaac, 2016). **Suburbs with low density will grow**. “*Transition-zones*” are distributed in the dense city centre, to pick up and drop off passengers. This leads to a replacement of the public transport sector. The energy consumption will increase because of the high usage of communication systems and technology (Maurer et al., 2015, chapter 11).

Figure 16 and Figure 17 translate Maurer’s visions and ideas into two separate scenarios that will be explored in the upcoming work. It will discuss new forms of autonomous driving. The first form describes the autonomous individual traffic in “***The Door-to-Door Society Scenario***”. The second form describes autonomous ride-sharing that is used socially in “***The Ride-Sharing Society Scenario***”. Chapter 6 then visualizes the effects of the new forms of mobility on greenery and walkability in each scenario, using the example of Gothenburg.

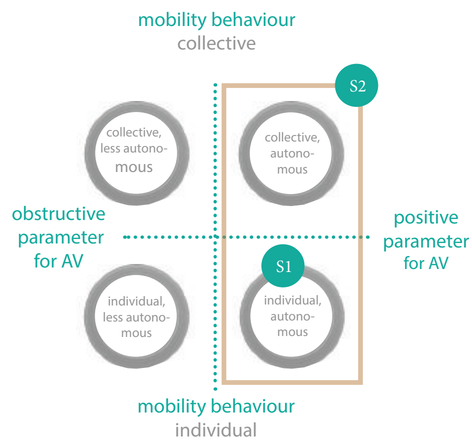


Figure 17 *Classification of future scenarios based on: (Gertz & Dörnemann, 2016)/ own figure*

SCENARIO 1
„The Door-To-Door Society“

Multimodal and flexible system, supported by **public transport**.

Highly **controlled streets**
Separation between road users

City centre

Intermodal **mobility hubs;** **Silos** instead of on-street parking

Denser city centres

Periphery

Polycentred urban structures, connected by **public transport**

Suburbs **growing with low density**

Greenery

- Mutual **influence of controlled street** space and trees
- Silos with green roofs
- City parks + **larger parks outside** the city

Walkability

- **Disruptive** locomotion of cyclists
- Separation from cars
- Bicycle streets designed as **green corridors**

SCENARIO 2
„The Ride-Sharing Society“

Highly connected **communication systems** in city + society

Autonomous **taxi fleet;** ride sharing; no private owned cars; **no public transport**

City centre

Central **transit points** - pick up, drop off passengers

Denser + growing city centre; adapted street systems to AV; no need for parking spaces

Periphery

Residential choice depends on **services**

Intensive work life or telepresence; Government **restrain to live in periphery**

Greenery

- More use of **inner-city space**
- More green in larger areas
- Less car lane release **more space for green**

Walkability

- Buffer between streets and cyclists
- Enlargement of pedestrian zones
- **Denser pedestrian & cyclist network**

Figure 16 *Future scenarios, based on: (Maurer et al., 2015, chapter 11)/ own figure*

AVs and its surroundings - Technology

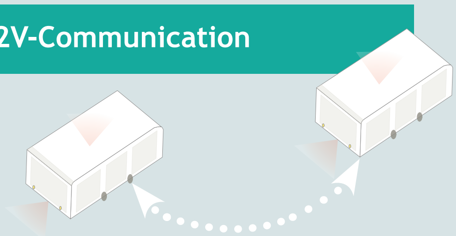
3D Maps + AV sensors

- Communicates the pre-scanned surrounding to the AV. Intersections, trees, buildings, road signs. AVs also scan the surroundings and match them with the 3D maps.
- Problems: **Construction sites, diversions, potholes** (physical changes)

Line based driving

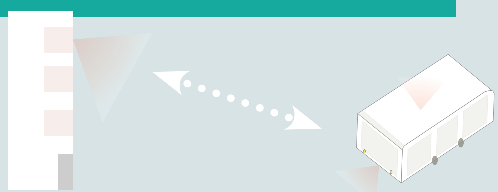
- The AVs can safely travel with the help of a line network. The route along the marked roadway is known.
- Problem: **weather (leaves, snow, rain)**

V2V-Communication



- All AVs are in close communication about their location. Accidents, unexpected actions can be exchanged.

Intelligent Streets



- The AVs are in communication with their environment. Communication is the main component that autonomous driving is possible.
- Problem: **Disturbing factors and obstacles must be avoided (trees, signs ...)** (Boudette, 2016)

Figure 18 *AV technology (Boudette, 2016)/ own figure*

4.5 CONCLUSION

Both industry and politics are looking to the future with anticipation and fancy visions. **Mobility plays a new role and will transform society in the long term**. The visions of the industry see pedestrians and cyclists as a potential energy source. "*Drive Sweden*" assumes, that full automation will lead to more space for recreation and leisure activities. The future should be smarter, easier, more convenient and innovative and that includes the whole urban system. Where not only AVs communicate with each other, but where also the urban environment is connected with the new form of mobility. But depending on the implementation of the technology in AVs, **different effects on walkability and greenery might occur**.

The car-friendly city seems to be already history in people's minds. **But is the introduction of autonomous vehicles really the solution to a more sustainable city with city-friendly cars**?

5. SCENARIO DEVELOPMENT

5.1 SCENARIO CONCEPT

The scenarios have been developed based on today`s situation. By the determination of **different criteria (layer)**, the information that is shown in each scenario has been reduced to the essentials. Table 05 illustrates the layers, that have been considered. The layers are available as an **open-street-map** source (OSM). In **QGIS** these can then be changed by adding, removing or modifying new features. For the subsequent evaluation of the scenarios, the tools in the **"*Vector*"-tab** can be used. These makes it possible to measure lengths and areas, but also to determine distances between patterns. The scenarios themselves are designed in three scales. Herby, not all layers are going to be included.

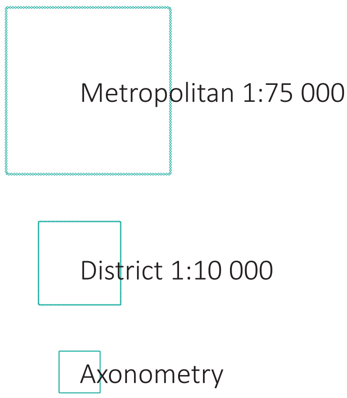
Time	T	1	2	T	1	2	T	1	2
Layer ↓ Scale →	Metropolitan			District			Axonometrie		
Greenery									
- playground	X	X	X					X	X
- forest	X	X	X						
- green urban areas	X	X	X		X	X		X	X
- pastures	X	X	X						
- sport & leisure	X	X	X					X	X
- agriculture	X	X	X						
- herbaceous	X	X	X						
Density									
- > 80%	X	X	X		X	X			
- 50-80%	X	X	X		X	X			
- 30-50%	X	X	X		X	X			
- 10-30%	X	X	X		X	X			
- < 10%	X	X	X		X	X			
Commuter	X			Not illustrated			Not illustrated		
Street network									
- motorway					X	X		X	X
- connecting roads					X	X		X	X
- small roads					X	X		X	X
Walkability									
- pedestrian zones					X	X		X	X
- living street						X		X	X
- cycle path					X			X	X
Public transport									
- bus lines		X			X				
- tram lines		X	X		X	X		X	
- bus stops			X			X			X
Parking places	X	X	X		X	X		X	X

Table 05 *Layers of requirement for scenario design*

The ***Metropolitan-map*** describes the development today and in each scenario in the scale 1:75 000. Highlighted layers are different **types of greenery and urban fabric**, that provides information about accessibility and distances. Additions, like commuter flow, parking spaces, hubs, public transport and transition zones are shown depending on the scenario, by moving, adjusting, modifying, extending or deleting different layers. If attributes have changed in the scenarios, the layer is marked with a red frame. If the layer has been transformed in its spatial habit, it is framed in green.

In the ***District-map*** a zoom-in into two areas of Gothenburg is shown. The first map shows an area of the **inner city**, and the second one explores an area in the **suburbs**. These maps are visualized in the scale 1:10 000. The **hierarchy of roads** plays an important role in this scale. It explores the influence of the new mobility form on **pedestrians and cyclists**. Further, the road hierarchy sets the terms for the **distribution of green structures**.

Each scenario concludes with ***axonometries*** to get a three-dimensional impression of urban changes. Walkability and greenery are in the core of the illustrations.



LEGEND

- X Mapped
- X Deviation between zoom-in areas
- T Today
- 1 Scenario 1
- 2 Scenario 2
- Change of attribute value
- Spatial transformation

5.2 SITUATION TODAY

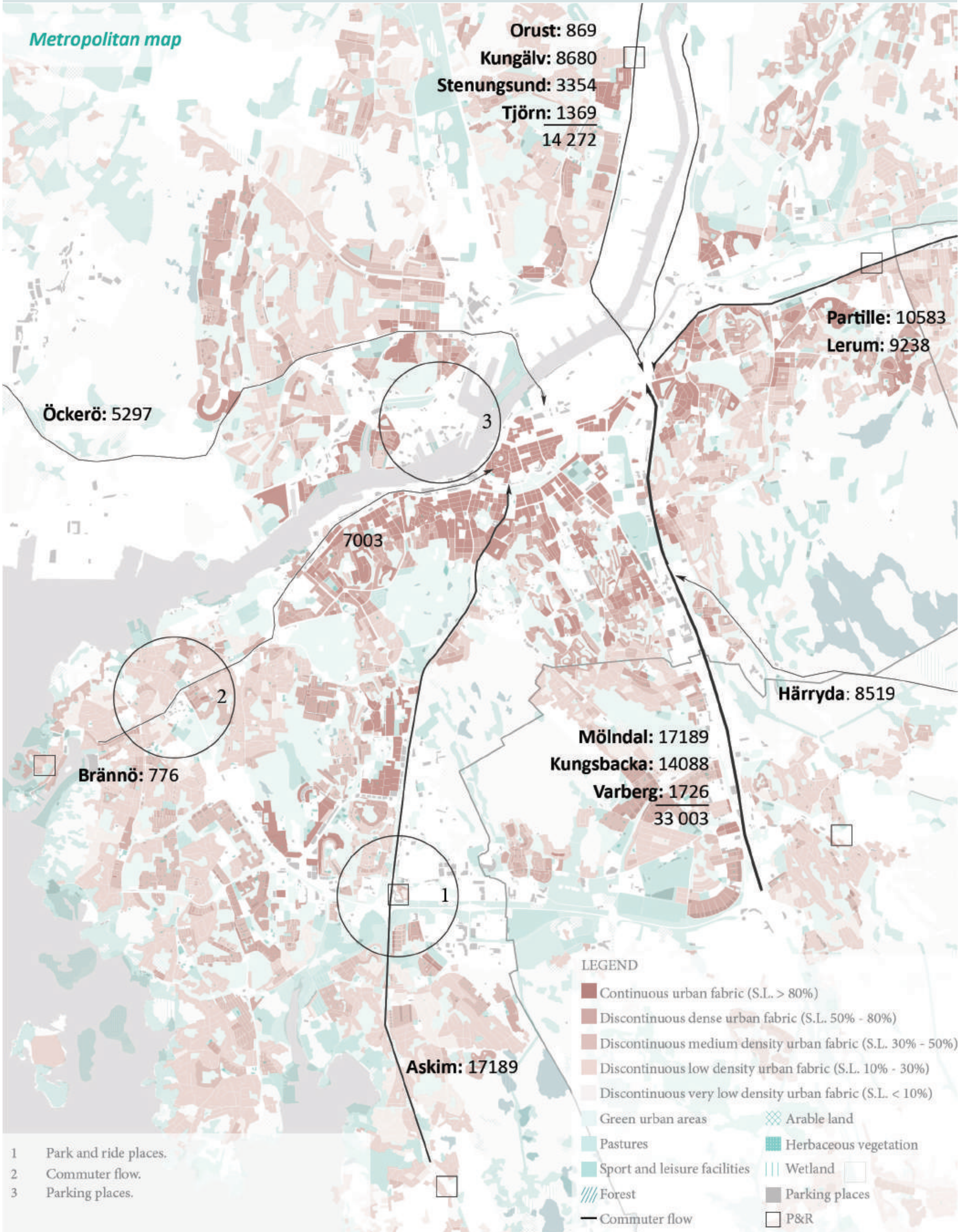


Figure 19 *Commuter flow in Gothenburg (Blomquist, 2013); Density of urban fabric in GTB today/ own figure* 1:75 000

Commuter & Density

Gothenburg is a commuter city. **More than half of the workers living in the neighbouring communes outside Gothenburg** commute daily to Gothenburg. From Partille it is even 67%. **117 000** commuters come to Gothenburg to work and 45 000 leave the city every day to do their work (Hyresgästföreningen, 2019) (Saxton, 2011). The **figures do not distinguish whether the journey is done by car or by public transport**. Nevertheless, figures from the city of Gothenburg from 2018 show, that **131 million commuters used the public transport** (Hellberg et al., 2014). Therefore, the availability of Park & Ride places is a necessity to ensure and promote multimodality. In Figure 19 the **commuter flows are classified according to their frequency by different line weights**.

The commuter flow illustrates, that Gothenburg is a city that growth into its suburban areas. This can also be seen in Figure 19, where suburban areas are illustrated in low-density, mostly along tram lines. The city of Gothenburg plans to enhance the transition points close to public transport and other important spots to **make the inner city better connected and accessible** (Hellberg et al., 2014). By determining certain areas that are going to be strengthen until 2035, the municipality aims to achieve a polycentric city structure in a "***Close-Knit City***" (Hellberg et al., 2014).

Greenery

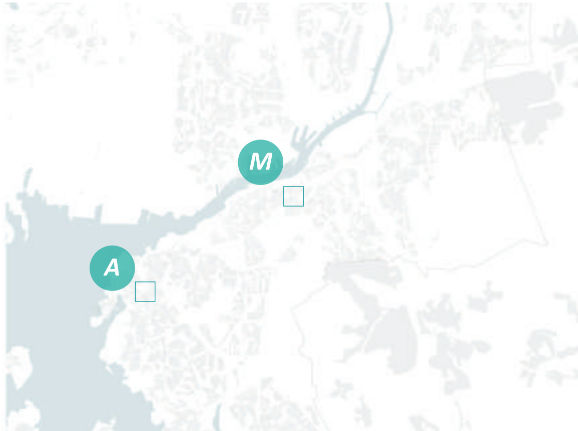
Gothenburg is mostly surrounded by forest, pastures and larger green urban areas. A proper link between surrounding nature areas and green urban areas inside Gothenburg is missing. Therefore, the municipality aims to create **well-distributed city parks and smaller residential parks in housing areas** that are in connection with each other (Park och naturnämnden, 2014). Figure 19 also shows the huge number of **parking places**, that are distributed in whole Gothenburg. These might work as residential parks in the future.

Walkability

In central Gothenburg, there are some pedestrianized areas reserved for pedestrians and cyclists. Nevertheless, pedestrian paths are **often intersected by public transport and multi-lane roads**. The goal of the city of Gothenburg is to prioritise the NMT and put it above motorised traffic. For this purpose, cycling and walking paths should be increased, and the speed of cars should be adapted to the speed of cyclists. **Security** and the connection between NMT and public transport should make **multimodality** more attractive and accessible to everyone (Hellberg et al., 2014).

5.3 COMMUTER STORIES

To develop different scenarios and take into account the **behaviours and the outcomes for the inhabitants** of the city of Gothenburg and the commuters, **two different characters** have been designed, based on the results of the survey (Figure 12). The characters have different lifestyles in order to gain the deepest possible insight into the impact of the future city on different population groups. The bracketed percentage indicates the **reference value of the survey**.



Mikkel (26)
Nationality: **Danish**
Date of Birth: **25/10/1992**
Family status: **single**
Children: **-**
Profession: **Student**
Address: **Skanstorget 9, 411 22 Gothenburg**

*"Halløj! I`m **Mikkel, 26** years old 26 years old and coming from Denmark. I'm living in Gothenburg since one and a half years doing my Master`s Degree at Chalmers. I got a very good job offer and that`s why I will stay in Gothenburg after graduation. If I would describe a usual day in the city, I would say that I`m mostly **travelling by bike (60%)**. I think it is much more worth to travel by bike or **public transport (66%)** than by car (44%) in the inner city. In Copenhagen more than 50% of all people travel by bike, what makes the city and the people healthier (Purtul, 2017). Especially, in Gothenburg you remain well trained, if you are a cyclist! When I`m doing the **groceries** in the afternoon, I can either go by **foot (54%)** what takes me 15 minutes, or by bike which of course goes even faster. In my free time I enjoy having a walk in Trädgardsföreningen close to Resecentrum or having BBQ at Slottsskogen or Delsjön. **Green cities are very crucial for my well-being**. For me it is important to go out into nature after a stressful day at school. In my opinion, the importance and the **meaning of cars is overestimated (86%)**. I think we could even better **live without cars in inner cities (66%)** in the future."*

Figure 20 *Localization commuters Anne and Mikkel*

Anne (55):
Nationality: **Swedish**
Date of Birth: **03/06/1963**
Family status: **married**
Children: **2**
Profession: **Architect**
Address: **Traneredsvägen 56, 426 77 Västra Frölunda**

*"Hejsan! My name is **Anne.** I`m in my **prime age and a proud mum of two lovely children** (33%). As our second child was born, by husband and I decided to leave the inner city and move to the west coast. Today we are living in a **single-family house in Tranered** with a beautiful garden where we can relax after the stressful working day. Anyway, the inner city of Gothenburg is still an important part of our life. I`m working full-time as an architect close to Stenpiren and my children are going to school at Scandinavium. By the reason, that I am doing many site visits for my work, I`m **commuting into the city with my own car** (38%). It is easy and comfortable and if possible, I`m also **carrying my kids** (12,12%) to school before I go to work (42,42%). Complicated and costly is the parking situation, I`m not happy about this. I know, I could also take the public transport to get to work, but I like the **freedom and independence** I have by car. On my way back home I`m doing the **groceries** (54,55%), and when I`m at home again, I can use the time only for my family. But of course, there are not only advantages using the car in the inner city. Many people do the same what results in **congestions**. That's why I start working one hour later than the majority. It makes a big difference!"*

5.4 DATA AND TOOLS FOR SCENARIO DEVELOPMENT

The scenarios have been developed in **QGIS**. The criteria of greenery and walkability were presented in different layers, as explained in step 5.1 "*Scenario Concept*". Table 06 shows the **sources** from which each layer information comes from. By using different data, all important information is provided for the development of the scenarios. The applied data worked sufficiently for the development of scenarios in the following scales. If the aim is to work more in detail on specific design solutions, further analysis would be necessary to capture the street space, for example in the districts. The infrastructure layers in QGIS represent mostly linear elements. To illustrate the scenarios in **three different scales**, different tools have been applied. These are described in Table 7.

QGIS parameter	Source
Density:	*Urban Atlas*
Greenery:	*Urban Atlas* https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012?tab=download
Public transport:	*GTFS Trafiklab* https://www.trafiklab.se/api/gtfs-sverige-2
Interest points:	*Open street map (OSM)* https://www.openstreetmap.org/#map=12/57.7082/11.9555
Street system:	*Geoportal Chalmers* https://geodata.chalmers.se/
Additional information about GTB:	*Geographical data (municipality GTB) provided by Chalmers* http://maps.arch.chalmers.se/

Table 06 *QGIS-Sources*

	Tools	Application
Metropolitan	**QGIS:** Attribute Table:	Used for reading layer properties. In the case of structural changes, these can be adapted. When adding structures in a layer, the attribute table is adjusted in parallel (eg city growth).
	Difference:	Used to represent spatial influences between two layers that overlap. The tool "*Vector*" - "*Geoprocessing Tool*" - "*Difference*" allows the definition of an input layer and an output layer, which structurally changed. Intersecting structures are deleted. The attribute table of the output layer ("*Difference*") will be adjusted.
	Group status:	This tool is used to summarize and display various properties of the attribute table.
	Editing layer:	Adding, deleting or cropping forms works through the "*Toggle Editing*" tool, with a right click on the layer to be edited. Tools under the "*Edit*"-tab can be used. Common tool for splitting surfaces: "*Split Features*"
	Assessment:	For the assessment the tools of the "*Vector*"-tab have been applied. "*Geoprocessing Tool*" to create "*fixed distance buffer*"; "*Geometry Tools*" to add "*Polygon Centroids*"; and "*Analysis Tools*" to develop a "*Distance Matrix*"
District	**InDesign:**	Overlay individual layers of exported PDFs (from QGIS) in InDesign. Additional information can be added manually (eg "*green trees*" as possible greening).
Axonometries	DXF Export:	For the Axos, a marked section (*Tool - "Select Feature (s)"*) (eg "*Building Layer*") was exported from QGIS as DXF ("*Project*" - "*DXF Export*").
	Vectorworks:	DXF files are opened in Vectorworks and created as individual layers. **Building heights:** Mark the buildings - then tab "*3D model*" - "*Create depth body*". The building height can be specified under delta "*z*". With the tool "*push, pull*" from the spatial tools, building heights can be adjusted individually. **3D-presentation:** Display under "*Teapot*" - "*Surfaces and Edges*". Then put on 3D view. Create a view area and export as a PDF. This is the basis for axonometries. All the layers that are needed can be imported into Vectorworks and represented as individual layers.
	Photoshop:	The exported PFDs from Vectorworks are printed out and serve as the basis for the drawings. Each imaged layer of the axonometries is drawn individually. Then all drawings are scanned and overlaid. In Photoshop, the surfaces can then be painted.

Table 07 *Tools for scenario design*

6. FUTURE SCENARIOS

6.1 „THE DOOR-TO-DOOR SOCIETY" WITH PRIVATE AUTONOMOUS CARS“

(Based on: “*The Regenerative City*” (Maurer et al.,2015))

Both scenarios in Chapter 6 are based on **fully controlled streets**. The environment with the AVs stands in **constant communication**. Important for the design of the urban environment is therefore, the **avoidance of disturbing factors along roads**. Since bicycles are not connected to the V2V-communication system, they remain **unpredictable for the AVs** (Figure 18).

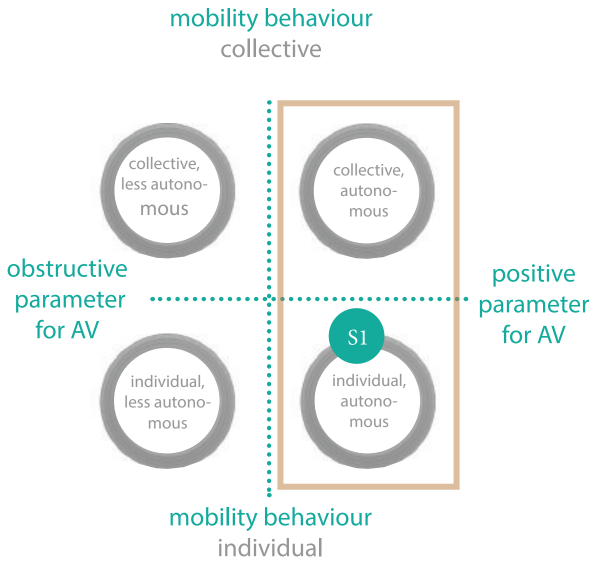


Figure 21 *Possible scenario diagram - Scenario 1 (Gertz & Dörnemann, 2016) / own figure*

6.1.1 Scenario 1 - Description

Public transport

In the ***“Door-To-Door Society”*** the technical progress had made it possible for ordinary people to afford an autonomous car. The prices dropped dramatically compared with electrical vehicles in the year 2019 and can be compared with a petrol-driven car of that time. Not everybody is owning a car. Ecoconscious people insist using the still existing public transport.

Figure 23 shows the infrastructure of the public transport system, that is the **same as in 2019**. Autonomous bus lines are supporting the tram system. It might also be possible, that there will be some on-demand services in rural areas, that carry passengers from home to the closest tram or bus station. Due to comfortable journeys in private autonomous cars, it is assumed, that the **demand of public transport will decline by 11%** (Gertz & Dörnemann, 2016).

Congestion

By the reason that the general public can afford a private autonomous car, it is presumed, that there will be **at least the same number of cars on the streets** as in 2019. As a passive passenger it is no longer necessary to own a driving license, what makes it possible for children to use the door-to-door service of autonomous cars. Also, elderly and handicap people can profit from this service and live a more independent life. This development might **increase the congestion on streets and lead to longer rush hours and longer journeys in general**. The autonomy only provides for a better used road capacity and for a constant and uninterrupted flow of vehicles. The time spent in the car is not bothered, because of the passive role of the passenger, and can be made exciting by other activities. This would allow people to travel longer, **as long as a door-to-door connection is guaranteed**.

Parking situation and charging

The range of electrical cars today is between 200 until 400 kilometres and the charging time takes between 30 and 60 minutes (Elektroauto-News.net, 2019). For this reason, it is important, that **single-family houses** in the periphery have their **own charging station** on their property, where the car can be charged over night (Figure 27, number 5). In the city centre, the distribution of parking places has changed during the time. The **on-street parking has been replaced by silos**, that are distributed in the city (Figure 23, number 3) and in bigger neighbourhoods (Figure 25, number 4). Due to an autonomous parking, covered car parks could offer parking space for **20% more vehicles** than before. Silos would provide more parking spaces and would be better utilized at the same time with **charging possibilities** (Belluomo, 2018). The omission of parking cars on the roadside would change the townscape and more space for pedestrians, cyclists and green structures could arise (Figure 26). Another form of parking are **zombie**

cars, that are driving empty while passengers are doing their shopping. Empty rides additionally will increase congestion on streets (Smolnicki, 2017).

Hubs

To connect the suburbs with the public transport system, hubs have been distributed at former park and ride places (Figure 23, number 1). **Autonomous cars can serve as a connection between front door and public transport**. After reaching the hub, the car can drive home independently. This service and the increasing congestion in inner cities makes it more **comfortable to live outside the city.**

Density

Therefore, it is assumed, that private autonomous cars contribute a **suburbanisation with low density**. A possible scenario could be, that smaller **villages will grow around hubs** (Figure 23, number 1). The connection to a well-developed service promotes the attractiveness of the locations. Due to the spread-out distribution of the hubs, **cities will grow in different directions.** This dispersion can have a positive effect on the distribution of traffic and possibly even minimize congestion on certain streets.

Street network

For a door-to-door connectivity, a well-developed street network is necessary. The quick accessibility of the destination is the priority of the passengers. Therefore, **different street types are needed in the city.** Figure 24 shows a district of the inner city of Gothenburg. A **fast-street network** (60km/h - Figure 24, number 1) runs homogeneously throughout the city. Through this, all parts of the city can be reached quickly. Because of safety issues it is important to **separate the road from other road users**. Cyclists on the same road as AVs would probably not work due to their unpredictability. They are too fast for the car to react. Therefore, it is necessary to **prohibit pedestrians and cyclists to cross the fast-roads at any point**. Crossings with traffic lights might be still necessary in this scenario what makes the NMT very disruptive. As a prohibition a **fence** could be possible (Figure 26, number 1).

Smaller streets, released for a slower speed (30 km/h – Figure 24, number 4/ Figure 26, number 4), **lead into residential areas**. Almost all city streets are opened for autonomous vehicle traffic to guarantee the door-to-door connectivity. In the suburbs, the slow-street only serves to reach the housing area (Figure 25, number 3/ Figure 27, number 4). By the reason that the speed is not as high as on the fast-roads, it would be **possible for pedestrians and cyclists to cross these streets**. A fence is not necessary. Nevertheless, all other streets in the suburbs are fast roads to ensure a fast connection to the inner city (Figure 25, number 1/ Figure 27, number 1).

Walkability

Due to the autonomation and the high technical networking of autonomous means of transport, the road network can no longer look like it does today. Road users must be separated for safety reasons. **The focus is on the accessibility with cars and a door-to-door transport** makes it also unnecessary or even unattractive to walk long distances. Therefore, **pedestrian-only zones remain to be the same as in 2019** (Figure 24, number 3). To enhance cyclists, it would be possible to close some streets for cars, that are not obstructing the accessibility (Figure 24, number 2).

Greenery

The **cycle-streets can additionally be used as a green corridor** to connect city parks with each other (Figure 26, number 3). Biodiversity in general, is suffering in this scenario. **Trees along streets are not possible**. They would interrupt the wireless connection between AVs and its surrounding. Therefore, only **grass and small bushes** can be planted to hide the fences (Figure 26, number 6). The inner-city parks (Figure 26, number 2) are serving as very important recreational areas with a diverse vegetation. In suburbs, the already existing **pedestrian zones close to buildings can be used as green oasis** that also serve as a green connection between the surrounded parks (Figure 27 number 2/3).

6.1.2 Design criteria

Different criteria and methods have been chosen in both scenarios to translate the theoretical knowledge including the criteria for walkability and greenery into spatial design. In Scenario 1 the **fast roads** follow the rule, that they provide a fast reachability of the destination, as it is the wish of the society. A dense network out of today`s "*motorways*" and "*connecting roads*" is therefore important to ensure door-to-door accessibility. The aim is, that 90 per cent of the whole street network in Scenario 1 is negotiable for AVs. Therefore, **slow roads**, that derived from today`s "*small roads*", are important to reach all areas of the city and suburbs. These should count at least 40 per cent of the whole street network. As **pedestrian zones** are an obstacle for accessing the destinations by car, these remain the same as today. **Bicycle lanes** are in favour of connecting city parks to enhance the qualities of greenery. Current roads, that have a two-lane bike path and are between city parks, were closed for cars in this scenario and transformed into green corridors. Crossing the fast roads is only possible through traffic lights, as many AVs occupy the street in close succession and high speed. That makes cycling interrupting. People prefer to live in suburbs, due to the high traffic volume in the inner city. The rule is therefore, suburbanisation with low **density** around hubs to provide multimodality, while changing to public transport. Suburbanisation process has effects on **green structures**, as the city grows into its surrounding. But, the transformation of some parking places in new residential parks, the possible greening of pedestrian zones, the green corridors and new sport & leisure areas in suburbs provide new green spaces. The rule for **public transport** is, that it remains to be the same as today. **Parking places**, in form of silos, are distributed along public transport, hubs, nature areas and in the inner city. In suburbs, parking and charging possibilities are provided on the property of single-family houses.

		SCENARIO 1 — Design criteria & methods	SCENARIO 2
DISTRICT	Fast roads	1. Based on: "*motorway*" + "*connecting roads*" 2. Well-developed road network- fast accessibility. 3. Mean distance inner city: 250m; suburbs: 400m.	1. Based on: "*motorway*" + "*connecting roads*" 2. fast accessibility not necessary; road density reduced by 50%. 3. Mean distance inner city: only main road; suburbs: 800m.
DISTRICT	Slow roads	1. Based on: "*small roads*" 2. Door-to-door connectivity. 3. Slow roads ≥40% of total road network; 90% of all streets should be negotiable for AVs.	1. Based on: "*connecting roads*" + "*motorway*" + "*small roads*" 2. Reachability of streets within 200m from each location. 3. Thinning of road network by 40-50% (compared to today)
DISTRICT	Pedestrian zone	1. Based on: "*pedestrian zone*" + "*pedestrian foot way*" 2. Obstacle for door-to-door accessibility. 3. No changes: 6,8% centre/ 32% suburb of whole street system.	1. Based on: "*small roads*" + "*pedestrian zone*" + "*living street*" + "*pedestrian foot path*". 2. Should count at least 50% of whole street-network. 3. Inside slow roads, that are reachable within 200m.
DISTRICT	Bicycle path	1. Based on: "*cycle path*" 2. Improving the connection between urban parks. 3. Closure of certain streets for bikes. 4. Mean distance: 400m.	1. Based on: "*tram lines*" 2. Improving the connection between urban parks. 3. Dense bike network.
METROPOLITAN	Density	1. Based on: *Urban fabric density* (<10%, 10-30%, 30-50%) 2. Multimodality- city growth around hubs. 3. Low density suburbs; inner city not attractive.	1. Based on: *Urban fabric density* (30-50%, 50-89%, >80%) 2. Additional service in inner city- cheaper life in centre. 3. Controlled expansion in inner city with high density.
METROPOLITAN	Greenery	1. Based on: *Greenery* (all types) 2. Low dense suburbanisation- impact on green. 3. Partly transformation of parking into residential parks. 4. Pedetstrian areas/bike corridor provide greening possibilities. 5. New suburbs: additional sport & leisure areas.	1. Based on: *Greenery* (all types) 2. High density extenstion of inner city- no impact on green. 3. Full transformation of parking into residential parks. 4.Pedestrian areas/ bike corridor provide greening possibilities. 5. New inner city districts: additional sport & leisure areas.
METROPOLITAN	Public transport	1. Based on: "*bus lines*", "*tram lines*" 2. Public transport unchanged to today's state.	1. Based on: "*bus lines*" 2. Bus stops serve as transition zones. 3. Inner city + suburbs: reachable + distributed within 200m.
METROPOLITAN	Parking	1. Based on: "*parking places*" 2. Partly transformed into silos. 3. Distributed: close to hubs, public transport, nature areas	1. Based on: "*parking places*" 2. Transformed into residential parks. 3. Some used as transition zones, close to nature areas. 4. Depots in industrial areas neccessary for charging issues.

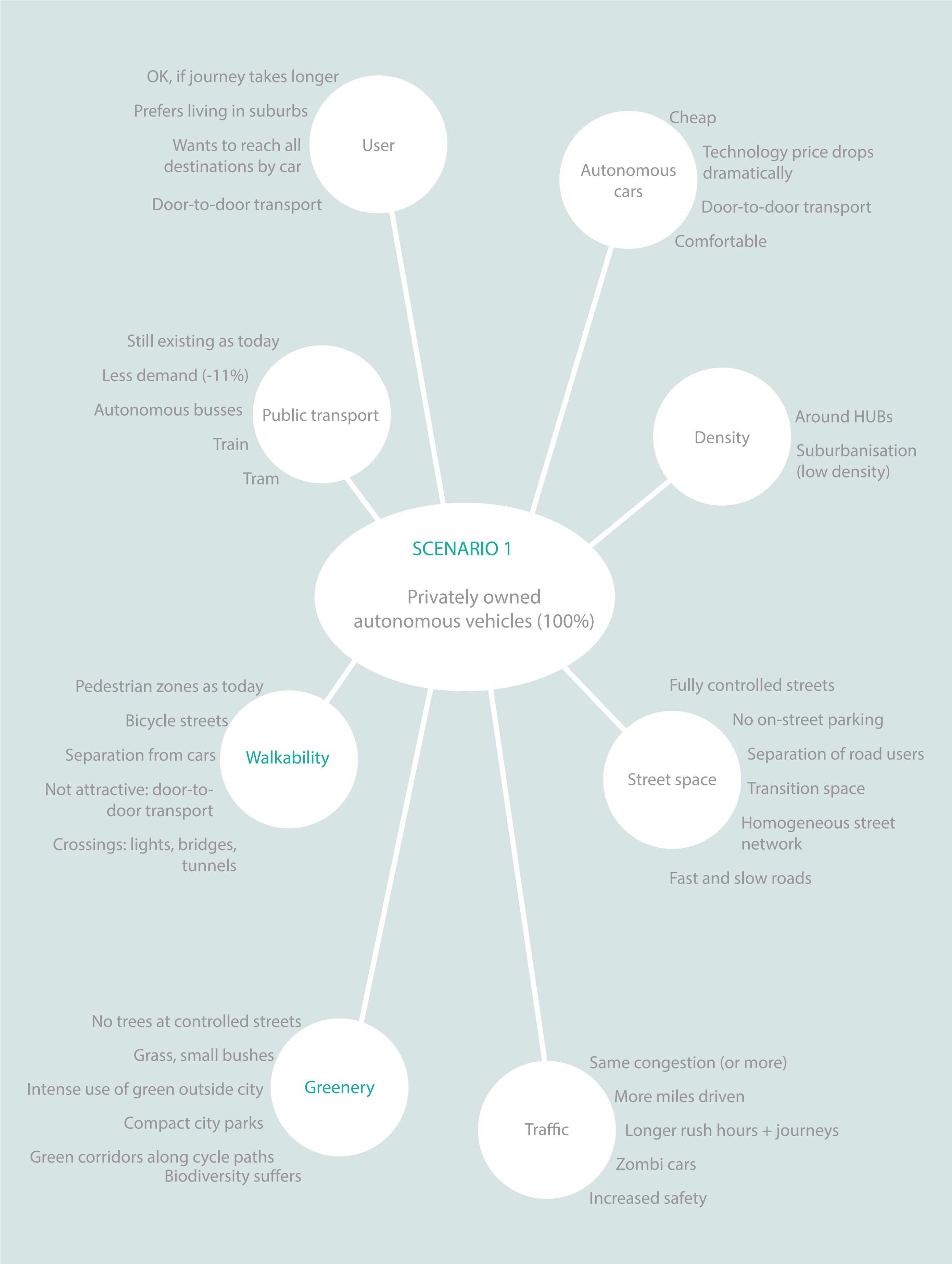
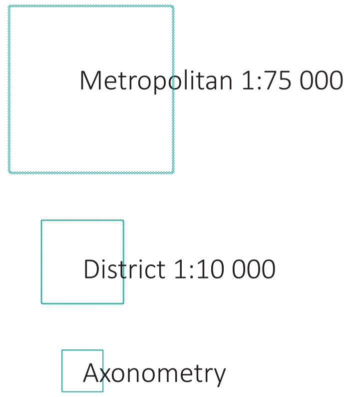


Figure 22 *Scenario 1 - summary / own figure*

6.1.3 Scenario 1 - Design

Table 08 shows the **parameters for the scenario design** in a more detailed way according to its scale. The change of the layers can be compared with the situation today, of Figure 19. If layers have been changed in its spatial habit, the criteria are marked with a green frame. If the value of attributes changed through interventions, a red frame is marking the difference. The adaption of the different layer can differ in both zoom-in areas, in the district scale, as well as in axonometries.



LEGEND
X Mapped
Change of Attribute Value
Spatial Transformation

SCENARIO 1

Scale → / Layer ↓	Metropolitan	District – Inner City	District – Suburb	Axonometry – Inner City	Axonometry – Suburb
Greenery					
- playground	X same as today				X same as today
- forest	X urban sprawl influences green structure				
- green urban areas	X	X same as today	X same as today	X green corri-dor + grass/ bushes	X green corri-dor + grass/ bushes
- pastures	X				
- sport & leisure	X additional sport areas in growing suburbs				X same as today
- agriculture	X				
- herbaceous	X				
Density					
- > 80%	X same as today	X	X		
- 50-80%	X	X	X growing with low density		
- 30-50%	X	X same as today	X		
- 10-30%	X growing around HUBs	X	X		
- < 10%	X	X	X		
Commuter					
Street network					
- motorway		X fast road	X fast road	X fast road fenced	X fast road fenced
- connecting roads		X fast road	X fast road	X fast road fenced	X fast road fenced
- small roads		X slow road	X slow road	X slow road/ residential area	X slow road/ residential area
Walkability					
- pedestrian zones		X same as today	X same as today	X same as today	X same as today
- living street			X foot way	X	X
- cycle path		X transformed road,corri-dor	X on pedestri-an path	X closed street/ corridor	X on pede-strian zone
Public transport					
- bus lines	X same as today	X same as today	X		
- tram lines	X same as today	X same as today	X	X same as today	
- bus stops					
Parking places	X silos + residential parks/ HUBs	X Silo	X Silo		X garages on property

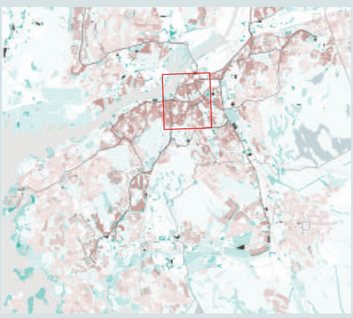
Table 08 *Concept Scenario 1/ own figure*

Scenario 1: Metropolitan map

Figure 23 *Scenario 1 - Metropolitan map Gothenburg/ own figure*

1:75 000

Scenario 1: District - Inner city, walkability and greenery



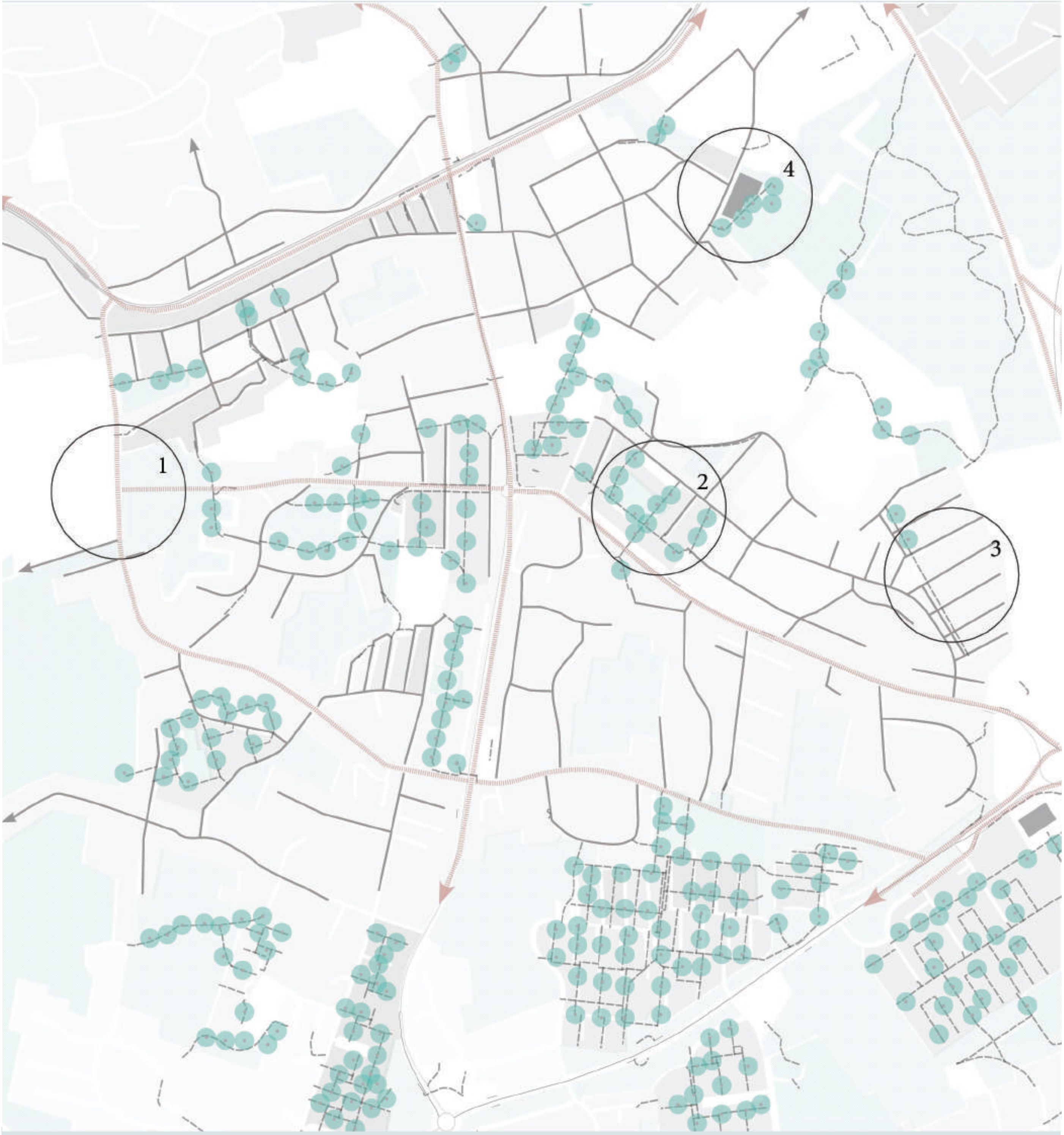
LEGEND
- - Bicycle line (2)
Possible greening
- - Pedestrian zone (as today) (3)
Fast roads (1)
Slow roads (4)
Green urban areas
Silo (5)

1 Fenced fast roads to ensure quick rides through the city.
2 Car-calmed bicycle line, serving as a green corridor.
3 Already existing pedestrian zones.
4 Slow roads leading to the residential areas. Can be crossed by foot.
5 Well maintained silos distributed in the city.

Figure 24 *Scenario 1 - District map - Inner City Gothenburg/ own figure*

1:10 000

Sceanrio 1: District - Suburb, walkability and greenery



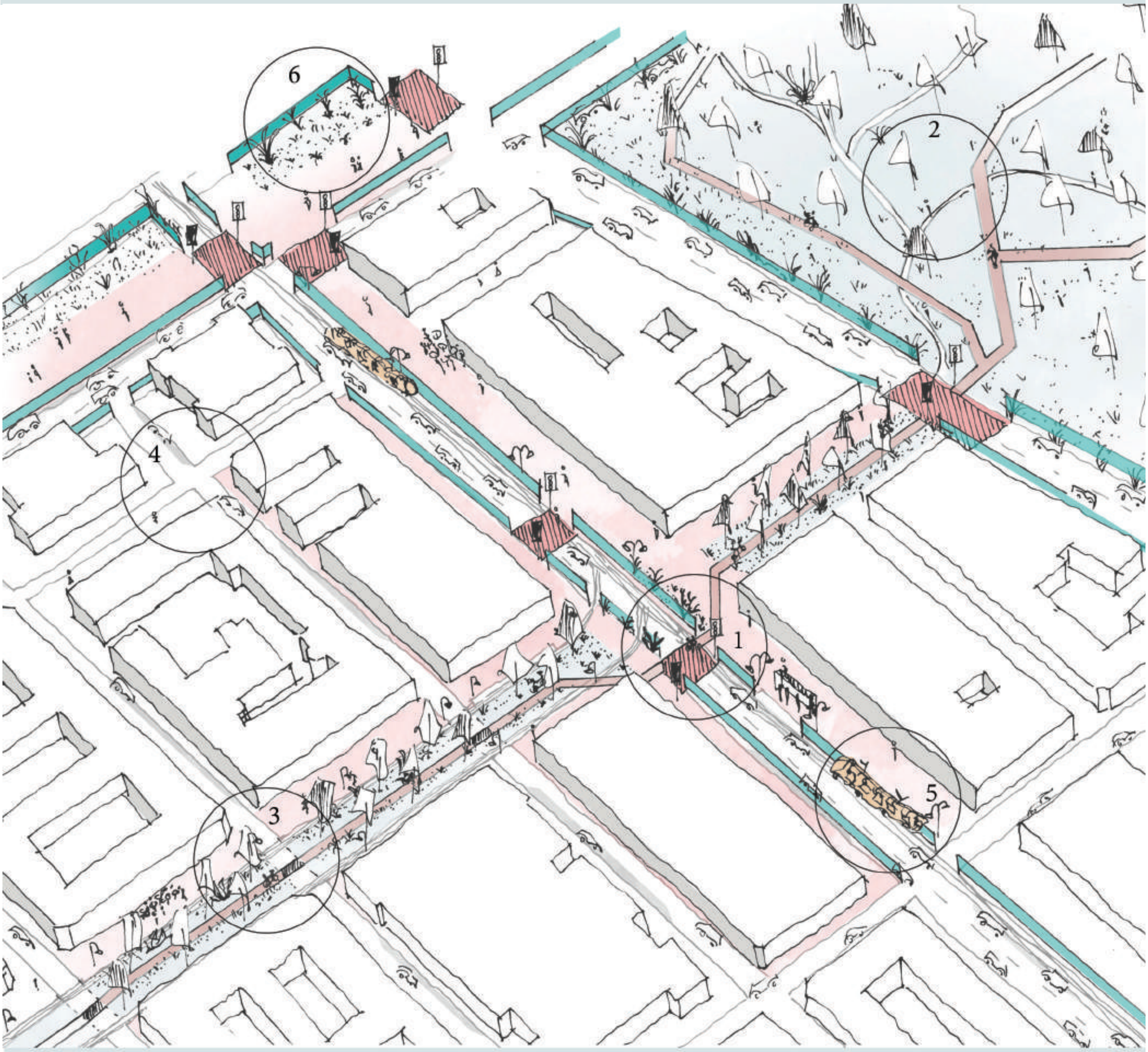
LEGEND
- - Bicycle line
Possible greening
- - Pedestrian zone (as today) (2)
Fast roads (1)
Slow roads (3)
Green urban areas
Silo (4)

1 Fenced fast roads to ensure quick rides to suburbs.
2 Already existing pedestrian zones.
3 Slow roads leading to the residential areas. Can be crossed by foot.
4 Well maintained silos distributed in neighbourhoods.

Figure 25 *Scenario 1 - District map - Suburb Gothenburg/ own figure*

1:10 000

Scenario 1: Axonometry - Inner City, walkability and greenery



1 Passage with traffic lights over the fenced fast-road.

2 City park with high recreational significance.

3 Bike path and green corridor where cars are excluded.

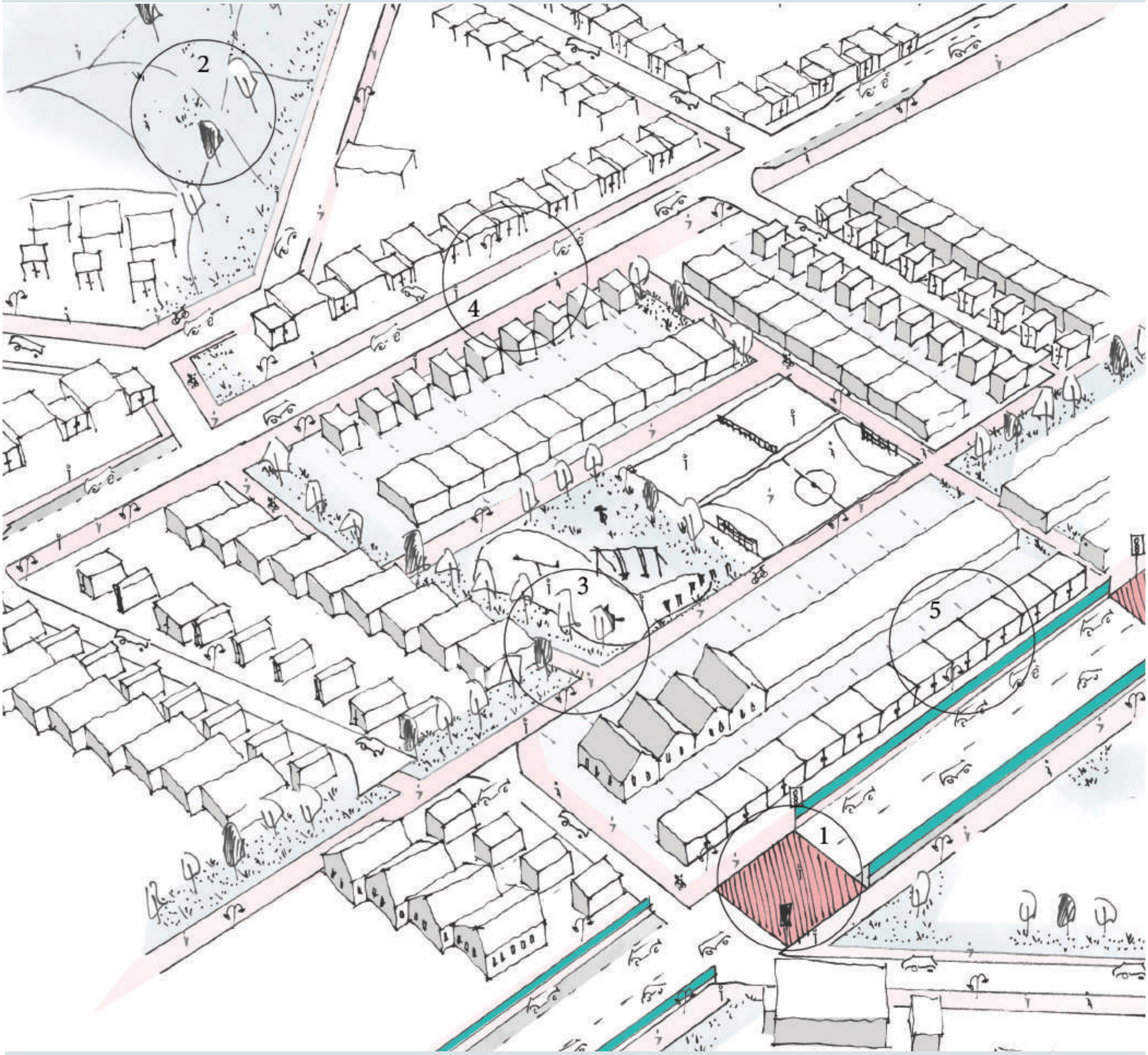
4 Slow roads leading to the residential areas. Can be crossed by foot.

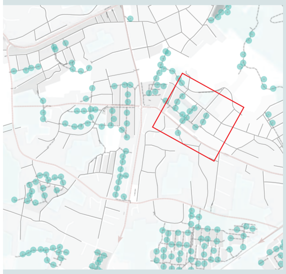
5 Public transport.

6 Bushes and grass to hide fences.

Figure 26 *Scenario 1 - Axonometry - Inner City/ own figure*

Scenario 1: Axonometry - Suburb, walkability and greenery





1 Passage with traffic lights over the fenced fast-road.

2 City park with high recreational significance.

3 Pedestrian area opened for cyclists; serves as a green corridor.

4 Slow roads leading to the residential areas. Can be crossed by foot.

5 Autonomous private cars require parking space.

Figure 27 *Scenario 1 - Axonometry - Suburb/ own figure*


GELATO
All these fences!
So many cars! It`s hardly possible to cross streets.

6.2 „THE RIDE-SHARING SOCIETY“ - WITH AUTONOMOUS TAXI FLEETS

(Based on: “*The Hypermobile City*” (Maurer et al.,2015))

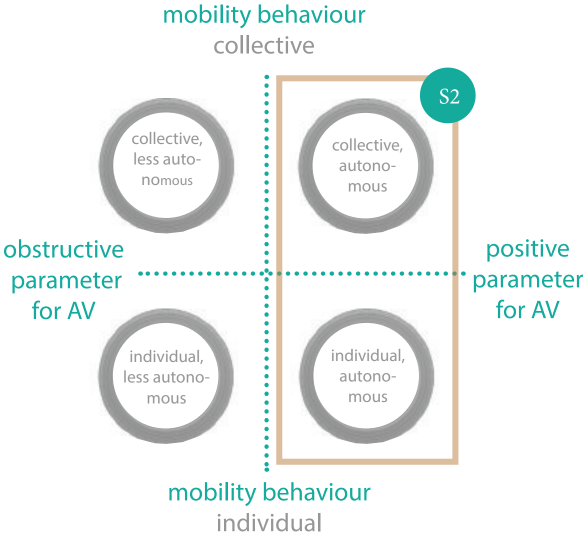


Figure 28 *Possible scenario diagram - Scenario 2 (Gertz & Dörnemann, 2016) / own figure*

6.2.1 Scenario 2 - Description

The “***Ride-Sharing-Society***” is characterised by an **autonomous taxi fleet** that picks up and drops off passengers with the same route. Due to the controversial accident liability regime, the government insists on having the AV offered only by **private and public companies**, but not by private people.

Public transport

Public transport in this scenario is replaced by the autonomous taxi fleet. Experts assume, that if trams and busses would exist beside autonomous fleets, they would decrease (Gertz & Dörnemann, 2016). Therefore, the scenario puts aside the “*usual*” public transport, but argues, that long distance journeys by trains might still exist, because of the limited number of kilometres of AVs. The fleets exist out of **small shuttles that can pick up ten until fifteen passengers**, that want to travel in the same direction. Additionally, the shuttles have the **capacity to carry two to three bikes**. Before starting the trip, passengers can book a shuttle via an application. The closest transition point to their location is selected as a starting point of the journey. By the reason that several passengers are collected on the track, it is not possible to hop in / hop off at any point. **Transition points, which are 200m apart and reachable within 200m from everywhere**, must be visited like a bus stop. Depending on the number of passengers that are sharing a ride, the shuttle is more or less flexible to take the shortest route to the destination.

Congestion

The overall **car stock of today can be reduced by 70% - 90%** if autonomous ride-sharing is taking over (Bratzel & Thömmes, 2018). That would lead to less congestion on streets and a more relaxed journey. The shuttles are running the whole time, what makes them fully utilized, in contrast to private cars, that are parking 95% of their life (Bratzel & Thömmes, 2018). By taking the number of commuters today (Figure 19) and dividing them by fifteen (capacity of a taxi shuttle), then 6.588 taxis would be needed to guarantee transport for all commuters. That would be a reduction of the car stock by 93 per cent (very objective calculation and due to different commuter times times & support of public transport today not representative).

Parking situation and charging

Parking is not required in this scenario, which in addition to better road capacity through AVs results in less and smaller streets, that offer more space for other purposes (Figure 33 number 1). The shuttles only need to stop while charging on a charging point in industrial areas outside the city. In the suburbs, where almost every single-family home has a garage or parking lot on the property today (Figure 27 number 5), **switching to a taxi fleet would mean more land** (Figure 34, number 5).

Hubs

Former bus stops have been transformed into transition zones for the autonomous taxi fleet, that are connecting the whole city (Figure 30). The transition points have a distance of 200m and are reachable within 200m from each location. People with reduced mobility can use the **non-automated service in pedestrian zones**. These are commuting between transition points and the exact destination (to-door service) of the passenger (Figure 33, number 1). This service is **only possible in inner cities** because of its effort. Suburbs, with a smaller user group, cannot benefit from the transition point-to-door service.

Density

Residential choice depends on services. By the reason, that the service in inner cities is much more developed, it is prognosed that the **inner city will grow with high density**. The more people using the shuttle service, the cheaper it becomes. In inner cities, the feasibility to share the ride with more passengers is higher than in spread-out suburbs. Due to the distribution of the shuttle service, the **city expansion additionally can be controlled**.

Street network

The "***Ride-Sharing-Society***", that lives mainly in inner cities, is accustomed to approach their destination so close that they can cover the rest of the route by foot. **It is enough for people to get close to their destination, not right up to the door**. That leads to a change of the street network. **Fast-roads** (60 km/h,Figure 31, number 1) are only necessary to enter the city. All other streets are **slow-roads** (30km/h, Figure 31, number 4). Because of the reduced vehicle stock on streets, the gaps between the shuttles increase. Streets are not as unsafe as in the first scenario, where a constant flow of cars was on the road. **Buffer out of grass is enough to separate the road users** from each other and makes it even possible to cycle. Traffic lights are no longer necessary. From the inner city, the suburbs can be reached by fast-roads, that ensure a quick connection (Figure 32 number 1). Small roads are then **leading into residential areas** and can easily be crossed by people.

Walkability

Due to the distribution of transition points (every 200m), many streets of the suburbs and inner city, as well, have been transformed into pedestrian-only zones. **This creates very quiet and green residential areas** (Figure 34, number 1/ Figure 33, number 1). Former tram lines transformed into **bicycle expressways** (Figure 31, number 2/Figure 33, number 2). They make it possible to reach the whole city and its outskirts fast and safe by bike (Figure 30, number 2). The NMT gains more importance in this scenario which is shown by a **dense network of pedestrian-only zones**. These are open for the cycle traffic, as well.

Greenery

Biodiversity benefits in this scenario. Former parking places transformed into **small residential parks** (Figure 30, number 3). Even though, that trees along wireless connected fast-roads and slow-roads are still impossible, the enlargement of the **pedestrian zone enables the distribution of greenery in form of trees, bushes and other forms of vegetation** (Figure 32, number 2/ Figure 34, number 1). They are serving as corridors between the different city parks. The cycle path additionally serves as a **green corridor, that is even connecting the city parks with the surrounded nature areas** (Figure 30, number 2).

6.2.2 Design criteria

A highly developed **fast-road system** is not necessary because rapid accessibility is subordinate to the ride-sharing model. The rules for the fast roads are a doubling of the distances and a decrease of the road density. In the city centre only the main street remains. **Small roads** are determined to be within 200m of each location. This thins out the network by 40-50%. **Pedestrian zones** should represent at least 50% of the total road network and determine the distances of the slow roads. Delivery vehicles, fire brigade, ambulance, garbage disposal and transition-zone-to-door service have access to the pedestrian zones. The **bike path** is derived from the tram lines that no longer exist in the scenario. A dense network for **bicycles** is created, which is also used as a green corridor. Crossing the fast roads can be guaranteed without traffic lights, because of larger gaps between vehicles. Good service in the city centre sets the rules of city growth. **Controlled growth of the city centre** with high density. This does not affect surrounding **green areas**. **Parking** is being converted into residential parks. In addition, both pedestrian areas, as well as bike corridors offer greening possibilities. New sport & leisure areas are being developed in the inner city. Former **bus stops** provide the localisation of transition zones. In the inner city and suburb, these are distributed and reachable within 200m. Parking is not necessary, but depots in industrial areas to park and charge the taxi fleets should be available.

	Design criteria & methods	SCENARIO 1	SCENARIO 2
DISTRICT	Fast roads	1. Based on: *"motorway"* + *"connecting roads"* 2. Well-developed road network- fast accessibility. 3. Mean distance inner city: 250m; suburbs: 400m.	1. Based on: *"motorway"* + *"connecting roads"* 2. fast accessibility not necessary; road density reduced by 50%. 3. Mean distance inner city: only main road; suburbs: 800m.
DISTRICT	Slow roads	1. Based on: *"small roads"* 2. Door-to-door connectivity. 3. Slow roads ≥40% of total road network; 90% of all streets should be negotiable for AVs.	1. Based on: *"connecting roads"* + *"motorway"* + *"small roads"* 2. Reachability of streets within 200m from each location. 3. Thinning of road network by 40-50% (compared to today)
DISTRICT	Pedestrian zone	1. Based on: *"pedestrian zone"* + *"pedestrian foot way"* 2. Obstacle for door-to-door accessibility. 3. No changes: 6,8% centre/ 32% suburb of whole street system.	1. Based on: *"small roads"* + *"pedestrian zone"* + *"living street"* + *"pedestrian foot path"*. 2. Should count at least 50% of whole street-network. 3. Inside slow roads, that are reachable within 200m.
DISTRICT	Bicycle path	1. Based on: *"cycle path"* 2. Improving the connection between urban parks. 3. Closure of certain streets for bikes. 4. Mean distance: 400m.	1. Based on: *"tram lines"* 2. Improving the connection between urban parks. 3. Dense bike network.
METROPOLITAN	Density	1. Based on: *Urban fabric density* (<10%, 10-30%, 30-50%) 2. Multimodality- city growth around hubs. 3. Low density suburbs; inner city not attractive.	1. Based on: *Urban fabric density* (30-50%, 50-89%, >80%) 2. Additional service in inner city- cheaper life in centre. 3. Controlled expansion in inner city with high density.
METROPOLITAN	Greenery	1. Based on: *Greenery* (all types) 2. Low dense suburbanisation- impact on green. 3. Partly transformation of parking into residential parks. 4. Pedestrian areas/bike corridor provide greening possibilities. 5. New suburbs: additional sport & leisure areas.	1. Based on: *Greenery* (all types) 2. High density extenstion of inner city- no impact on green. 3. Full transformation of parking into residential parks. 4.Pedetstrian areas/ bike corridor provide greening possibilities. 5. New inner city districts: additional sport & leisure areas.
METROPOLITAN	Public transport	1. Based on: *"bus lines"*, *"tram lines"* 2. Public transport unchanged to today's state.	1. Based on: *"bus lines"* 2. Bus stops serve as transition zones. 3. Inner city + suburbs: reachable + distributed within 200m.
METROPOLITAN	Parking	1. Based on: *"parking places"* 2. Partly transformed into silos. 3. Distributed: close to hubs, public transport, nature areas	1. Based on: *"parking places"* 2. Transformed into residential parks. 3. Some used as transition zones, close to nature areas. 4. Depots in industrial areas neccessary for charging issues.

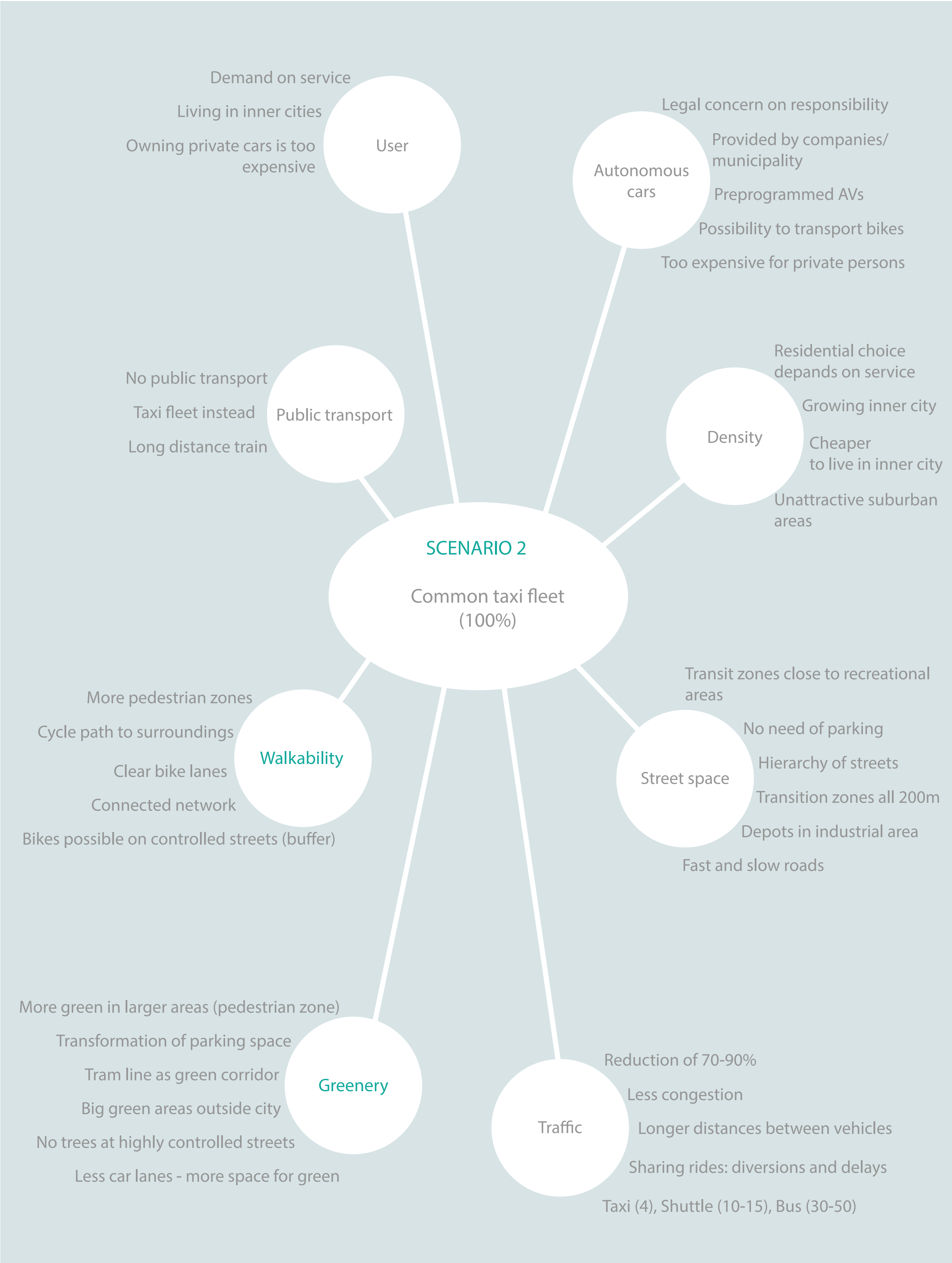


Figure 29 *Scenario 2 - summary / own figure*

6.2.3 Scenario 2 - Design

Table 09 shows the **parameters for the scenario design** in a more detailed way according to its scale. The change of the layers can be compared with the situation today, of Figure 19. If layers have been changed in its spatial habit, the criteria are marked with a green frame. If the value of attributes changed through interventions, a red frame is marking the difference. The adaption of the different layer can differ in both zoom-in areas, in the district scale, as well as in axonometries.

Metropolitan 1:75 000

District 1:10 000

Axonometry

LEGEND
X Mapped
Change of Attribute Value
Spatial Transformation

SCENARIO 2

Scale → / Layer ↓	Metropolitan	District: Inner City	District: Suburb	Axonometry: Inner City	Axonometry: Suburb
Greenery					
- playground	X same as today			X added	X same as today
- forest	X				
- green urban areas	X densification of inner city might have impact on greenery	X same as today + more green in pedestrian zones	X same as today + more green in pedestrian zones	X green corridor + greened pedestrian zones	X green corridor + greened pedestrian zones
- pastures	X				
- sport & leisure	X				X
- agriculture	X				
- herbaceous	X				
Density					
- > 80%	X densification	X densification	X same as today		
- 50-80%	X	X	X		
- 30-50%	X controlled expansion of inner city	X	X		
- 10-30%	X	X	X		
- < 10%	X	X	X		
Commuter					
Street network					
- motorway		X fast road	X fast road	X fast road/ buffer	X fast road/ buffer
- connecting roads		X slow road	X slow road	X slow road	X slow road
- small roads		X pedestrian zone	X pedestrian zone	X pedestrian zone	X pedestrian zone
Walkability					
- pedestrian zones		X enlarged green	X enlarged green (slow streets)	X enlarged green (slow streets)	X enlarged green (slow streets)
- living street		X	X	X	X
- cycle path				X	X
Public transport					
- bus lines					
- tram lines	X transition zone	X transition zone	X transition zone	X on former tram line/ greened transition zone	
- bus stops	X green corridor + bike lane	X bike lane/ greenery	X bike lane/ greenery	X	X transition zone
Parking places	X residential parks/ transition zone	X residential park	X residential park		X larger garden

Table 09 *Concept Scenario 2/ own figure*

Scenario 2: Metropolitan map

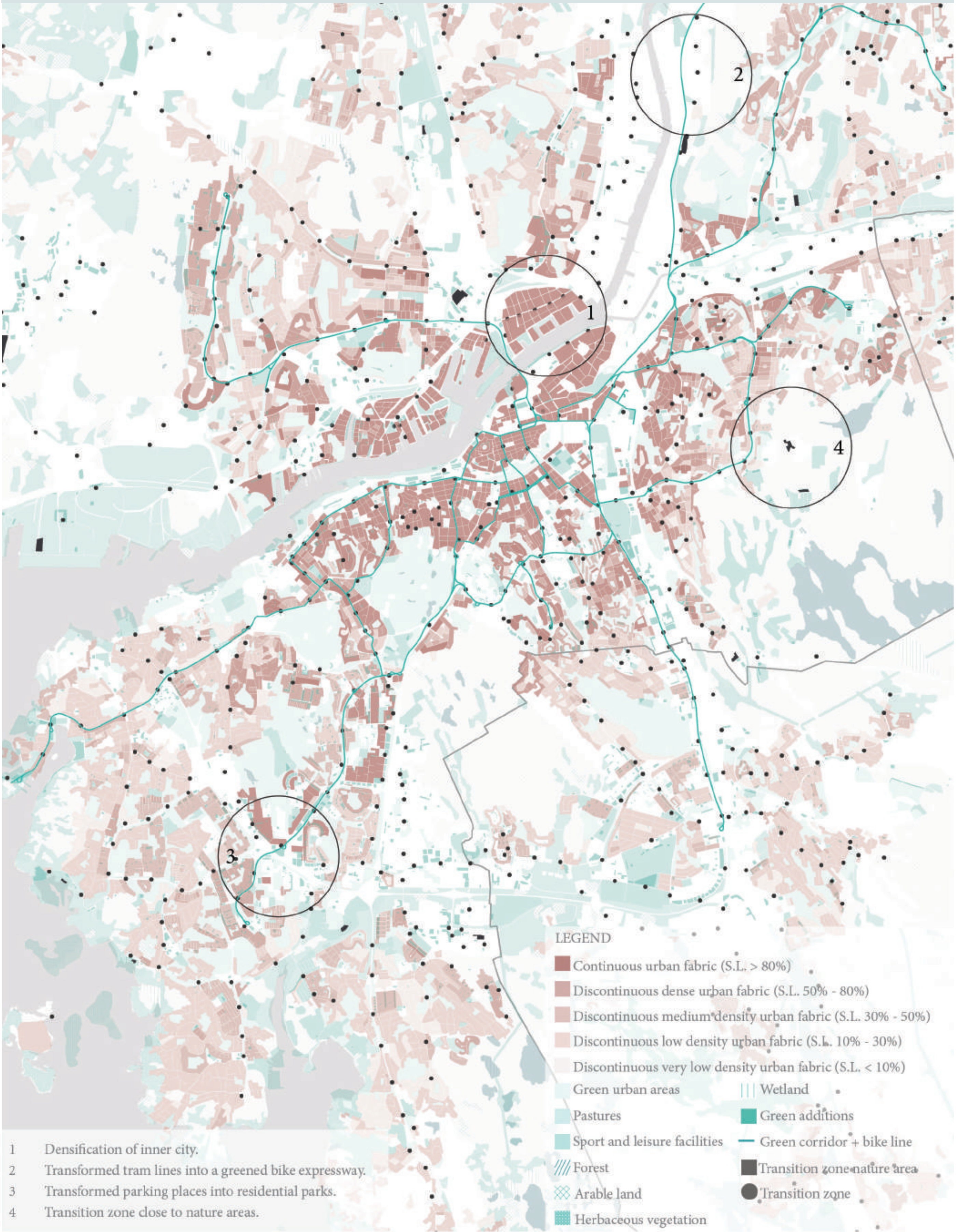
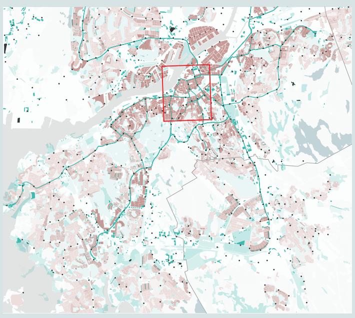


Figure 30 *Scenario 2 - Metropolitan map Gothenburg/ own figure*

1:75 000

Scenario 2: District - Inner city, walkability and greenery



LEGEND
- - Bicycle line (2)
Possible greening
- - Pedestrian zone (3)
Fast roads (1)
— Slow roads (4)
Green urban areas
Silo-city park (5)
Transition zone

200m

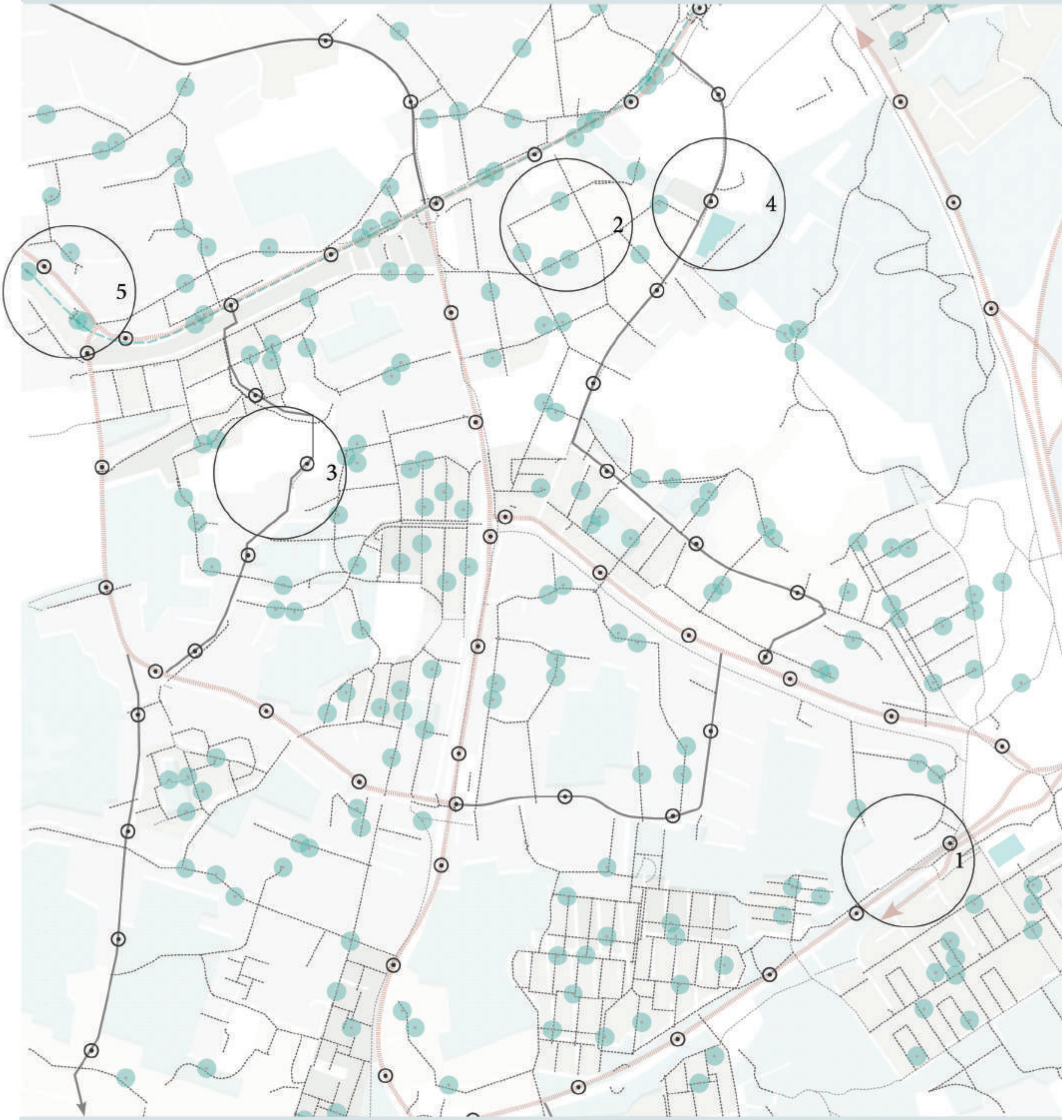
200m

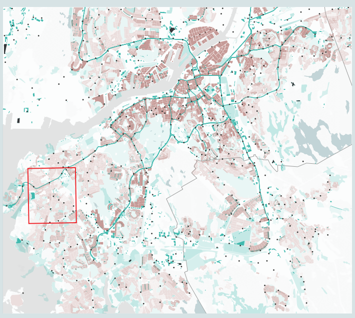
1 Fewer fast-roads leading through the city.
2 Tranformed tram lines into greened bicycle corridor.
3 Green pedestrian area with supporting transit point-to-door service (not autonomous) for people with impaired mobility.
4 Slow roads leading to the residential areas. Can be crossed by foot. Transition zones for pick up, drop off of passengers.
5 Former silo areas transformed into city parks.

Figure 31 *Scenario 2 - District map - Inner City Gothenburg/ own figure*

1:10 000

Scenario 2: District - Suburb, walkability and greenery





LEGEND
- Bicycle line (5)
- Possible greening
- Pedestrian zone (2)
- Fast roads (1)
- Slow roads (3)
- Green urban areas
- Silo-city park (4)
- Transition zone

200m

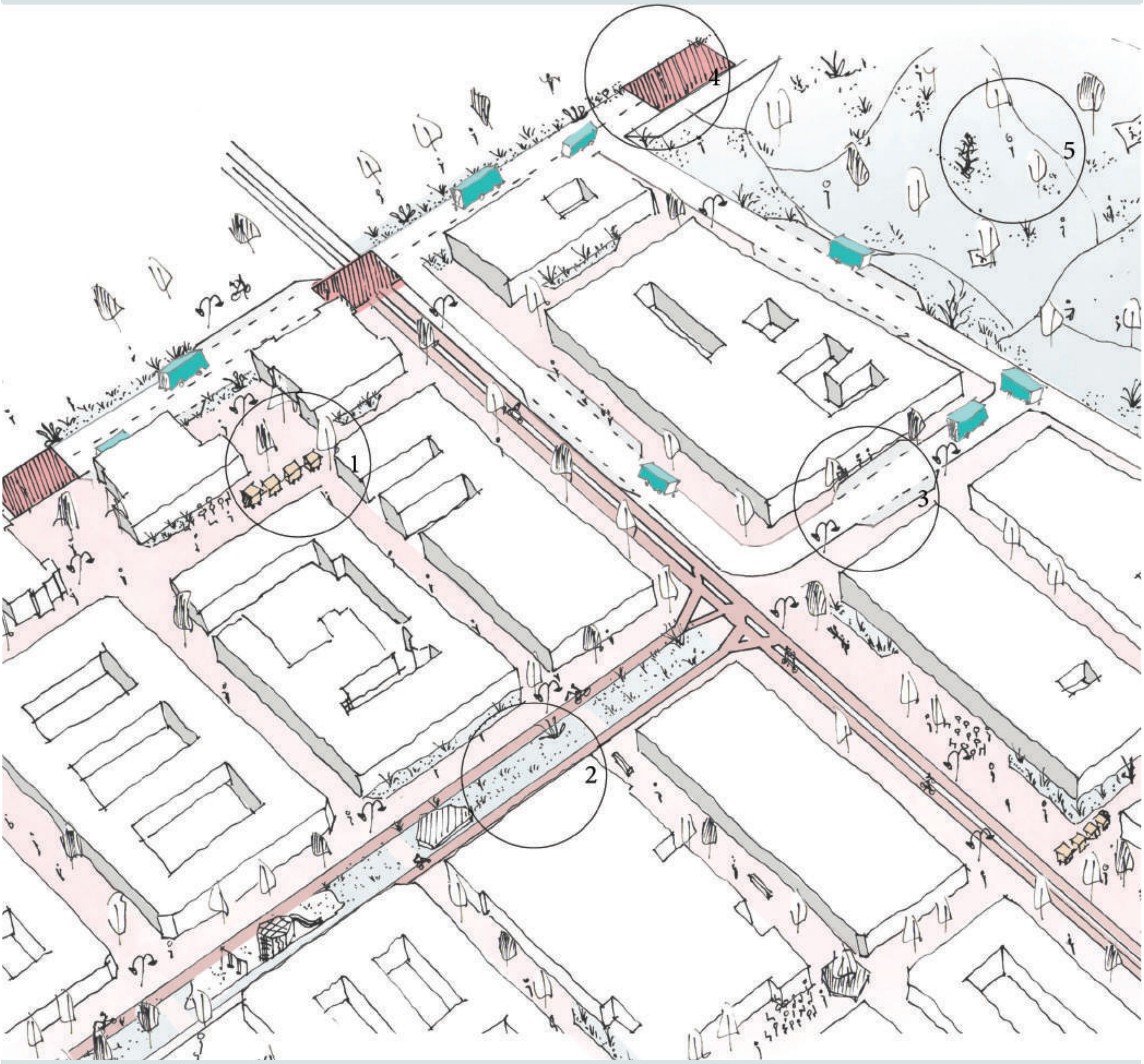
200m

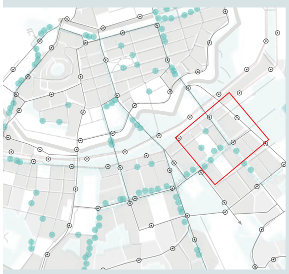
1	Fast road network into suburbs.
2	Green pedestrian area, in residential area. No support of door-to-door services.
3	Necessary slow roads leading to residential areas. Transition zones for pick up, drop off of passengers.
4	Former silo areas transformed into city parks.
5	Tranformed tram lines into greened bicycle corridor.

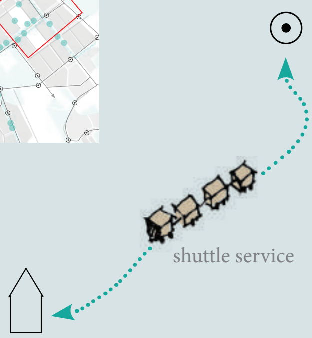
Figure 32 *Scenario 2 - District map - Suburb Gothenburg (GIS)/ own figure*

1:10 000

Scenario 2: Axonometry - Inner City, walkability and greenery







1 Green pedestrian area with supporting transit point-to-door service (not autonomous) for people with impaired mobility.

2 Transformed tram lines into a greened bike expressway.

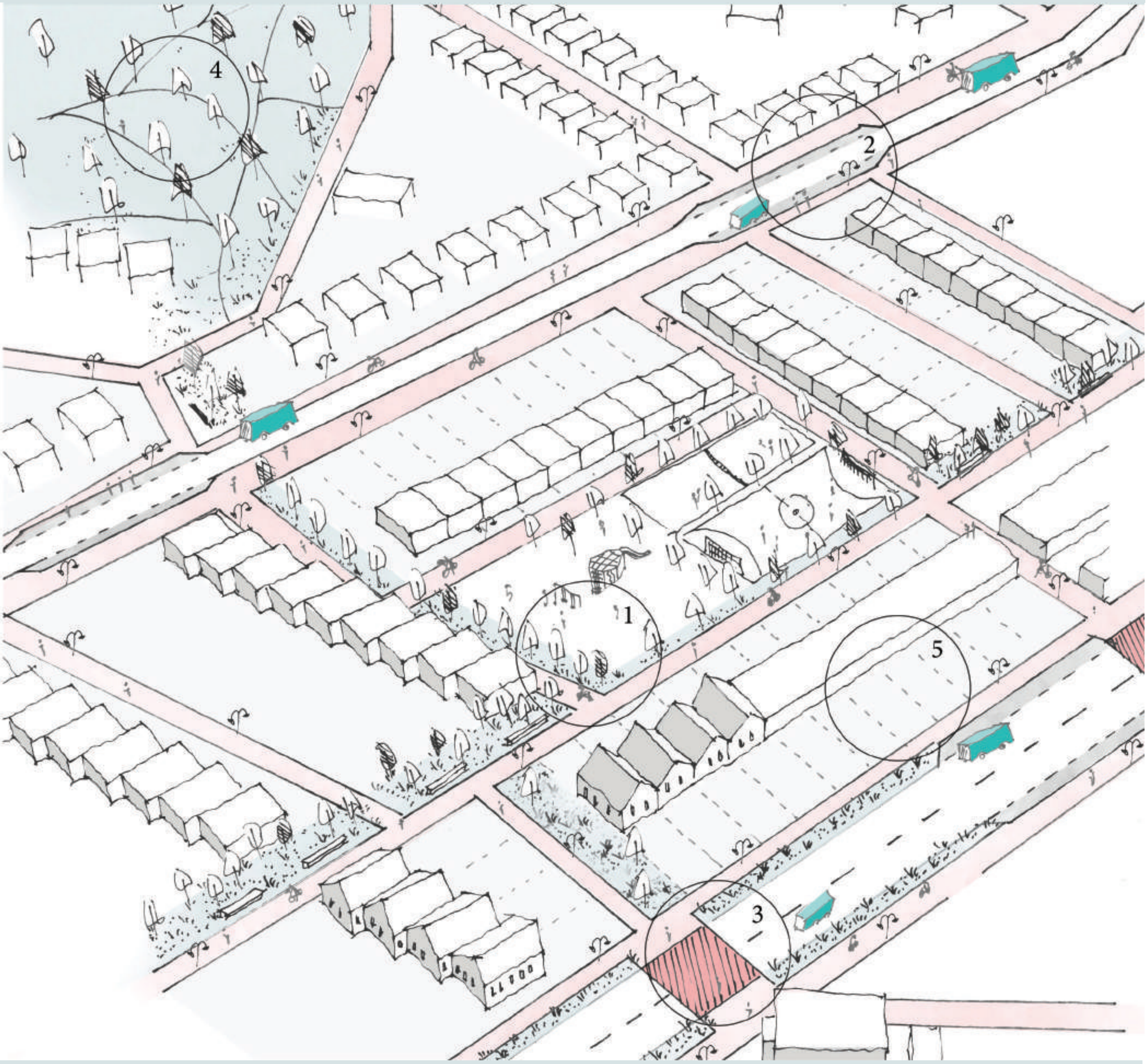
3 Slow roads leading to the residential areas. Can be crossed by foot. Transition zones for pick up, drop off of passengers.

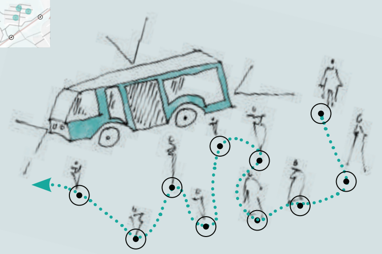
4 Passage over fast-road. Traffic lights and fences not needed.

5 City park for recreation and biodiversity.

Figure 33 *Scenario 2 - Axonometry - Inner city/ own figure*

Scenario 2: Axonometry - Suburb, walkability and greenery





1 Green pedestrian area, connecting city park with smaller residential parks. No support of door-to-door services.

2 Slow roads leading to the residential areas. Can be crossed by foot. Transition zones for pick up, drop off of passengers.

3 Passage over fast-road. Traffic lights and fences not needed. Transition zone for drop off and pick up of passengers.

4 City park for recreation and biodiversity.

5 Garages not necessary. More plot of land by household.

Figure 34 *Scenario 2 - Axonometry - Suburb/ own figure*


GELATA
Oh! I need to catch the taxi! Bye!
The pedestrian-zones are a blessing for our city!

7. ASSESSMENT OF FUTURE SCENARIOS

Chapter 6 has shown the **spatial effects** of the two different uses of autonomous vehicles on the **urban environment based on scenarios**. How **greenery and walkability** might be developed in the new mobility age has been visualized and explained. In the next step it is important to go deeper into detail by **calculating the exact changes of the two scenarios, that are compared with the today`s situation**.

Chapter 7 assesses the scenarios in a **quantitative way**, to **calculate direct impacts** on the street system, the distribution and area size of greenery and on the overall length of the pedestrian area. With these calculations, the spatially recognizable changes get a concrete number, which varies depending on the scenario. The effects of the two modes of autonomous driving and the differences between the two scenarios are clearly visible. All calculations are done in QGIS (geographic information system). This is a computer-based tool to calculate and describe spatial features.

Additionally, a **qualitative assessment** of the commuters Anne and Mikkel is performed. In this step, it is important to be able to understand the demands of commuters. An insight into their mobility behaviour has already been described in Chapter 5. In the assessment part, it is important to **experience their feelings, limitations, problems, wishes and thoughts about the two scenarios**.

The methods for evaluating the individual quality criteria were selected with regard to the available time at the end of a master's thesis and its easy replicability. The criteria are divided into **linear measurable and spatially measurable** factors. Working with buffers to capture the catchment areas of parks and the associated examination of interconnections of parks with each other, have emerged from the book „*Urbanes Grün in der integrierten Stadtentwicklung – Strategien, Projekte, Instrumente*" by Bläser et al. in 2012, on behalf of MBWSV NRW (Germany).

7.1 Assessment Criteria

- **Greenery**
  - Length of roads for green (in m)
  - Well-connected and distributed green urban areas
  - Total size of green areas (in m^2)
  - Types of green areas (in m^2)
  - Access to green (in m^2)
- **Walkability**
  - Density of urban fabric (in m^2)
  - Parking area (in m^2)
  - Area of pedestrians (in m)
  - Prioritizing roads (in m)

Greenery

Length of roads for greenery

This indicator contains all **roads that have been changed in their function** and are therefore suitable for greening. Including **bicycle-only streets of Scenario 1**, that are used as a green corridor in the same time and all **pedestrian-only zones of both scenarios**. Scenario 2 additionally **transformed tram lines into green corridors**, that are free for cycling, as well.

These indicators have been assessed by measuring the length of the lines in QGIS. A new column in the *Attribute Table* has been created for the dimensioning of the lengths of each layer to be transformed. Using the *Field Calculator - Geometry - $length*, the lengths of each road section are calculated. The *Group Status Tool* can then be used to calculate the sums of the individual lengths (*values*). The result is a new table that contains the total sum of the road length – that can be used for greenery.

Total size of green areas

The total size of green areas **includes all types of green that is located in, and in the surroundings of Gothenburg**. The total size results from the sum of the individual green types (calculated as in step: "*Types of green*").

Well-connected green urban areas

Connectivity describes **how different green areas are related and connected to each other**. A close relationship between green pattern enables species to pass through and to reach new habitats.

To calculate the connectivity in QGIS, a buffer of 100 meter around each polygon was done (*Vector – Geoprocessing Tool – Fixed distance buffer*). The new buffer layer was then examined for how often the polygons intersect. This is done via *Vector – Data Management Tools – Join attributes by location*. As a result, a new column is created (called "*count*") with the number of intersections (*substracted by 1)*. **Scenario 1** has additionally to the "*usual*" green areas, a **bicycle-corridor in the inner city**. The suburb remains the same as today. In **Scenario 2 the transformed tram lines to a bicycle corridor** increases the overall number of intersections.

Well-distributed green urban areas

The distribution of green areas measures the **average distances between patches**. Scenario 1 and 2 additionally have included cycle paths, that are also used as green corridors. To calculate the average distances, the middle points of each patch were determined (V*ector – Geometry Tools – Polygon Centroids*). The new layer "*centroids*" than has been put into a *Distance Matrix* (*Vector – Analysis Tools – Distance Matrix*). In the *Attribute Table*, the shortest distances are mapped. Then calculations of the average of these numbers for the district areas in today´s situation, Scenario 1 and Scenario 2. These numbers can be compared and a percentual deviation can be calculated.

Types of green

Gothenburg is surrounded by different kinds of green, that can be seen in Figure 16. For calculating the size of each type in square meters, a new column ("*New field*" – called "*area size*") was added in the *Attribute Table*. By using the *Field Calculator – Geometry- $area*, each polygon got its size. With the tool *Group Status*, the "*area size*" then can be summed up. The result is a table with the area size of each type of green. **Depending on the interventions of each scenario, the size is varying**.

Access to green

This indicator describes the **catchment area within a certain distance of green urban areas**. The aim is to find out which **buildings have no direct access to green urban areas within a certain distance**. Additionally, the green corridor for cyclists of Scenario 1 has been added and the transformed tram lines of Scenario 2.

To measure distances in QGIS it is possible to create a "*Fixed distance buffer*" (*Vector – Geoprocessing Tool – Fixed distance buffer*) of the green urban areas. This has been done twice with two different buffers (200m for larger areas, and 100m for smaller areas). The same approach has also been done for the cycle ways (buffer 100m). The next step is to calculate the *Difference* between the *Input layer* (Urban green areas) and the *Difference layer* (Buildings/ or Urban fabric). The Difference (1) shows the buildings, that are located outside the buffer. The same procedure is done for the cycle corridor (of Scenario 1 and Scenario 2), using the Difference (1) as the new difference layer that is going to be cut by the buffer. The result is a new difference layer (2), that includes buildings that neither have access to green urban areas, nor to the cycle corridors.

The maps illustrating the access to green of each scenario, can be found in the appendix.

Walkability

Density urban fabric

The density of the urban fabric can also be seen in Figure 19. The **inner city has mostly a densification value higher than eighty percent**, while **suburban areas** are characterized by **their low-density urban fabric**, that has a value with less than ten percent up to thirty percent. Depending on the Scenarios and the distribution of the people, these values will change.

For calculating the changes, the same procedure has been done, as for the types of green. A new column ("*New field*" – called "*area size*") was added in the *Attribute Table*. By using the *Field Calculator – Geometry - $area*, each polygon got its size. With the tool *Group Status*, the "*area size*" then can be summed up. The result is a **table that shows the area size of each urban fabric value**.

Parking area

Parking area includes all larger **parking places** (excluded on-street parking) that are **distributed in Gothenburg**. Figure 19 highlights their location. By the reason, that the **Scenarios decrease the number of parking**, many of them are going to be **transformed into small residential parks**.

For calculating their size, a new *column* "*area size*" has been added in the *Attribute Table*. These areas have been calculated with the *Calculator – Geometry - $area* and summed up with the *Group Status* again. Depending on the Scenarios, the number of residential parks differ. They have been calculated in the same way and then subtracted of the total amount of the parking area. **The results are the area size of the Silos** (in Scenario 1) and the **transition zones** (of Scenario 2) plus the **size of residential parks**.

Area of pedestrians (in m)

The pedestrian areas differ depending on the Scenarios. While the **areas remain the same as today in Scenario 1**, **they increase in Scenario 2**. The length in metres have been calculated in the same way, as the indicators of "*length of roads for green (in m)*".

Prioritizing roads

The road system changed in the scenarios, compared to today. **Scenario 1 contains a denser road network** in general to guarantee a door-to-door transport. Many fast roads ensure fast connections. **Scenario 2 opens only the most important streets for AVs**, that are needed to reach all destinations within 200 meters by foot from the transition points. Therefore, the overall road network deceases. The lengths have been calculated as in the step "*length of roads for green (in m)*".

7.2 QUALITATIVE ASSESSMENT SCENARIO 1

Anne`s opinion abut „The Door-To-Door Society“

*In my opinion the **private autonomous car is a good achievement**. I relax the time commuting to the city without stress to search for parking possibilities. It takes a bit more time because of longer rush hours, but I can use the time in the car efficient to prepare myself for upcoming meetings.If I need the car for my work, I just order it close to the entrance. **In the evening, I`m happy to leave the car-crowded city**. The journey home goes very fast, because most of the roads I`m using are fast roads. Our house is connected to a small road, which makes it possible to park in our garage on our property. Some **pedestrian-only zones are in front of our house**, that invite to have a walk or to play some tennis on the tennis court. On the weekend we are enjoying the time in our garden or in some nature area, that are in walkable distance, as well.*

Mikkel’s opinion abut „The Door-To-Door Society“

*In my opinion **private autonomous cars made inner cities less attractive**. Many streets are **crowded by a constant flow of cars**. It is harder to cross the streets, because the dominating **fast roads are fenced in**. Only some crossing with traffic lights enable to come to the other side. As a pedestrian or a cyclist, as myself, you need a lot of patience. **Cycling is very disruptive, and you must stop and push your bike in many areas**. If you can manage to cycle only on the car-free bicycle zones, then you can look forward for a nice ride in the green. To escape the stressful city life, I try to **spend a lot of time in green urban areas or in larger nature areas outside the city**. But to get there, I take the public transport, and not my bike.*

7.3 QUALITATIVE ASSESSMENT SCENARIO 2

Anne`s opinion about „The Ride-Sharing Society“

*In the beginning I was sceptical about sharing rides with other people and not enjoying the luxury of owning my own car. But now, as I`m used to it, I see many advantages by this system. **We don`t need to have a parking place in front of our house**. The space can be used as an additional outdoor space. The whole area we are living became less noisy **and even better connected for pedestrians and cyclists**. My kids can play outside without the fear to getting hit by a car. The only disadvantage I see in this system is, that if you are commuting from suburbs to the city, you are becoming a bit **less flexible in choosing the fastest route**. The taxi picks up many other passengers with the same destination or direction, and sometimes, you are **traveling a detour** to reach them. Sometimes, it is a bit annoying, I have to say. But I have no problem to walk the last hundred meters from the transition point, to reach by destination. In general, I think I can reconcile with the situation.*

Mikkel`s opinion about “The Ride-Sharing Society“

*The ride-sharing principle is exactly what I always wished for inner cities. Most of the streets are **pedestrian zones**, which **enhances the quality of cities** enormously. Less cars are in the city, what makes it easy for pedestrians as well as for cyclists to cross them. In pedestrian zones many new cafés opened, and the trees are donating shadow in the summer. The city became a **paradise for cyclists, that can use well-marked bicycle fast roads**, that are leading through the whole city. Sometimes, I`m booking a taxi, but most of the time I enjoy moving freely and unconcerned by foot or by bike to my destinations.*

7.4 COMPARISON OF SCENARIOS WITH TODAY

Gothenburg today is surrounded by different types of nature. The total size equates **428 million square meters** (Table 10 - Appendix). Anyway, there is a big potential for the future, **to connect green urban areas** in the inner city and in the suburb better with each other. In the inner city, green urban areas averagely **intersect with five other patches** (Greenery- diagram 2). In suburbs the value is lower than four. The distance in the inner city between the patches counts 137 meters (Greenery - diagram 3). In **Suburbs even 155 meters**. There is also a lack in the accessibility of green urban areas, from the housing area (surrounding nature areas are not included in the calculation). This numbers show **demands for improvement in the future urban development of Gothenburg** (Table 10 - Appendix). It can also be recognised, that the overall parking area requires a lot of space (Walkability - diagram 3).

How these numbers might change in the future, is explored in the comparison of the scenarios and the today`s situation in Figure 36. Due to a design approach it is not possible to get very precise numbers. But the result and the deviation between the scenarios and today, are **indicators of how the situation might change. As a result, forecasts of the possible change can be estimated**.

This chapter compares the scenarios with the today`s situation. A more detailed assessment for each scenario can be found in the appendix, as well as a table with all calculated numbers.

Figure 35 *Comparison situation today & scenarios - Greenery, based on Table 10*

The diagrams of Figure 35/Figure 37 summarise the spatial effects on the assessment criteria, that have been introduced in Chapter 7. The differences between the situation today and scenario 1 or 2 are fast visible. **Scenario 2** with a common taxi fleet enables to **enhance the overall situation for greenery**. Streets, that can be greened or serve as green corridor increase enormous in their length (Greenery - diagram 1). In inner cities an increase with approximately 364 percent can be expected (Figure 36). Also, in suburbs more streets will be available for greening in the "*Ride-Sharing Society*". In **Scenario 1**, some of the streets are transformed into greened bicycle-corridors. This enhances the available space for green structures by 147%.

Connectivity between green urban areas is increased in both scenarios compared to today. Also, the distances will be shorter, what makes it easier for species to pass through. The accessibility between housing areas and urban green space becomes easier in the future. The areas, that formerly had no access within 200m to green urban parks decreas (Figure 36). This makes it easier for inhabitants to reach parks, that are close to their houses.

Due to the suburbanisation in the "*Door-To-Door Society*", there might be an increase of the urban fabric by twenty-three percent (Figure 36). The urban growth in Scenario 2 is better guidable due to available on-demand services.

Deviation between situation today, Scenario 1 & Scenario 2

	Metropolitan		District - Inner City		District - Suburb	
	S1	S2	S1	S2	S1	S2
Greenery						
Length of roads for green (in m)			+147%	+364%	0%	+207%
Well-connected green urban areas (intersection)			+19%	+32%	0%	+5%
Well-distributed (distance between) green areas			-19%	-15%	-21%	-22%
Total size of green areas (in m2)	-2%	+2%				
Types of green areas (in m2) residential parks	+5.895.899%	+6.352.130%				
No access to green (in m2)			-71%	-89%	-58%	-82%
Walkability						
Density of urban fabric (in m2)	+23%	+5%				
Parking area (in m2)	-89%	-97%				
Area of pedestrians (in m)			0%	+795%	0%	+206%
Prioritizing roads (in m)			-28%	-54%	-3%	-40%

Figure 36 *Deviation between situation today & scenarios - based on Table 10/ own figure*

In general, a **decrease in the street system is recognisable** (Walkability- diagram 4). Especially, the on-demand service of Scenario 2 makes it possible to close many streets for AVs. But also, in Scenario 1 where a high connectivity and a door-to-door service is expected, some streets are transformed into bicycle lanes. The transformation of parking places, that are distributed in the whole city of Gothenburg today, deliver **space for new recreational areas** in both scenarios (Walkability - diagram 3).

The scenarios have many factors in common, but the effects on the assessment criteria also show, where more and less impacts on greenery and walkability will appear.

Figure 37 *Comparison situation today & scenarios - Walkability, based on Table 10*

8. SYNOPSIS

8.1 REFLECTION

The thesis has shown the importance of the collaboration between **research and design** in order to identify possible effects of AVs on the future urban environment. The theoretical approach has shown strategies, goals and the historical handling of urban qualities (greenery & walkability) that serve for the scenario development and the subsequent evaluation. Due to this approach it is possible to **recognise unfavourable and beneficial impacts on the qualities**, that work as a learning tool for future urban developments. Research and design are working hand in hand, where the **literary approach**, gives the **framework, limitations and the necessary knowledge** to build scenarios. The **design of scenarios**, demonstrates an additional tool, **to explore the theoretical statements in practice**. It is difficult to imagine what impact autonomous driving might have on the urban environment, by only exploring the literature. But by translating theoretical information into spatial design, the differences, challenges, obstacles and possibilities become visible. Design is therefore an important tool to gather complex information and to make it understandable also for layman. The literary approach alone, would not have given the answer to the research question.

LINK BETWEEN LITERATURE AND SCENARIO DESIGN

An important element between theory and design is the **criteria table** (Table 05). This represents the individual layers of greenery and walkability that are used to design the scenarios. At the same time, the literature delivers the **demands for the qualities**, and determines how the individual layers in each scenario can be evaluated. Further, the table shows the **changes** that were made in each layer, depending on the scenario and scale. Working with a table worked very well. In the beginning it was difficult to transfer the collected results of the literature to the scenarios and their evaluation. Through a focused **summary of the criteria of greenery and walkability after each chapter**, it was possible to formulate the most important goals. These could then be collected in the criteria table and thus served for the scenario design.

SELECTION OF TECHNOLOGY

In order to be able to select technologies of future AVs, it is important to gain an insight into the **state of the art** of the car industry, which are currently being discussed and developed. Above all, it is important how AVs can move safely on roads and how they relate to their environment. The determination of a particular form of these technologies, which is assumed in the scenarios, includes uncertainties because other possible forms are excluded. This decision was necessary regarding the restricted time. Selective measures make it possible to derive **observations that are tested on the scenarios**. These provide information about possible influences that a certain form of autonomous driving might have on the urban environment and its qualities. The choice of technology is purely speculative, but its **influencing factors and/or disturbing factors must be considered when developing the scenarios**. The city planner’s task is to make these decisions in order to explore and investigate spatial impacts.

SCENARIO DEVELOPMENT

The decision to investigate two controversial scenarios emerged based on the work of **Maurer et al. (2015)** described in Chapter 5. Maurer provides a theoretical description of future scenarios that emanate from 1. private AVs and 2. a taxi fleet. The theoretical background gave important information about possible effects on society, urban structures and urban qualities. This information has been scientifically studied in Maurer`s report but has not been reviewed for spatial impacts. The **translation of Maurer`s forecasts into spatial extreme scenarios, makes it possible to identify problems on the urban environment and quality factors** early and enables to react on them. Nevertheless, many research articles argue, that a shift towards full automation cannot be realised from one to the other day. Therefore, it would be also important, to explore other scenarios with the coexistence of petrol-driven cars and AVs, and to study their effects on the urban environment and its qualities.

FENCES, OR NO FENCES?

Reflecting the question can be asked, whether fences could not have been a possible solution for both scenarios? The work assumes that fences are necessary **depending on speed and traffic volume**. The opinion of traffic planners and urban planners could differ in this point. Therefore, this decision also has uncertainties and room for interpretation. Nevertheless, by establishing the rule that fencing is dependent on speed and traffic volume, design measures can be derived. **The traffic volume of private AVs and taxi fleets differs in both scenarios**, while they are driving with the same speed. Therefore, sometimes smaller and sometimes larger gaps between the vehicles arise. In conclusion, it was determined that **crossing high traffic volumes is not possible** for safety reasons, and therefore fences play an important role. With larger gaps of the taxi fleet, there is more time for pedestrians to prepare for a crossing and to estimate the traffic. Fences are not seen as a necessity. As an urban planner, the definition of the dependence on speed and traffic volume helped to define decisions. This ensures safety in the scenarios and weighs the effects of the mobility form on the spatial environment. At this point, it would be important to include a **comprehensive analysis** that calculates the actual traffic in Gothenburg in both scenarios. In the thesis, the reduction of the AV stock was derived from the predictions of Bratzel & Thömmes (2018) and adopted into the scenario design.

DECISION FOR SCALES

The thesis aimed to explore the scenarios in three different scales. To understand the **whole urban system and the effects AVs might have on the urban environment and quality factors**, were the driving forces for the selection of these scales. The message of the maps should be reduced to the essentials, to not overload them with unnecessary information. **OSM data** was used to design the maps. This tool was suitable for getting all the important layers, and for adapting and changing them. Nevertheless, it is difficult, especially on the large-scale of the metropolitan map to make high claims. Particularly, in the ability to confirm and compare the data against the real world. The presentation of data and results on a large and detailed scale may therefore deviate from reality. Additionally, the complexity and the amount of work involved in presenting different scales, **might risk of not going that deep into important details**.

Perhaps it would have been an alternative to **only focus on the large-scale development** of the whole city of Gothenburg. More time would have been available to deal more extensively with the possible urban development and to go more into detail. The focus could have been on the distribution of green structures, by studying the density of biodiversity in different ecosystems. The impact of urban growth, coupled with the new form of mobility, could have helped to draw conclusions about biodiversity and its limitations/benefits in the assessment. Otherwise, a **restriction to the spatial changes of the inner city and suburb** would have been possible with a subsequent critical comparison. The districts could have been examined in more detail and more extensively. It would have been important to weigh how the traffic volume would really be in both scenarios and what that would mean for the capacity of the roads and other road users. In addition, it would have been possible to focus more on biodiversity. Not only proposals for possible green areas, but rather to carry out a comprehensive ecological integration. One target species (bees, for example) could have helped to examine the scenarios for their ecological diversity and suitable habitat of this specific species.

ASSESSMENT

The method for evaluating the scenarios resulted from the definition of the quality criteria. These were subdivided into **spatially measurable and linear measurable qualities**. QGIS was used as a tool because it can measure spatial changes with simple methods and is freely accessible. The applied methods can be used without much prior knowledge and transferred to other studies. Potential effects on greenery and walkability are recognized and numerically recorded. By a larger timeframe, **already existing methods could have been explored and applied to assess the scenarios**. Perhaps these have even led to a more extensive and more accurate result. Some of them could have been explored and applied in this work or could have served to derive own methods for the assessment. This could be considered as a suggestion for further theses, which also deal with a quantitative analysis of spatial forms in QGIS. Furthermore, it would also be possible to develop analytic workflows based on the design criteria. The utilization and connectivity of the road system of each scenario could be checked for accuracy. For the assessment, attention was paid to the own knowledge in dealing with QGIS and the limited time period for the evaluation. **Using these clear and easily reproducible methods, it is possible to quantitatively evaluate the developed scenarios** in a short period of time and to compare their differences.

8.2 ANSWER TO RESEARCH QUESTION

The presentation and the comparison of two scenarios with two different forms of autonomous driving clearly showed possible effects on greenery and walkability. Thereby, the severity of the effects on the quality factors differ in both scenarios. By examining these more closely, it can be recognized, that the influences on **liveability do not depend on the autonomy**, but on the mobility behaviour of the society. **By switching to ride-sharing models, a paradigm shift towards city-friendly cars could be initiated**. There is no need to wait for the implementation of autonomous vehicles to achieve this goal. **Political decisions** could already be taken today, which sustainably reduces the car as property and replaces it with subsidised ride-sharing models. The liveability of our cities can be promoted, expanded and sustainably improved by switching to sharing models. **With a taxi fleet, cars would become city-friendly**.

1. What are the existing strategies and regulations of greenery and walkability?

In order to find out rules and strategies for greenery and walkability, it is important to study them at the global, national and regional level. This provides a deep insight into the **objectives of different cities and countries**. I learned how important it is to deal with the strategies for the quality factors. At the same time, I also recognised **how difficult the implementation into the urban context is**, under different mobility models. For architects and urban planners, this method is very important in order to get a common thread under which the design can be built. This makes it easier to weigh and evaluate possible effects on the qualities in each scenario. In this way it is possible to evaluate, if ecosystems are well distributed, connected and accessible in cities. And if the scenarios meet the needs of pedestrians and cyclists in terms of safe and short-distance routes.

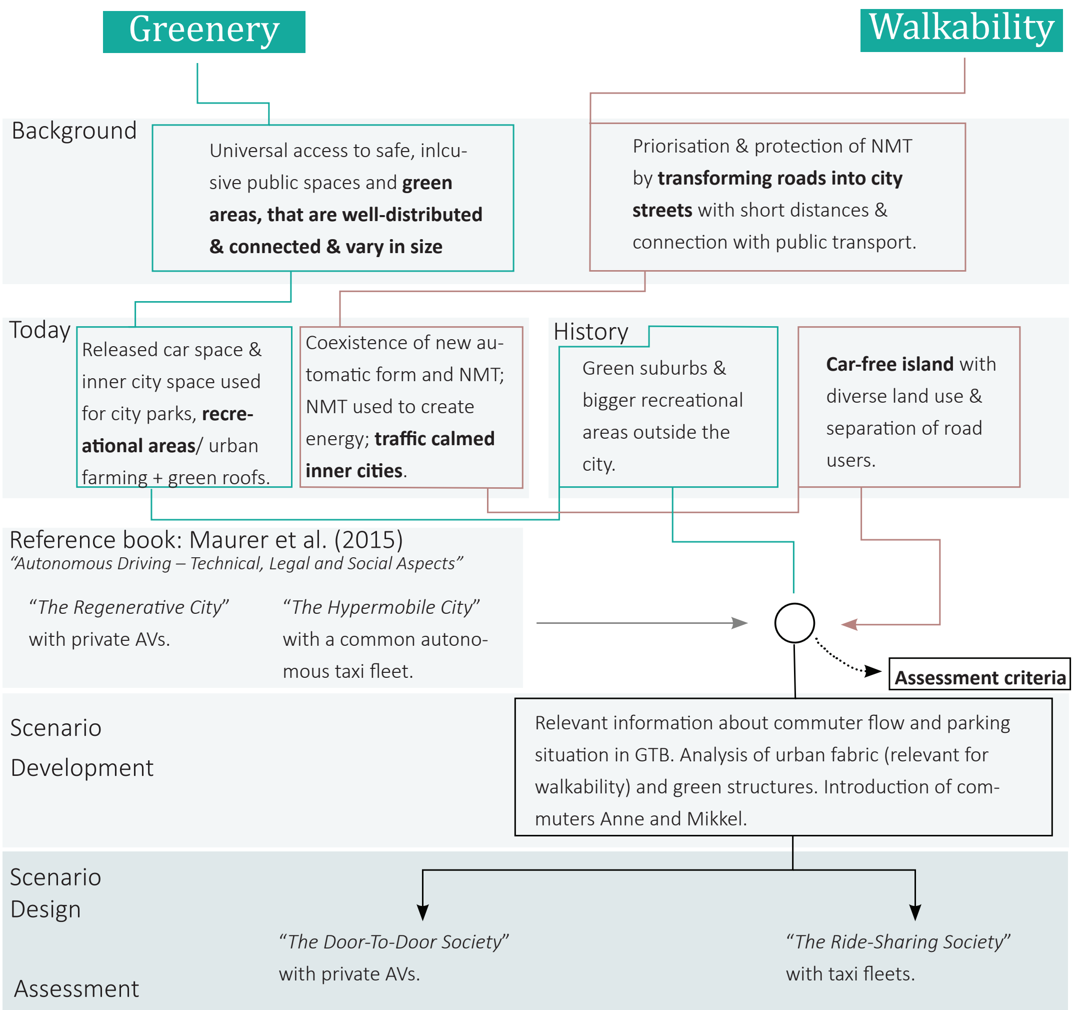


Figure 38 *Structure greenery & walkability/ own figure*

2. What can we learn from the mobility transitions and the city development of the past?

By a review into the past the architect gets an insight in how greenery and walkability was handled under the conditions of the car-friendly city. This approach gives answers about what a specific mode of transportation means for the urban development. After the scenario design it is possible to **compare similarities and differences with the history** and state, which factors must be considered in the future, to not repeat the same mistakes as in the past, which put the car in the centre of urban planning.

3. What are the visions of the industry and the policy of the future mobility?

The overall visions of the industry and policy is, that AVs will be introduced into cities. This presents them as well as urban planner with great planning, political and legal challenges. At the same time, it also enables to make cities more sustainable and to create **guidelines for the new form of mobility**. The visions of the policy can help planners to develop future scenarios. The prediction of possible effects on the urban environment can thus be **spatially evaluated in the scenarios**. That gives conclusions about what the cities of tomorrow might look like.

4. What are possible spatial effects of autonomous vehicles on the city structure?

Depending on the form of autonomous driving, both scenarios have responded with an **adaptation of the road system**. Thus, in each scenario, the demands of the society are spatially implemented. These have a direct impact on urban growth, on the roads and their crossings. The hierarchy of streets, depending on the form of mobility, has made it possible to **analyse spatial effects**. I think that it is important for planners to follow strict rules in order to be able to design scenarios.

5. What could the liveability of future cities look like?

At the same time, the street hierarchy sets the terms for greenery and walkability. The form of mobility, therefore, has direct impact on the implementation and the characteristic of liveability in cities. By understanding the **connection between the road system and the distribution of the quality factors**, the scenarios can be designed. Depending on the scenario, the qualities benefit sometimes more, sometimes less. It also makes it easier to understand the impacts of the form of mobility on the urban environment.

8.3 THE WORK IN A WIDER CONTEXT

Due to a **research by design** method, different future scenarios have been chosen. The **spatial effects of autonomous driving on the urban environment** were shown and evaluated using the **regional example** of the city of Gothenburg.

The methodology and implementation are not only possible within the example of Gothenburg. **Other municipalities**, that are facing a mobility change and whose urban changes are still unexplored by autonomous driving, **can acquire the methodology and carry it out on their own urban environment**. Possible positive, but especially negative influences of autonomous driving on the liveability of the city can be analysed. Cities can then recognize the potential impact on the urban context and its sustainability, at an early stage.

Scenarios visualize structural changes. Working with visualizations has an additional impact, as it emotionally affects the population and urban planners. It contributes to a quick assessment and opinion-making, in which the viewer can easily explain what he or she thinks about the possible future of the city. The presentation of data enables, or disables the understanding of possible changes. **These practices will allow other municipalities to respond to potential complications and prepare for the challenges ahead**. It also makes it easier for municipalities to choose a particular scenario, that they think has the least or positive impacts on the city's liveability and sustainability in the future.

The work serves as a source of ideas and signposts for other cities (on a global level) to prepare for the mobility change. **It is the power and responsibility of local governments to see mobility as a way to make cities more sustainable**. The car of the future can be used in a **city-friendly way**, if the society is willing to switch to ride-sharing models. This change would positively shape urban mobility in harmony with the urban environment.

8.4 FURTHER RESEARCH

Due to the scope of the Master`s Thesis and the available work time, some topics could not be analysed and explored. The following points can serve as research fields that build on the thesis. They would contextually expand and support the work.

- **Commuter flow**: Figure 19 illustrates the commuter flow in Gothenburg today. In further research it would be interesting, how many cars would occupy the street space in each scenario. Is it manageable to reduce the car stock in the "***Ride-Sharing Society***" by ninety percent, if the same number of people would commute into the city as today? In the "***Door-To-Door Society***" more people move into suburbs. How would this affect the number of cars and congestions on streets? And would it be possible to make the public transport so attractive to promote a multimodal traffic behaviour, to reduce the car traffic? Additionally, the **transition zones** are important to explore more in detail. How will they look like during rush hours in each scenario? Will there be a **queue out of AVs**, when people arrive at hubs to change to public transport in Scenario 1? And how will the transition zones of Scenario 2 look like, that should be so constructed to not affect the steady **stream of autonomous taxis**? These questions need also be explored for possible events, like a football match or a concert.

- **Silos**: Further some calculations about the capacity of the distributed silos in the city would be necessary. Parking solutions are going to change, depending on scenarios. Scenario 1 with private autonomous cars has still the need for parking. Therefore, a further study could compare the today`s number of parking with parking that is needed in the "***Door-To-Door Society***". Better maintained silos with more capacity could adopt this task. The question is, **how many would be needed and how much space would they occupy**? And **how does the streetscape look like**, if there are many zombie-cars?

- **Parking in city**: On-street parking and other open-air parking places, will remain the past. Herby, further **studies and calculations about the freed-up space** would support the thesis. Exact numbers about new street space for pedestrians and greenery in each district could be determined.

- Further it could be interesting to explore the scenarios, if autonomous cars would follow another technique than the V2V-connectivity. How would this affect the liveability of cities in the future? Additionally, **it would be interesting to add further scenarios**. One scenario could be a mix between petrol-driven cars and autonomous vehicles. And what will happen, if we continue in the same way as today? **Are there anyway possibilities to enhance greenery and walkability in cities**?

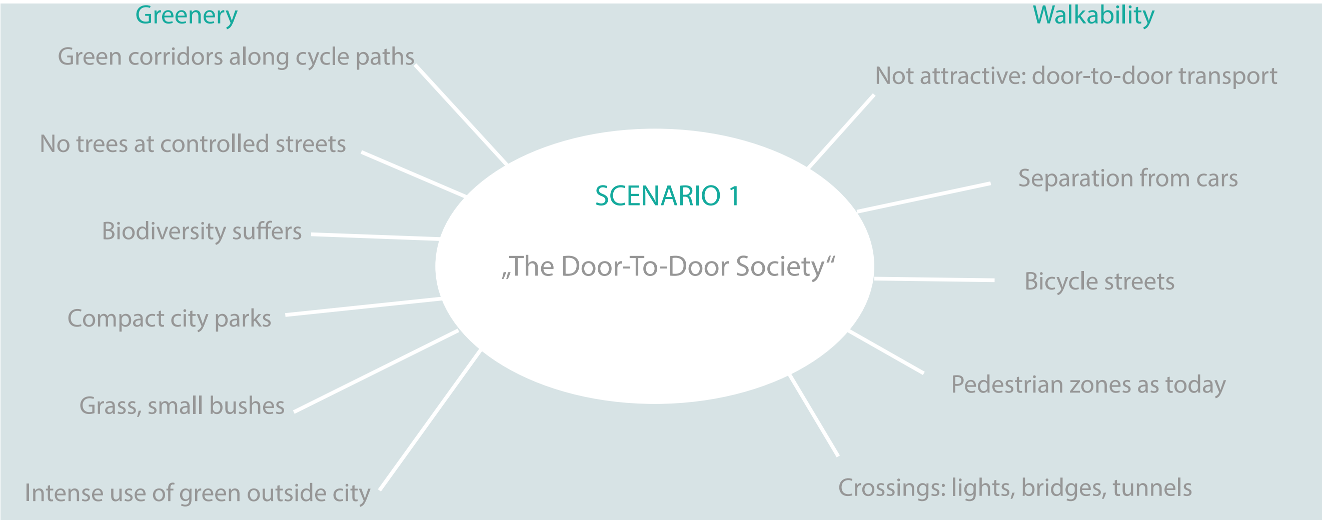
- **Detail**: In the future work it would be important to **translate the scenarios into a proper design**. This would enable to see the effects on the urban development not only in an abstract way, but also with real proportions. Additionally, the **biodiversity** needs to be explored. What kind of ecosystems are needed in cities to guarantee suitable habitats for plants and animals?

As I stated in the delimitations, the **social aspects** would be interesting to discover. To focus more in detail what effects autonomous vehicles might have on **public spaces** and on urban life, would additionally support the extent of the work. Here, **design solutions** of specific public spaces can be added.

By exploring and adding these steps, the thesis would become even more detailed and extensive. Street spaces could be examined more closely, and the spatial effects could be shown by details and sections. The more intense integration of biodiversity would give the work additional accuracy and depth. Through additional calculations, unresolved questions about the scenarios could be answered and presented. **The work therefore, serves as an inspiration for municipalities and other theses and offers scope for further developments**.

APPENDIX

ASSESSMENT - SCENARIO 1



Quantitative assessment

Walkability

In Scenario 1 it is expected that the **city will grow with low density around hubs**, due to the comfortable transport situation coexistent out of public transport and private autonomous cars. Based on Figure 23, the urban fabric has been calculated and compared to the today`s situation (Figure 19). Hereby, an **area increase of twenty-three percent is expected** (Figure 36). No structural changes are foreseen in the inner city with a density factor between 30-80%. Only the suburbs with low urban density consisting of less than ten percent up to thirty percent are expected to increase.

The **street system** in Scenario 1 is built up out of many **fast roads to guarantee a fast connection** from suburbs to inner city and backwards. Suburbs, as well as the inner city are crossed by a **dense street network** to make a **door-to-door connection** possible (Figure 24/ Figure 25). This development can also be seen in the calculations of Figure 40 (“*Prioritizing roads*”). The expected lengths of **fast roads** in the district scale is around 26.5 kilometres in the inner city and 15.7 kilometres in suburbs. Additional, 28 kilometres of **slow roads** in the inner city and 28.6 kilometres in suburbs are supporting a high connectivity and accessibility.

As the **pedestrian network remains to be the same as today**, it is not expected that there will be a dense car-free network. In the inner city, only four kilometres are reserved for pedestrians. In suburbs the number is higher and around 21 kilometres (Figure 40 “*Area of pedestrians*”).

The overall amount of parking area has changed dramatically. The “*normal*” parking places (Figure 19) have been transformed into **well-maintained silos**, that are distributed in the whole city (Figure 23). These account **11% of the total parking stock today**. Parking in suburban residential area is still consisting on the property of private people (Figure 27)(Figure 40 “*Parking area*”).

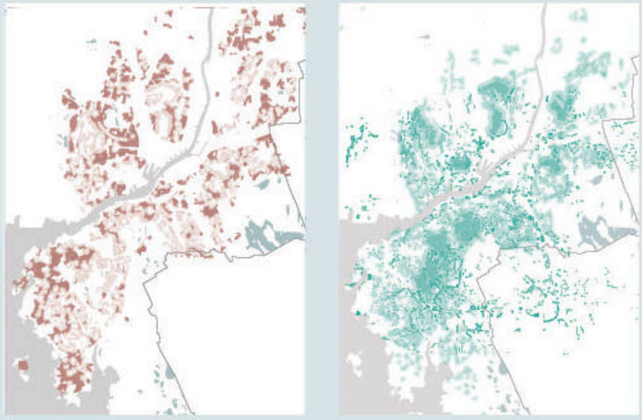
Greenery

Many of the parking places have been transformed into **residential parks**. These are additional small recreational areas, that did not exist before. These constitute **1,4% of the whole green area of Gothenburg**. Anyway, due to the expansion of low-density suburbia structures, there is a **pressure on green areas in general. It is expected to shrink by 2%** (Figure 36). The largest recognizable changes can be seen in forest areas. But also the wetland, arable land and the herbaceous vegetation are suffering under the densification pressure. Only sport areas might increase due to new city districts.

In Scenario 1, biodiversity in general is suffering. The focus in on a high connected accessibility of urban structures, what leads to a well-connected street-network system. On these streets it is, as stated in Chapter 6, impossible to plant trees. Only smaller bushes and grasses, used to hide fences, can take over important duties and serve as living habitats for species. Anyway, the **17 kilometers long bicycle way, deals as an important corridor** in the same time (Figure 40 "*Length of road for green*"). It connects green urban areas with each other, and not only enables a nice ride with the bike, but also serves as a **corridor for species to reach their patches** (Figure 26). The pedestrian-zones in suburbs (still the same as today – 21,7 kilometers), can additionally be used for important green connections (Figure 27). Green stripes are crossing residential areas and combine residential parks and green urban areas with each other.

Hereby, 59% of all inhabitants have **access to any green area within 200 meters from their homes** (Figure 39). In the **inner city, 71%** have full access and in **suburbs 58%**. The overall **connectivity between green urban areas** of Scenario 1 **increased by 19%** in the inner city, compared to the today`s situation. In Suburbs, the connectivity remains the same, while the average distances between patches shrank (Figure 36).

Green buffer - metropolitan



Whole area of Gothenburg

Green buffer - district inner city

Urban green buffer in **inner city** + green corridor (200m lager/ 100m smaller green areas)- no direct access: **29%**

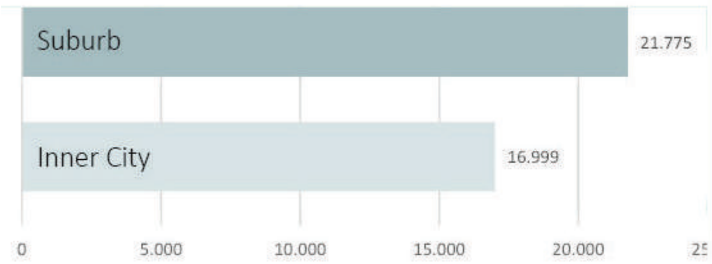
Green buffer - district suburb

Urban green buffer in **suburbs** + pedestrian area (200m larger/ 100m smaller green areas) - no direct access: **42%**

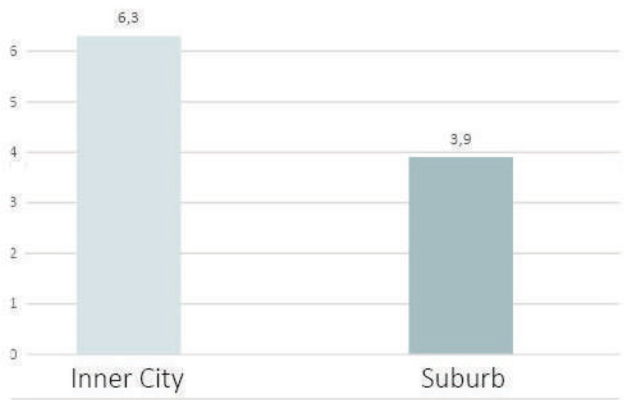
Figure 39 *Access to green, Scenario 1/ own figure*

Greenery

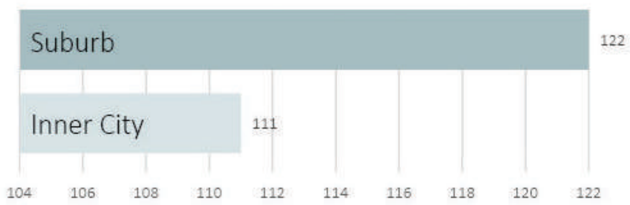
Length of road for green (in m)



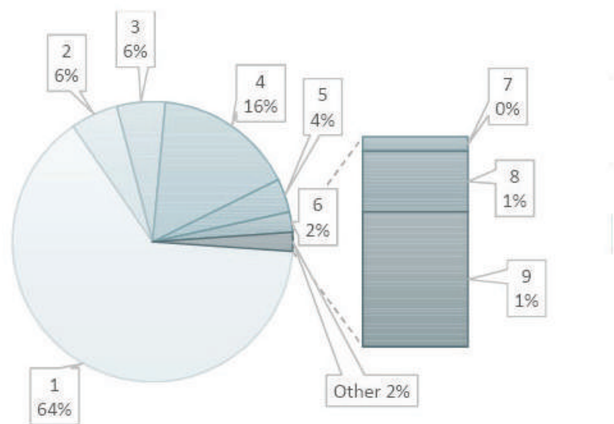
Well-connected green urban areas (intersection)



Well-distributed green urban areas (in m)



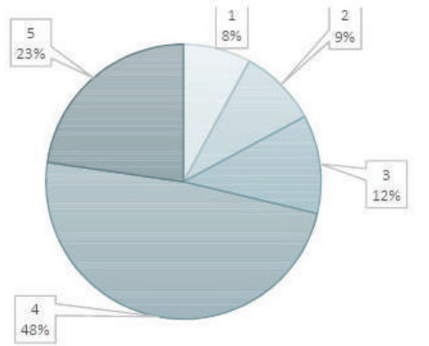
Types of green areas (in m2)



1: Forest 2: Green urban area 3: Herbaceous 4: Pastures 5: Sport 6: Arable 7: Playground 8: Wetland 9: Residential parks

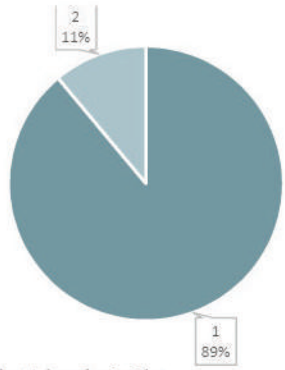
Walkability

Density of urban fabric (in m2)



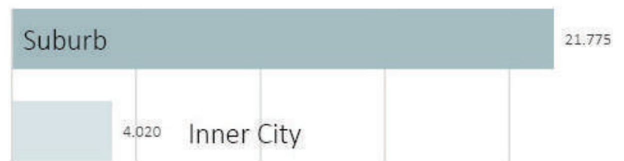
Urban fabric 1: (>80%) 2:(50-80%) 3: (30-50%) 4: (10-30%) 5: (<10%)

Parking area (in m2)



1: New residential parks 2: Silos

Area of pedestrians (in m)



Prioritizing roads (in m)

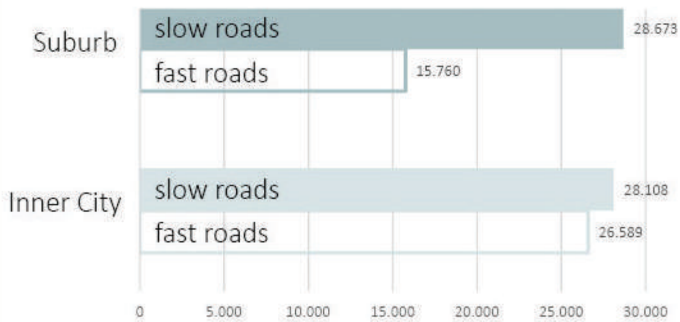
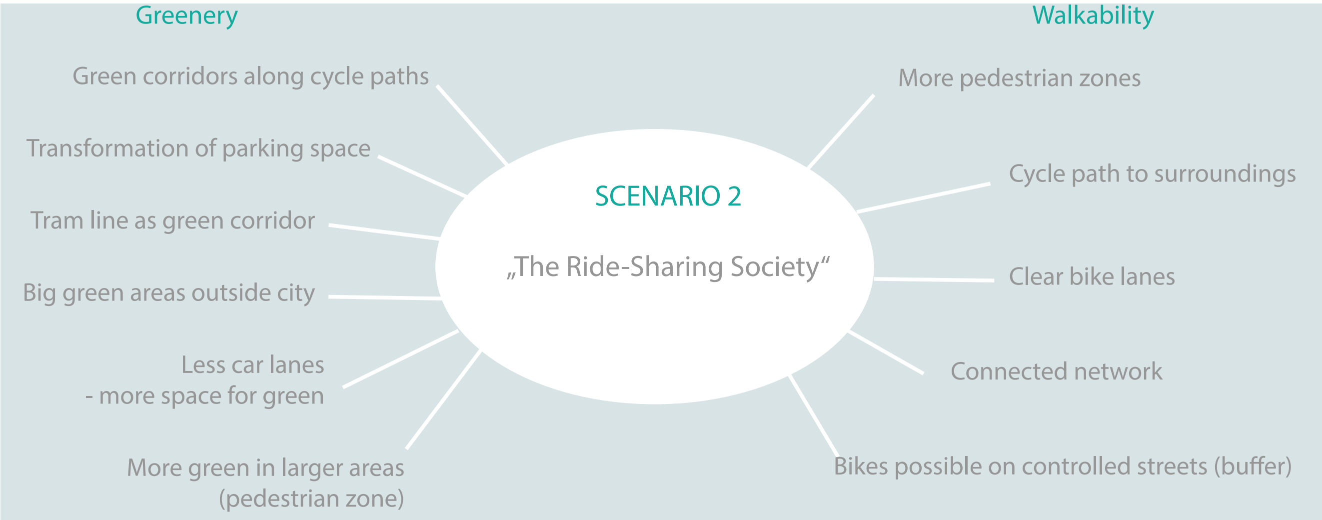


Figure 40 *Assessment Scenario 1*

diagrams show calculated numbers of each parameter in Scenario 1, based on Table 10

ASSESSMENT - SCENARIO 2



Quantitative assessment

Walkability

Scenario 2 is dealing with an autonomous taxi fleet that is based on an on-demand service. In the **inner city the service is well built what makes it cheaper and more comfortable for people to live there**. Therefore, it is expected that the inner city will be densified. Compared with Figure 19 the continuous **urban fabric area with a density factor of more than 80 percent, is growing by 62 percent in Scenario 2** (Figure 30). By the reason, that the inner city is becoming denser in general, lower dense urban fabric areas have been transformed into denser areas.

Scenario 2 describes a "*Ride-Sharing Society*" that is willing to walk to their destination. This attitude has direct impact on the street system. Only some **fast roads** are distributed in the city (Figure 31). They count **eleven kilometres** (Figure 42 "*Prioritizing roads*"). In **Suburbs, 14 kilometres** of fast roads are located, that guarantee faster connection between different parts of the city (Figure 32). Slower streets have been minimized. **23 kilometres of slow streets are crossing the inner city** (Figure 33), while **27 kilometres are still existing in the suburbs** (Figure 34).

Many of the slow streets have been transformed into pedestrian-only streets. Scenario 2 shows a **very dense and well-connected pedestrian network**. This enables **36 kilometres** of car-free zones in the **inner city** (Figure 31), and **66 kilometres in suburbs** (Figure 32) (Figure 42 "*Area of pedestrians*").

The overall number of parking has been transformed into residential parks. Only **4% of the former parking areas are left and used as transition zones** close to larger nature parks outside the city (Figure 30) (Figure 42 "*Parking area*").

Greenery

Greenery is benefiting in Scenario 2. The **total amount greenery is expected to grow up to 435 million square metres**. This increase is made thanks to the new residential parks that are distributed in the whole region of Gothenburg (Figure 30 - *green additions*) (Table 10).

The rules for the wireless connected streets are the same in Scenario 2. Trees cannot be distributed along streets. Nevertheless, there are less streets in suburbs and inner city than today. A better connected and larger pedestrian-zone makes it possible to increase the overall number of green structures in Gothenburg. **The inner city increases the capacity for green structures by 53 percent** (Figure 33). Also, in **suburbs the number rises to 33 percent** (Figure 34). Former tram lines additionally, have been transformed into a bicycle way, that is also used as a green corridor (Figure 30). This development makes it possible for cyclists to **cycle more than 80 kilometres across Gothenburg** (Table 10). Additionally, green urban areas and smaller residential areas are connected through this corridor with larger nature areas outside the city (Figure 30).

The better distributed green structures have direct impact on the accessibility to green. In the **inner city, 89 percent can reach any kind of green within 200 metres**. In **suburbs the accessibility with 82 percent** is high, as well (surrounded nature areas not included in calculations) (Figure 41). The **connectivity** in inner city of green urban areas increased by 32 percent. Also, in suburbs the green areas are better connected to each other, with five percent (Figure 36). The **average distance of green urban areas in both districts, compared to today, shrank**. Anyway, there might be deviations in the calculation. The centroids are always in the centre of a patch and the tram corridor illustrate a continuous patch, with only one centre. The overall distribution is therefore much higher, than the numbers show.

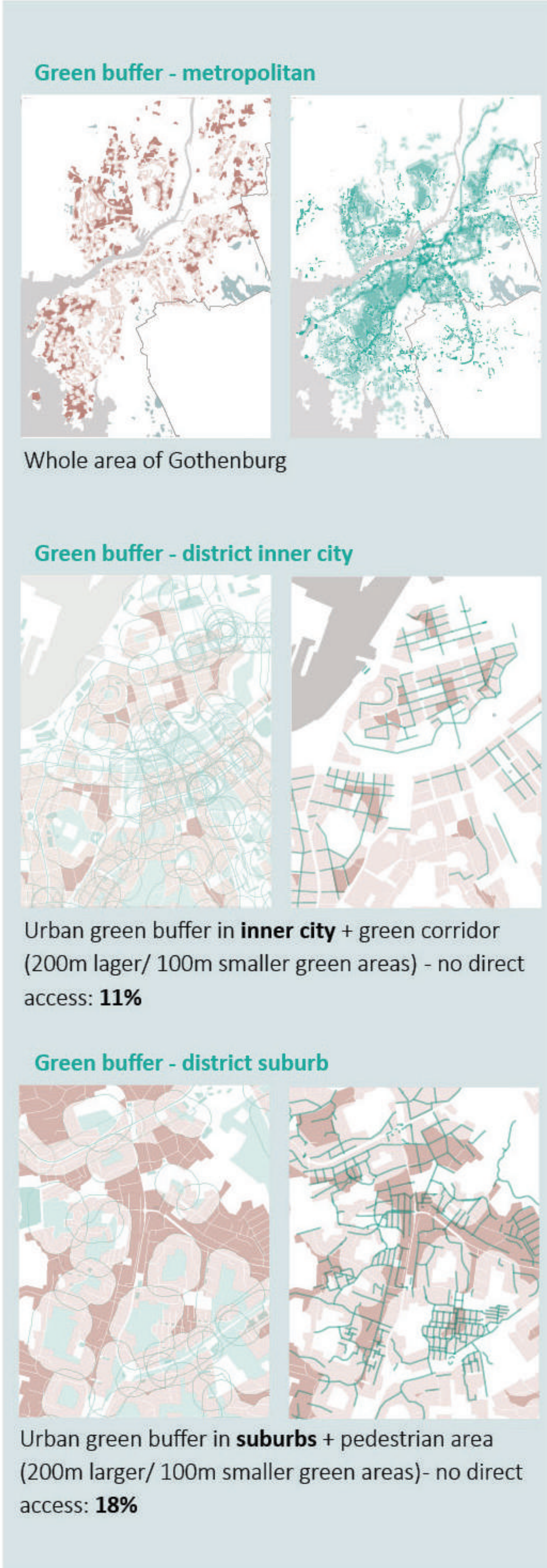


Figure 41 *Access to green, Scenario 2/ own figure*

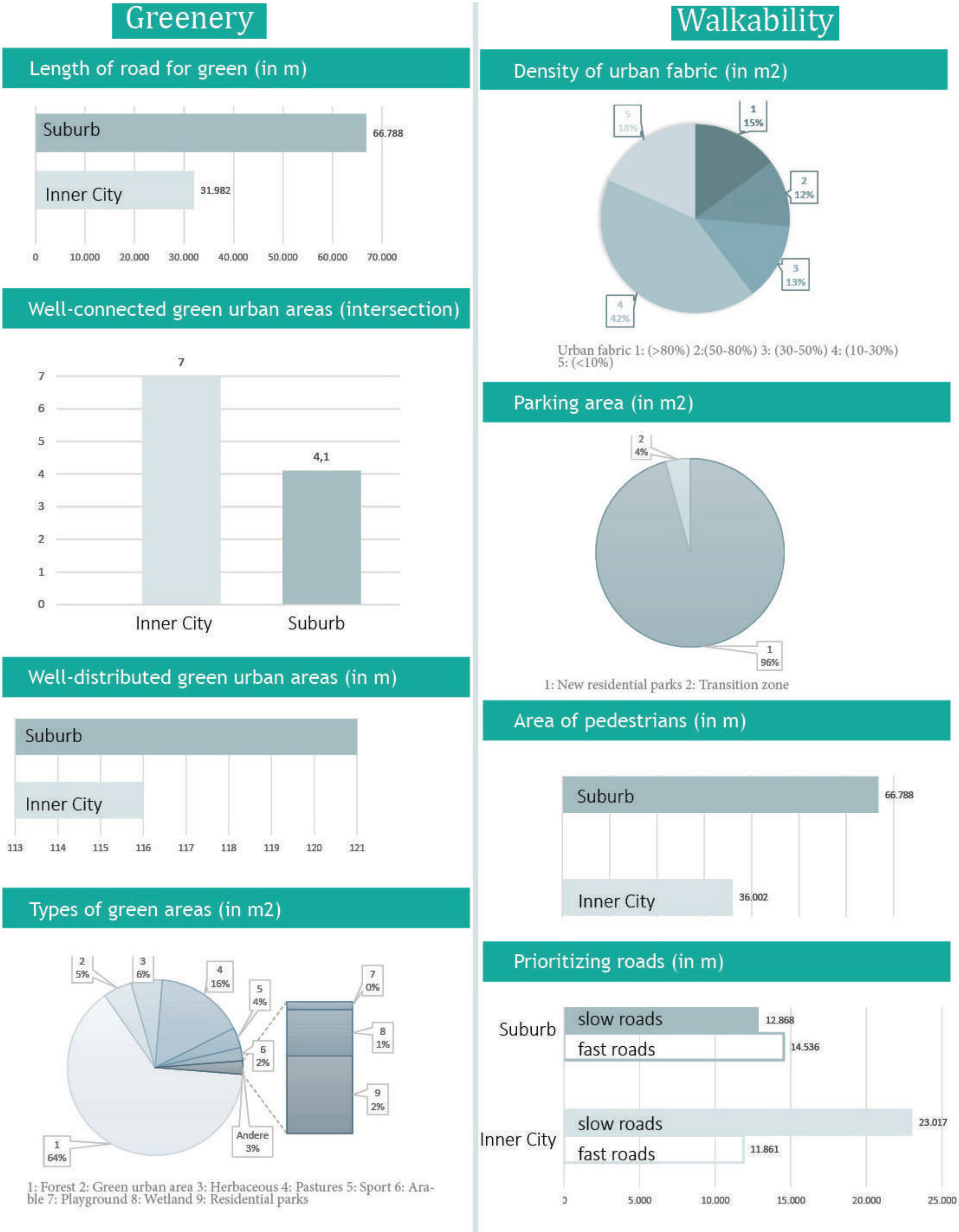


Figure 42 *Assessment Scenario 2*

diagrams show calculated numbers of each parameter in Scenario 2, based on Table 10

Layers	Today			Scenario1			Scenario2		
	Metropolitan	Inner City	Suburb	Metropolitan	Inner City	Suburb	Metropolitan	Inner City	Suburb
GREENERY									
1. length of the road for green (in m)		6.888	21.775		16.999 (bicycle line (closed for cars))	21.775 (foot way can be greened)	88.568 (former tram lines)	31.982 (all pedestrian-free ways)	66.788 (all pedestrian-free ways)
2.1 well-connected (average intersection with other green patches)		5,3	3,9		6,3	3,9		7	4,1
2.2 well-distributet (average distance between patches) **(in m)**		137	155		111	122		116	121
3. Size total (in m2)	**428.440.885**			**420.803.841**			**435.111.657**		
4. Type of area in m2									
4.2 type of area **(in m2)**									
4.2.1 Forest	278.700.000			270.667.000			278.700.000		
4.2.2 Green urban areas	23.084.700			23.057.100			23.084.700		
4.2.3 Herbaceous vegetation (natural grassland, moor)	24.908.600			23.425.000			24.908.600		
4.2.4 Pastures	70.885.800			68.339.300			70.885.800		
4.2.5 Sport and leisure facilities	15.897.200			16.383.247			16.215.842		
4.2.6 Arable land	10.503.500			9.751.530			10.503.500		
4.2.7 Playground	648.205			648.205			648.205		
4.2.8 Wetland	3.812.880			2.636.560			3.812.880		
4.2.9 Residential parks (former parking area)	0			5.895.899			6.352.130		
5. Access to green (buffer) (Today shows TOTAL area in m2) Shown is the difference area (no access to GREEN URBAN AREAS):	45.737.980	1.742.158	3.252.239	18.823.640	507.263	1.373.335	17.217.010	194.880	585.891
WALKABILITY									
1. Compact City - Density (in m2)									
1.1 Continuous urban fabric (S.L. : > 80%)	6.871.600			6.871.600			11.214.989	(additional area *"Rivercity GTB"*: 3.500.221 m2)	
1.2 Discontinuous dense urban fabric (S.L. : 50% - 80%)	7.943.240			7.943.240			8.717.772		
1.3 Discontinuous low density urban fabric (S.L. : 30% - 50%)	10.032.000			10.032.000			10.032.000		
1.4 Discontinuous low density urban fabric (S.L. : 10% - 30%)	33.459.900			41.966.190			31.777.410		
1.5 Discontinuous very low density urban fabric (S.L. : < 10%)	13.857.700			19.659.570			13.867.700		
TOTAL	**72.164.440**			**88.492.042**			**75.609.871**		
2. Parking area (in m2)	6.629.036			Silos: 733.137			Transition zone 276.906		
3. Area of pedestrians (length in m)									
3.1 added pedestrian zone					0	0		25.993	45.013
3.2 living-street					0	0		5989	0
3.3 foot way			21.775		0	21.775 (existing between buildings)		0	21.775
3.4 existing pedestrian zone		4.020			4.020	0		4020	0
TOTAL (in m)		**4.020**	**21.775**		**4.020**	**21.775**		**36.002**	**66.788**
4. Prioritizing roads									
4.1 fast roads **(length in m)**		28.333	13.180		26.589	15.760		11.861	14.536
4.2 slow roads **(length in m)**		48.197	32.724		28.108	28.673		23.017	12.868
TOTAL (in m)		**76.530**	**45.904**		**54.697**	**44.433**		**34.878**	**27.404**

Table 10 *Assessment table of today`s situation & Scenario 1 & Scenario 2*

- table shows calculated numbers of each parameter, based on assessment critera (Chapter 7.1).

SURVEY

Question sheet &

The Future Of Our Cities

SOME QUESTIONS ABOUT YOU

1. I identify as:

- Male
- Female
- Other
- Prefer not to say

2. Which of the following categories belong to your age?

- under 17
- 18-20
- 21-29
- 30-39
- 40-49
- 50-59
- 60 +

3. I am a parent:

- Yes
- No
- Prefer not to say

ABOUT YOUR FROM OF MOBILITY

4. I am owning a car: (If yes, how many?)

- No
- Yes
- 1 car
- 2 cars
- 3 cars
- more than 3 cars

5. Is the car representing a status symbol for you?

- Yes
- No
- Prefer not to say

6. How much time do you spend in a car in a week?

- 0-1h
- 1-2h
- 2-3h
- 4-5h
- more than 5 hours
- Other

7. What do you use the car for?

- Drive to work
- Do shopping
- For leisure activities
- Just for fun
- Transport of children
- I am not using a car
- Other (please specify):

8. How much time do you spend on your bike per week?

- 10 - 20 minutes
- 20 - 60 minutes
- 1 - 2 hours
- 2 - 4 hours
- 4 - 6 hours
- 6 - 10 hours
- more than 10 hours

9. By which means of transport do you reach your destination? Do you switch between different modes of transport? (multiple answers)

- Only by private car
- Car from a car-pool
- Public transport (bus, tram)
- By bicycle
- Long-distance travel
- By foot
- Other (please specify):

10. What distances would you be willing to walk to reach your destination?

- less than 500 meters
- 500m - 1km
- 1km - 1,5km
- 1,5km - 2km
- 2km - 2,5km
- 2,5km - 3km
- more than 3km

11. What distances would you be willing to cycle to reach your destination?

- less than 1km
- 1km - 3km
- 3km - 5km
- 5km - 7km
- 7km - 10km
- more than 10km
- Other (please specify):

ABOUT THE FUTURE

12. Do you think it is possible to have a car-free city in the future, if the public transport is well connected and bicycle paths are available?

- Yes
- No
- Prefer not to say

13. Should cars remain as private, or as a common good (car-pool or autonomous cars that pick you up and bring you to your destination)?

- Definitely private
- Preferably private
- Mix of private and common good
- Preferably a common good
- Definitely a common good
- Other (please specify):

14. What are you expecting of the city of the future? (multiple answers)

- More greenery and public spaces
- Better public transport network
- Better bicycle network
- Better street network for cars
- Traffic-calmed inner cities
- More parking places
- Mix of functions that can be reached by foot
- No changes, it`s good as it is today

15. I could live without the car in the future!

- Yes
- No
- Prefer not to say

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IMPORTANT ABBREVIATIONS

AV- Autonomous vehicles.
NMT- Non-motorized transport.
QGIS- Geographic information system.

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