



THE MOBILITY-LIVABILITY REVOLUTION

ENGAGING AUTOMATED VEHICLES TO IMPROVE AMSTERDAM'S CITY CENTRE

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The Mobility-Livability Revolution
Engaging Automated Vehicles to Improve
Amsterdam's City Centre

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to mum and dad,

for being supportive throughout my studies. It has been quite the adventure and somehow you always supported and respected my decisions.

to Isabel,

for being patient, understanding, and loving during my graduation.

to Jurre,

for helping me out in times of need.

to Pieter,

for proofreading my report. I blame you personally for any remaining errors.

to Cecile,

also for proofreading my report. Don't worry, if any errors remain. It's Pieter's fault.

to my friends and family,

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The city of Amsterdam has been growing and it continues to grow. While both the amount of visitors and the amount of residents continues to grow, the amount of public space stays approximately the same. This has led to an increasing pressure on livability, accessibility, and public space. Pedestrians, cyclists, and drivers alike often face the negative consequences of overcrowding. Much of this problem can be traced to the excessive space use of cars. Cars, while only accounting for 9% of movements in the city centre, take up approximately 77% of all public space that is not water. This project set out to remedy the pressure on livability, accessibility, and public space through the improvement of conditions for pedestrians and cyclists. These modalities have been chosen because their use was shown to correspond with a more efficient flow of people, a more livable city, and a more efficient use of public space. To do this, the promising upcoming technology of automated vehicles is engaged. This technology was found to possess the ability to completely change urban areas. This, however, can either deteriorate or elevate livability, accessibility, and public space. Therefore, taking a pro-active role in development for automated vehicles is essential.

First, a literature research on walkability and cyclability was conducted which resulted in the establishment of eight pillars of walkability and cyclability: mixed uses, network coherence, legibility, protection of pedestrians and cyclists, dimensioning of infrastructure, presence of green, visual stimulation, and connecting of attractors. The project sets out to strengthen these pillars in order to mediate the problems the city faces. To do this, a literature research on automated vehicles has been conducted which explores possible implications of automated vehicles. These possibilities have been explored further through design within scenarios. The scenarios were constructed based on a scenario building methodology that was established through an in-depth literature research on scenarios and scenario building. The literature on automated vehicles and further exploration through designing within the scenarios has yielded 26 instruments that describe possibilities made possible either directly by automated vehicles or indirectly through interaction with automated vehicles. These instruments are priority lanes, induction charging

roads, digital roads surfaces, convoy driving, shared space, subcanal parking, multimodal app, logistics app, multi-use vehicles, logistics nodes, time-dependent infrastructure, bike-share smart locks, bicycle GPS transmitters, car fleet as battery, centrally owned fleet, hodosses, park and charge hubs, replacing trams with AVs, tourist tram lines, delivery assistance vehicles, supply over water, autonomous boats, multimodal nodes, bicycle parking, bicycle sharing programme, and conditional access roads. Interactions between these instruments were researched and five main clusters were derived from the clustering of the instruments: new parking, mobility as a service, new logistics, multimodal travel, and network principles. These clusters of instruments, along with individual instruments, have then been applied on Amsterdam's city centre to improve its walkability and cyclability in an iterative process of trial and error, reflecting the results with regard to the pillars of walkability and cyclability after each iteration.

The most important findings of the project are that automated vehicles should be made to park themselves in garages to open up public space, and should be made to drive efficiently in convoys so they can replace buses and trams. Also the vehicles should both feed to and receive information from the cloud so they do not require signage, road markings, and traffic lights which clutter public space, and most importantly, should not be allowed to drive everywhere unconditionally. Rather, the connected nature of automated vehicles should be exploited to create individual route options for each vehicle based on its use and user. Neighbourhoods should not be accessible to automated vehicles unless they have specific exemptions. These exemptions can be granted by the municipality for reasons that can change over time. These reasons can include being a resident, being an emergency service, travelling through extreme weather, working in a neighbourhood, being physically impaired, or many other reasons. This conditional access, implemented strategically with other suggested instruments, will allow neighbourhoods to become healthier, safer, and generally more livable areas while remaining accessible for important purposes.





PROJECT BACKGROUND

**“If you plan for cars and traffic, you get cars and traffic.
If you plan for people and places, you get people and places.”**

William H. Whyte (1980)

As a lifelong admirer of the city of Amsterdam, I visit the city often. I always enjoy walking through it and every now and then I sit along one of the canals just observing the city happening. At a certain moment I realised that Amsterdam had existed before cars did and that parking along the canals had obviously been realised after that. This idea fascinated me and slowly I started to imagine what the city centre would look like if cars would be banned from it. Of course I knew this wasn't realistic but still I couldn't help but dream. Years later I had a discussion with a friend about automated vehicles and how they would impact society. After a while we figured out that if they were fully automated they would be able to park themselves anywhere and it was at this moment that we realised that the point at which people wouldn't need a parking spot right next to their house might be closer than ever. Not long thereafter I realised this could mean that for Amsterdam, the canals could become free of parked cars and as a pedestrian I would then be able to actually see the canals again when walking along them. And so it began.



¹City in transition: Dam Square in 1690, 1890, 1989, and 2016 (left to right, top to bottom).



²The view on the canal from the sidewalk at the Reguliersgracht.

Amsterdam has seen many mobility transitions since its establishment. Like most cities, when people first settled, they exclusively walked through the city. For Amsterdam, soon an infrastructure for boats was added and through time, this was succeeded by infrastructure for stage coaches, trams, bicycles and cars.¹ The city has always been in transition and the way people move around has had a major impact on the city and its residents. New ways of moving around bring new possibilities and endlessly optimistic humans always welcome these new ways of moving around, often thinking they will solve the problems caused by previous modalities. Sometimes they do. Fortunately, Amsterdam's streets are no longer covered by a thick layer of horse shit. But often, they bring along a completely new range of problems. So when a new modality looms on the horizon, we are often eager to welcome it, because it will solve all of our problems. Now, we have seen that while cars have brought us a range of new possibilities, they have come to dominate public space and our sensory observations of it.² Many new modalities are being produced at the moment though and some might offer solutions. Looking at the work of Filarski (2008) on mobility transitions, one modality in particular seems promising. It answers to all criteria set by Filarski required for a mode of transport to become successful; it is faster, cheaper, more comfortable, more reliable, and is fit for mass use. This modality is the self-driving car.

The city of Amsterdam has been growing and continues to grow. In the period between 2008 and 2013 the city grew by 75,000 residents, 50,000 new working people, and tourists stayed a whopping additional 4,200,000 hotel stays per year (Gemeente Amsterdam, 2015b). All these people move through the city using different modalities, yet the amount of public space stays approximately the same. According to simple initial measurements by the author, for a representative part of the inner city of Amsterdam, approximately 77% of public space that is not occupied by the canals is occupied by car infrastructure. Some of this infrastructure is also used by public transport but the share seems excessive, considering only 9% of movements in the centre is made by car (Gemeente Amsterdam, 2015a). The remaining 23% is recreational public space and infrastructure specifically for slow moving traffic.³ This absence of ample space for slow traffic leads to uncomfortable and sometimes unsafe conditions. Cyclists increasingly report they experience disadvantages of using a bicycle; bicycle paths are getting increasingly more crowded and so are bicycle parking facilities (Gemeente Amsterdam, 2015a). On top of this, 7% of cyclists has been involved in a traffic incident over the course of six months preceding the report, the amount of road deaths is stable at 15 a year while the amount of serious traffic injuries is rising (Gemeente Amsterdam, 2015a). Meanwhile, pedestrians often have to do with sidewalks no wider than half a meter that somehow double as bicycle parking nonetheless.⁴ In short, the problem statement can be defined as follows: **Amsterdam attracts many people. The number of residents is increasing and the number of visitors has also risen over the last years. This growth has many benefits for the people of Amsterdam and for entrepreneurs, but at the same time it puts pressure on accessibility, public space and livability.** These three aspects revolve around slow traffic. First, accessibility is improved by slow traffic greatly. According to Jeff Speck (2012), a typical bicycle lane handles five to ten times the traffic volume of a car lane twice its width. Pedestrians take up even less space and it doesn't take a genius to figure out that they accommodate a higher traffic volume than car lanes as well.⁶ Second, public space, if we are talking about recreational public space here, the public space meant for interaction, then it can be argued that pedestrian networks are this type of public space. As Jane Jacobs put it: "Lowly, unpurposeful, and random as they may appear, sidewalk contacts are the small change from which a city's wealth of public life may grow" (1961, p. 72). If we are talking about the quantity of public space, slow traffic uses



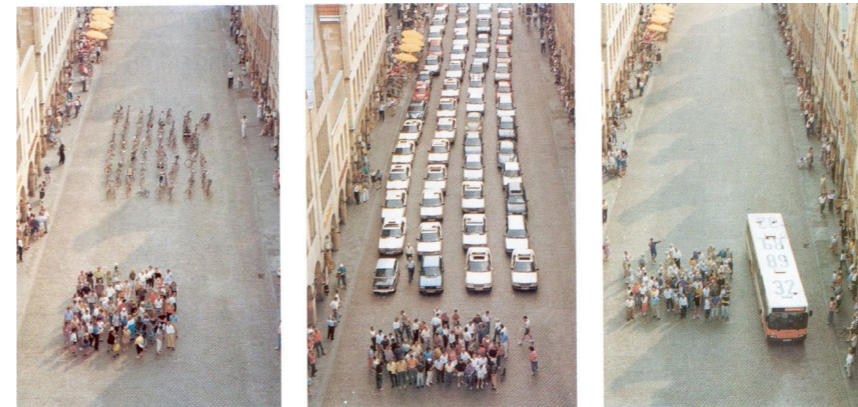
³ Calculations of percentage of public space that is respectively occupied by recreational public space, slow traffic infrastructure and fast traffic infrastructure (left to right, top to bottom).



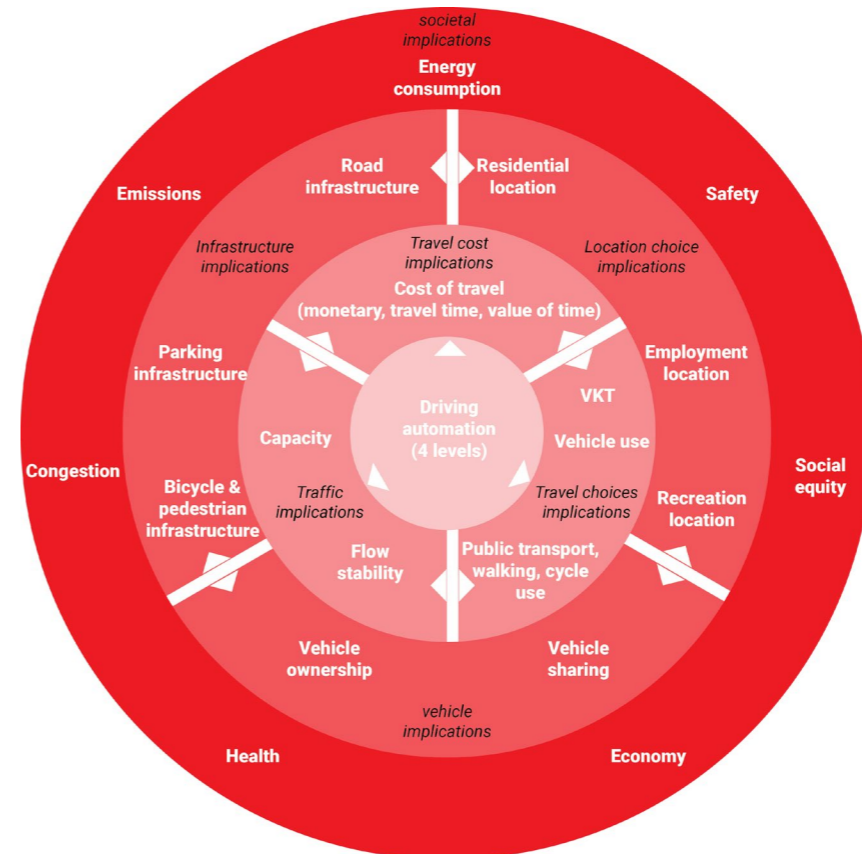
⁴ Narrow sidewalk occupied by bicycles at the Geldersekaade.



⁵ An installation showcasing how many bicycles can park instead of one car.



⁶ In these famous photos, the difference is shown in space occupied by cars, bicycles, a bus, and pedestrians.



⁷ Ripple scheme of implications of automated vehicles, low levels of automation influence aspects in the inner ring while levels of automation from conditional automation and up (as defined by SAE (2014)) also influence the outer two ripples (Milakis, Van Arem, & Van Wee, 2015).

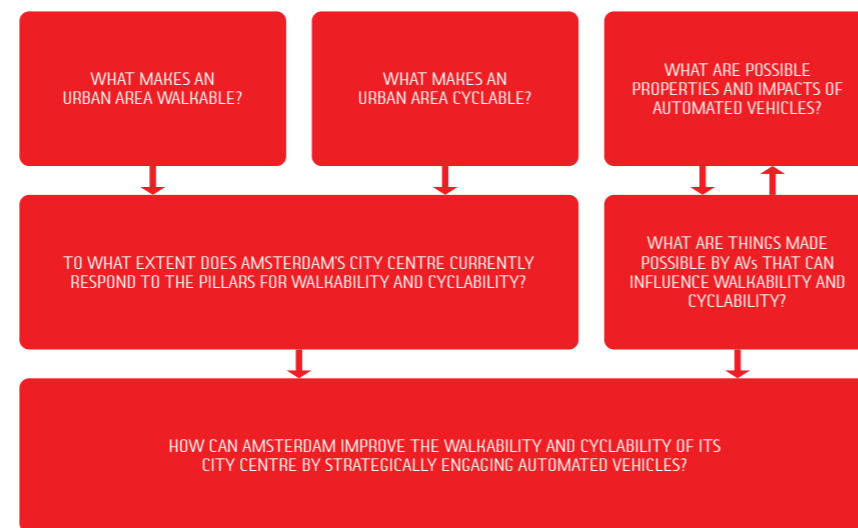
significantly less space. It was already noted that cars use approximately 77% of public space, this is only logical, considering the amount of space a car occupies. According to Speck (2012), the amount of space needed to park a single car can accommodate ten bicycles.⁵ Pedestrians take up even less space, they park their shoes indoors and occupy no public space in doing so. Third, livability, this is also greatly improved by favouring slow traffic over motorised traffic. In his book *Life Between Buildings*, Jan Gehl (2011, p. 72) put it this way: "It is important that all meaningful social activities, intense experiences, conversations, and caresses take place when people are standing, sitting, lying down, or walking. One can catch a brief glimpse of others from a car or from a train window, but life takes place on foot." Speck (2012, p. 10), notes that the pedestrian is "the canary in the coal mine of urban livability". Finally, as was pointed out in Artgineering's installation 'More Cycling - Better City' at the IABR (2016), cities that are appealing to cyclists are also appealing to residents (and tourists and businesses for that matter). Summarising, if the city wants to address its problems concerning accessibility, public space, and livability, it needs to improve its walkability and cyclability. Part of this task is to transform car lanes or car parking spots into slow traffic networks. This poses a new problem as most of Amsterdam's city centre has just one lane for car traffic and there is already a shortage of parking. But there might be a solution: the automated vehicle (AV), which is also known as the self-driving car. The AV has been under development for quite a while already and road-testing is happening more and more often (Anthony, 2014; Topham, 2016). This new technology poses a lot of new opportunities. It is predicted that early AVs with relatively low levels of automation will impact VKT, vehicle use, public transport use, bicycle use, flow stability, road capacity and cost of travel. As opposed to later versions with high levels of automation up to full automation that will also impact bicycle and pedestrian infrastructure, parking infrastructure, road infrastructure, location of residence, employment and recreation, vehicle sharing, vehicle ownership, safety, energy consumption, social equity, economy, health, congestion, and emissions (Milakis, Van Arem, & Van Wee, 2015).⁷ This project aims to explore the possibilities of automated vehicles and develop a strategy for engaging the transition to improve accessibility, public space, and livability through the improvement of walkability and cyclability.

1.4.1 Research Questions

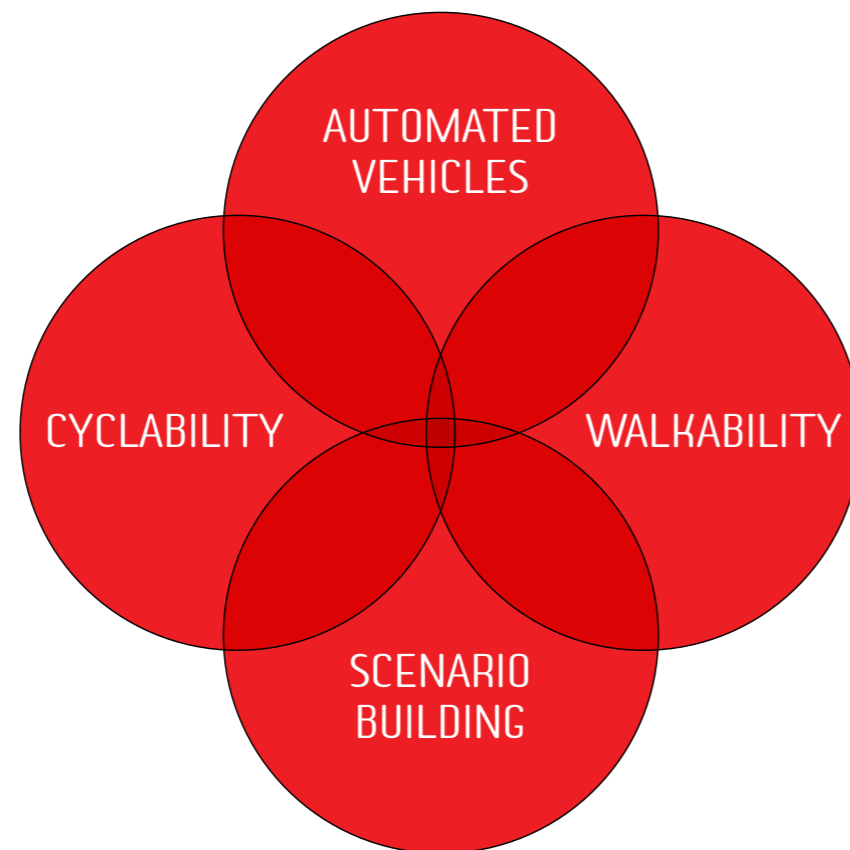
Because the project is mostly exploratory, an open research question has been formulated as the main research question. This question reads as follows: **“How can Amsterdam improve the walkability and cyclability of its city centre by strategically engaging automated vehicles?”** If a satisfactory answer is to be found to this question, some sub questions will have to be answered to provide a solid foundation for answering the main research question.⁸ Firstly, it is important to research walkability and cyclability. If Amsterdam’s city centre is to be made more walkable and more cyclable, it is essential to first establish what makes an urban area walkable and cyclable. Therefore, the first two subquestions are **“What makes an urban area walkable?”** and **“What makes an urban area cyclable?”**. The answer to these questions will be used to answer the next research question, which reads **“To what extent does Amsterdam’s city centre currently respond to the pillars for walkability and cyclability?”**. This question aims to find out in which ways Amsterdam’s city centre is currently underperforming with regard to walkability and cyclability. The answer to this question will help prioritise interventions during the design phase. Parallel to these questions, research will be carried out on automated vehicles. They are the driving force in the project and as such, research needs to be conducted on what they comprise. The corresponding research question reads **“What are possible properties and impacts of automated vehicles?”**. This question is followed by the question **“What are things made possible by AVs that can influence walkability and cyclability?”**. Answers to these two questions will be sought in tandem, since researching either one can lead to finding answers to the other. When proper answers are found to all of these subquestions, a foundation for answering the main research question is established.

1.4.2 Methodology

Different methods are used to answer fundamentally different questions throughout the process. During the first phase, literature research will be carried out on four major subjects: walkability, cyclability, automated vehicles, and scenarios. This research will form the theoretical framework.⁹ The research on walkability and cyclability will spawn a set of pillars which show what a walkable and cyclable urban area responds to. The research on automated vehicles will explore their possible properties and subsequent possible implications for public



⁸ The hierarchy of the different research questions.



⁹ The theoretical framework and its building blocks.

space. The study on scenarios will be used to create a scenario building methodology, which will be employed during the next phase.

During the second phase, different possible futures will be explored for automated vehicles and their implementation. This will be done by designing four scenarios, using the theoretical knowledge obtained during the first phase. All four scenarios will be developed into perspectives by designing within these scenarios. This will be done by thinking about different possible uses of automated vehicles in the different contexts. An array of possible ways to engage automated vehicles will subsequently be derived from the perspectives and will be systematically researched and expanded upon during the next phase.

After creating the scenarios, an overview will be made of the possibilities that arise following the introduction of automated vehicles. Each of these possibilities will be described as an *instrument* which can be applied alone or in combination with other instruments. The instruments will be described, possible implementations will be discussed, and the advantages and disadvantages of the instruments will be discussed. After all the instruments are described, a syntax will be provided for implementation of the instruments. This syntax will be given in the form of a diagram showing types of interactions between the instruments. The catalogue comprised of all the instruments will form the basis for design during the last phase.

The final phase will be the design phase. This phase consists of two parts. The first one is a desk analysis on Amsterdam’s city centre with regard to its walkability and cyclability. This is meant to find to what extent the pillars of walkability and cyclability are met by Amsterdam’s city centre. It will help prioritise interventions. The second part of the design phase will consist of implementing the instruments in Amsterdam’s city centre. In this last part, additional research will be carried out to fill the unavoidable voids that are left after applying the catalogue of instruments on the city centre. This research can be conducted through design, consulting of literature, or any other means appropriate for the problem at hand. The design will consist of a large scale revision of the city centre’s infrastructure, an illustration of small scale interventions and the impact of large scale interventions on a smaller scale, and four vignettes about the life of different personae and how their life will change as a result of the interventions.

1.4.3 Project Relevance

1.4.3.1 Scientific Relevance

Large companies like Google, Apple, Volvo, and Uber have been road-testing automated vehicles for several years already and gradually they are introducing the public to this new technology.^{10,11} Even though research on AVs indicates that they will have a large impact on society and urban contexts (Milakis, Snelder, Van Arem, Van Wee, & Homem de Almeida Correia, 2015), as of yet, not much research has been conducted on what the spatial implications will be. Cities are facing the Collingridge dilemma concerning automated vehicles: they lack sufficient information about the technology to predict its impacts but when the information will be available the technology will already be so embedded that it will be much harder and more expensive to control and use it (Collingridge, 1980). The scientific relevance of this project is to find out what the impacts of AVs on the urban context can be and how the transition towards AVs can be engaged to solve problems concerning accessibility, livability, and public space rather than to let it tear apart cities as has happened with the car.

1.4.3.2 Social Relevance

Residents of cities around the world, like Amsterdam, are increasingly facing the negative effects of urbanisation and globalisation. Increasingly more people visit and move to the city. This has put pressure on accessibility, livability, and public space. Citizens are complaining about tourism and its effects on the city more than ever before. Overcrowding has become the new reality and infrastructures are increasingly being outgrown by demand.¹² The social relevance of this project lies in finding a way to make the city centre retain its qualities that make it an attractive place for all its users.



¹⁰ An automated vehicle, the Mercedes-Benz F 015, drove through Amsterdam and then displayed itself dramatically at Dam Square on March 13, 2016.



¹¹ Still from Volvo commercial showing a woman go through her drawings while on the road.



¹² Amsterdam's Kalverstraat is one of the city's most overcrowded spaces.



THEORETICAL FRAMEWORK

“With any scientific advance, [rather than sounding an alarm bell, urging us to step backward to avoid risk], a better strategy is for us to arm ourselves with knowledge and to hope that wisdom will follow.”

Colin Ellard (2015)

This part of the theoretical framework aims to establish pillars for walkability and cyclability. These pillars can subsequently be used to test the walkability and cyclability of Amsterdam's city centre during the design phase. This will allow prioritisation. The basis for the pillars is adapted from Jeff Speck, who provides an excellent framework in his book *Walkable City* (2012). According to Speck, a city is walkable if it provides the means for walking to be useful, safe, comfortable, and interesting. He further states that all of these conditions are essential and none alone is sufficient. Interestingly, Speck (2012) states that the same things that make a city walkable also make it cyclable. He further notes that if an urban area is useful, safe, and interesting for pedestrians, it also is for cyclists. This means that separate pillars need to be set for cyclability only with regard to comfort. This claim is supported by the *design guide for bicycle traffic* published by Kennisplatform CROW (2016), which names five similar value categories a city requires to be cyclability: consistency, directness, attractiveness, safety, and comfort. The last three translate directly to Speck's criteria while the first two can be combined into Speck's usefulness. The four categories will be elaborated upon by specifying their underlying pillars. These pillars will mostly be based on Speck's ten steps of walkability but are adapted for a European context and elaborated upon based on further research.

2.1.1 Usefulness

2.1.1.1 Pillar I: Mixed Uses

For both walkability and cyclability, usefulness means that most aspects of daily life should be present within a walking or cycling distance respectively and that they should be organised in a way that walking and cycling serve them well. This is beneficial both for customers and entrepreneurs (Ewing, 1994; Kennisplatform CROW, 2014; Shladover, 1977; Speck, 2012). In *Amsterdam Aantrekkelijk Bereikbaar*, the municipality of Amsterdam recognises that pedestrians are the most important group of customers in shopping streets such as the Van Woustraat (Gemeente Amsterdam, 2013a).¹³ In shopping areas, pedestrians should be prioritised because they take up the least space while spending the most money. For the most essential facilities such as supermarkets, cyclists should also always be taken into account.

2.1.1.2 Pillar II: Network coherence

Network coherence is a two-sided pillar. It means that networks should always offer relatively direct options on the one side and that networks interconnect on the other



¹³ While pedestrians are the most important group of customers in streets like the Van Woustraat, they are assigned little space.



¹⁴ Luud Schimmelpennink, who devised the first ever bicycle sharing programme thinks it is "strange and unreasonable" that Amsterdam does not have a proper bicycle sharing programme (Van der Zee, 2016).



¹⁵ Dimensioning infrastructure is essential. Pedestrians are often present in numbers larger than the infrastructure designated for them can optimally support. Pictured above is Amsterdam's Damrak, a prime example of skewed distribution of space.

side, i.e., networks for different modalities should connect to each other. For pedestrian networks, it is especially important that public transport and bicycle networks are accessible. These supplement pedestrian networks because they offer a faster and more convenient option to travel over longer distances. This coherence is achieved by offering ample connections which are accessible from both sides and by making transfer points between different networks explicit. For cyclists, a coherent network also requires bicycle parking facilities. An additional bicycle sharing programme can further improve the coherence of a bicycle network (Copenhagenize Design Company, 2015).¹⁴ For public transport, a coherent network means that every place in the city should be accessible by use of public transport when only complemented by a short walk no longer than 300 meters.

2.1.1.3 Pillar III: Legibility

Another pillar that supports the usefulness of pedestrian and bicycle networks is their legibility. If people are unable to find their way using a specific modality, they might start using a different modality. This is true for both pedestrians and cyclists (Speck, 2012; Copenhagenize Design Company, 2015). In practice this means that the network needs to be coherent and a clear hierarchy in connections that form the network needs to be present (Lynch, 1960; Tversky, 1993).

2.1.2 Safety

2.1.2.1 Pillar IV: Protection

The safety of pedestrians and cyclists is a two-sided pillar. It consists of actual safety and perceived safety. Actual safety can be achieved in different ways. The first, and most obvious, way is to separate different modalities from each other (Speck, 2012). This however can create a false feeling of safety as even people using the same modality can use it in different ways and at different velocities. This method also requires a lot of space. Another option would be to employ shared space, which is the opposite: all modalities share the same infrastructure. Safety results from the fact that people tend to be more watchful under uncertain conditions. Shared space favours slow traffic and can fit many different modalities in a limited amount of space and might thus be an interesting solution. Another important safety measure is the presence of sufficient crossings to prevent unpredictable crossing behaviour.

2.1.3 Comfort

2.1.3.1 Pillar V: Dimensioning

If people are to move around in a particular way, be it by foot, bicycle or car, it has to be comfortable. This translates spatially to proper dimensioning of infrastructure. People like to be able to move around at their own pace, without being pushed aside or without having to push aside others. If infrastructure is too narrow, it leads to overcrowding and extended travel times.¹⁵ Conversely, if an infrastructure is too wide, it also fails to attract pedestrians (Speck, 2012). Comfort for cyclists furthermore means that ample parking facilities are present throughout the city, especially at important infrastructural nodes (Copenhagenize Design Company, 2015).

2.1.4 Interestingness

2.1.4.1 Pillar VI: Presence of Green

Urban green has been shown to reduce stress (Ulrich, 1983; Ulrich et al., 1991) and to have many cognitive benefits (Berman, Jonides, & Kaplan, 2008; Ellard, 2015). Trees are a way to divide areas into subareas while in the process making the area more interesting and inviting.¹⁶ Furthermore, planting trees has been proven favourable for increasing pedestrian movement (Jensen, 2007; Foltête & Piombini, 2007) and cyclist satisfaction (Chen, 2016).

2.1.4.2 Pillar VII: Visual Stimulation

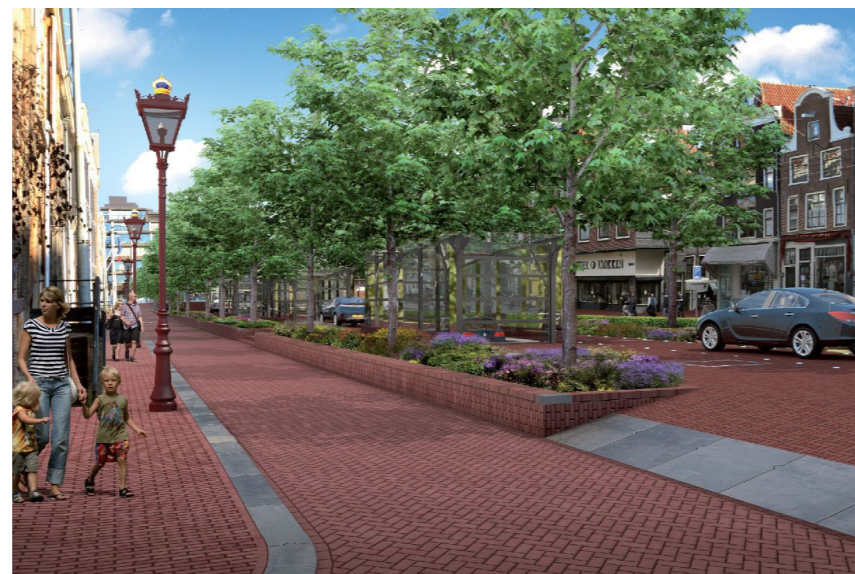
Pedestrians and cyclists value having something to look at while they move around (Ellard, 2015; Foltête & Piombini, 2007; Gehl, 2011; Speck, 2012). This can translate into spatial qualities such as unique buildings, or urban life. This means that the qualities that the city has to offer should be visible from a pedestrian and a bicycle perspective. For example, parked cars along the canals form a problem because they block the view on the water, which is seen by many as one of Amsterdam's defining qualities.

2.1.4.3 Pillar VIII: Connect Attractors

Creating attractive and uninterrupted routes between the cities attractors will further stimulate walking, particularly among tourists, who form a large part of Amsterdam's walking crowd, but also among residents (Speck, 2012).¹⁷ This pillar overlaps with the second and third pillar but requires amplification of legibility for connections to and from attractors.



¹⁶ Planting trees can make a street more interesting and inviting. While many streets in Amsterdam's city centre have an abundance of trees. Narrower streets such as the Zeedijk pictured above are short of trees because the dimensioning of the street currently does not allow pedestrian infrastructure, bicycle infrastructure, car infrastructure, and trees.



¹⁷ Amsterdam's 'Rode Loper' aims to create an entrance to the city which connects many of the centre's attractors.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes
4	High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

¹⁸ Levels of automation as defined by SAE International.

AUTONOMOUS VEHICLE	CONNECTED VEHICLE
AI located within the vehicle.	AI wirelessly connected to an external communications network.
"Outward-facing" in that sensors blast outward from the vehicle to collect information without receiving data inward from other sources.	"Inward-facing" with the vehicle receiving external environment information through wireless connectivity, and operational commands from an external entity.
AI used to make autonomous decisions on what is best for the individual driver.	Used in cooperation with other pieces of information to make decisions on what is "best" from a system optimal standpoint.
AI not shared with other entities beyond the vehicle.	AI shared across multiple vehicles.
A more "capitalistic" set-up.	A more "socialistic" set-up.

¹⁹ Differences between autonomous and connected vehicles according to Bhat (2014).

2.2.1 Research on Automated Vehicles

This part of the theoretical framework will explore what possibilities automated vehicles hold for the future. Because this project aims to explore all possibilities of automated vehicles, extreme possibilities have been taken into account and the likelihood of development is not considered an important factor. This serves to allow exploration of both likely and extreme possibilities.

Before going into more detail on possibilities, a short introduction will be given on automated vehicles. First off, there are different levels of automation and a transition from regular cars to automated vehicles will likely be a gradual one (Litman, 2015). SAE International recognises six levels of automation (SAE International, 2014): no automation, driver assistance, partial automation, conditional automation, high automation, and full automation.¹⁸ In this project, the final level, full automation, will be considered as it presents the most possibilities. Another important division is between autonomous vehicles and connected vehicles (Bhat, 2014). The former functions autonomously and acts based on inputs observed by the vehicle itself, while the latter functions through inputs received from an external communications network.¹⁹ Timmer and Kool (2014) state that autonomous and connected vehicle technology will have to complement one another if a reliable cost-effective automated vehicle is to be developed. Ultimately, vehicles will both provide and receive information. They will communicate with each other, a centralised source, and the infrastructure (Fagnant & Kockelman, 2015; Timmer & Kool, 2014). Such a vehicle is what will be used for this research, as it offers most possibilities for exploration.

Next to this general outline of what an automated vehicle will be able to do, a more specific list will be provided which lists possible effects that automated vehicles will have. This list is an elaboration on the ripple scheme provided by Milakis, Van Arem and Van Wee (2015), which comprehensively shows categories that are influenced by automated vehicles.⁷

2.2.1.1 Travel Choice Implications

Travel choice implications include vehicle kilometers travelled (VKT), vehicle use, and choice of modality.

Many authors state that VKT might increase as a result of the introduction of automated vehicles. Reasons for this are that more groups of people will be able to use AVs than regular cars, namely the

elderly, children, disabled people, inebriated people, and people who simply do not have a driver's license (Brown, Gonder, & Repac, 2014; Fagnant & Kockelman, 2015; Harper, Hendrickson, Mangones, & Samaras, 2016; Litman, 2015; Sivak & Schoettle, 2015).²⁰ Other reasons for an increase in VKT are a higher travel convenience (Fagnant & Kockelman, 2015; Litman, 2015), a new sprawl, induced by automated vehicles (Litman, 2015), cars parking themselves in peripheral areas to avoid high parking costs (Fagnant & Kockelman, 2015), and a reduction of traffic congestion and vehicle operating costs, which could induce additional vehicle travel (Brown et al., 2014; Litman, 2015). A decrease in VKT could be witnessed as a result of efficient car sharing (Fagnant & Kockelman, 2015), improved public transport through automation (Litman, 2015), improvement of pedestrian infrastructure and urban living (Litman, 2015), the reduction of "cruising for parking" (Brown et al., 2014; Bullis, 2011; Litman, 2015; Shoup, 2005), and through the phenomenon of behavioural economics, which in this case occurs if mobility services offer cheap transport even if only a few trips are made over long periods (Grabar, 2016).

The introduction of automated vehicles will likely increase vehicle use; users no longer have to pay attention to the road. They can also do other things like work on their laptop, read a book, call friends, or eat an apple (Fagnant & Kockelman, 2015; Gucwa, 2014; Litman, 2015; Snelder, Van Arem, Hoogendoorn, & Van Nes, 2015).²¹ These new possible uses of vehicles might be accompanied by larger vehicles to accommodate the new activities (Gucwa, 2014).

People might choose a different modality when automated vehicles are introduced for an array of reasons, some of which were already discussed above. Namely, a higher degree of comfort, reduction of congestion, reduction of vehicle operating costs, and a reduction of "cruising for parking" might influence the choice of modality to go towards automated vehicles more often. On the other hand, an improved pedestrian or bicycle infrastructure might make people walk or cycle more often while improved automated public transport might make people take public transport options more often. Litman (2015) notes that a new form of public transport, on-demand automated vehicles might emerge, this could also induce the choice for vehicular traffic. Another factor that might induce travel by AV is that an initial rise in vehicular traffic can lead to more degraded walking and cycling conditions (Begg, 2014; Litman, 2015).



²⁰ Still from Mercedes-Benz' commercial 'Baby' showing a baby in (what is currently still known as) the driving seat, driving through a city with its dad asleep in the backseat.



²¹ Still from Volvo's visionary commercial 'Drive Me' showing how self-driving technology revolutionises travel by offering travellers currently unthinkable experiences such as eating an apple behind the wheel.



²² Increased comfort and the ability to spend time freely on work or recreation can increase the value of time during travel.

2.2.1.2 Travel Cost Implications

Travel cost implications include monetary cost, travel time, and value of time.

Monetary cost is likely to decrease relative to the distance travelled. An important driver for this decrease is the more efficient use of fuel (Bullis, 2011; Fagnant & Kockelman, 2015; Litman, 2015). Also, car travel can become more affordable because of car sharing, which will become more convenient with AVs (Fagnant & Kockelman, 2015; International Transport Forum, 2015; Johnson & Walker, 2016).

Looking at the literature, it is possible that travel times will decrease but it is likely that travel times will remain the same because a reduction of congestion and an improvement of traffic flow will induce more vehicular traffic (Fagnant & Kockelman, 2015; Litman, 2015). Marchetti's constant dictates that the average daily commuting time always remains approximately one hour (Marchetti, 1994). It is based on the premises that people adjust their living conditions based on available modes of transport and infrastructural conditions. This supports the idea that travel times will remain approximately the same.

As has been discussed before, value of time is likely to change significantly due to automated vehicles. A higher degree of comfort and the freedom to work or recreate while travelling by AV are the cause of this change in value of time (Fagnant & Kockelman, 2015; Gucwa, 2014; Litman, 2015; Snelder, Van Arem, Hoogendoorn, & Van Nes, 2015).²²

2.2.1.3 Traffic Implications

There is a consensus among scholars that, when AVs reach a market penetration of 100%, flow stability will improve. AVs can anticipate other vehicles braking and accelerating through vehicle-to-vehicle communication, this leads to a reduction in traffic-destabilising shock waves (Fagnant & Kockelman, 2015; Musk, 2016). Furthermore, AVs are expected to use car lanes and intersections more efficiently because of shorter gaps between vehicles, coordinated driving in convoys (Fagnant & Kockelman, 2015), and swarm behaviour at intersections (Ingels et al., 2010; Kabbaj, 2016). Another implication is that automated vehicles might incentivise car sharing, which can improve car occupancy rates, leading to a traffic reduction (International Transport Forum, 2015). Furthermore, cars can be routed for a higher-level objective, basing route choice on what is best for society rather than their user (Grabar, 2016). Finally, vehicles can be allowed to adjust their speed to real-time

context, allowing them to reach higher average speeds.

2.2.1.4 Vehicle Implications

Vehicle ownership is likely to decrease as a result of AVs. The trend of sharing vehicles, which is complementary to automated vehicles, will likely reduce car ownership (Fagnant & Kockelman, 2015; Litman, 2015; Silberg et al., 2012). Johnson and Walker (2016) calculated that automated taxicabs will reach cost-parity with vehicle ownership shortly after the introduction of automated vehicles. Vehicle sharing might lead to an increased occupancy rate, reducing the average amount of vehicles required per person (Brown et al., 2014).

2.2.1.5 Infrastructure Implications

Automated vehicle infrastructure can undergo different transformations. First, it can be rid of cluttering signage, traffic lights, and other visual cues indicating to drivers how to behave.²³ This information will be sent to cars from the cloud. The infrastructure can also be made responsive to real-time inputs through vehicle-to-infrastructure communication. Finally, the dimensions of AV infrastructure can change. More efficient driving can reduce the lane width (Fagnant & Kockelman, 2015). Conversely, cars can increase in size to accommodate new on-road activities (Gucwa, 2014).

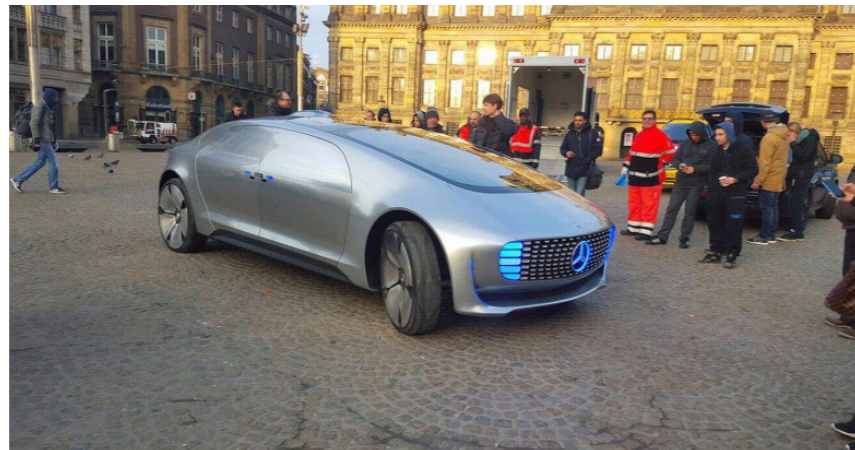
Parking infrastructure can also change significantly. First, cloud awareness of parking occupancy can reduce the amount of required parking places because vehicles will always be able to effectively find a parking spot (Brown et al., 2014; Bullis, 2011; Litman, 2015; Shoup, 2005). Secondly, because AVs can park themselves anywhere, parking facilities can be moved to urban peripheries where land prices are much lower (Anderson et al., 2014; Begg, 2014). Thirdly, car sharing services can reduce the amount of parked cars because cars are driving a larger proportion of the time (Claudel & Ratti, 2015; Fagnant & Kockelman, 2015; McDonald & Rodier, 2015). Lastly, because AVs can drive more precisely, parking spaces can decrease in size (Fagnant & Kockelman, 2015), this, however, could be curbed by an increase in car sizes (Gucwa, 2014).

2.2.1.6 Location Choice Implications

If the past is a good indicator for the future, residential, employment, and recreation locations are likely to change. If AVs can drive more efficient and subsequently congestions are reduced, people will likely adjust their travel distances to maintain similar travel times (Marchetti, 1994). A new sprawl could result (Fagnant & Kockelman, 2015).



²³ The Drive Me project visualised possible implications of automated vehicles. Above, a still from the video 'Drive Sweden - Our Vision - A new approach to mobility' shows the removal of superfluous signage.



²⁴ Encapsulated vehicles disconnect passenger from their surroundings.

2.2.1.7 Societal Implications

Emissions are likely to be reduced by AVs. Firstly, because AVs drive more efficient (Bhat, 2014; Fagnant & Kockelman, 2015; Litman, 2015) and secondly because AVs will likely drive on electricity rather than gasoline (Fagnant & Kockelman, 2015). Conversely, an increase in car size can contribute to an increase in emissions (Gucwa, 2014).

A reduction of "cruising for parking" and an increase in car sharing can decrease energy consumption (Brown et al., 2014; Bullis, 2011; Claudel & Ratti, 2015; Fagnant & Kockelman, 2015; Litman, 2015; McDonald & Rodier, 2015; Shoup, 2005). Furthermore, if automated vehicles lead to a higher use of car rental services, right-sizing of vehicles can lead to a reduction in energy consumption (Hopper, 2016).

Safety can increase because automated vehicles are not subject to human error. Currently, driver error is estimated to be the main reason behind approximately 93% of all car crashes (National Highway Traffic Safety Administration, 2008). Scholars agree that vehicle crashes will reduce with the introduction of AVs (Fagnant & Kockelman, 2015; Litman, 2015).

Social equity is likely to increase with the introduction of automated vehicles. Operating costs will decrease as a result of more efficient driving and better car sharing services will provide an affordable car travel option for the less wealthy.

Automated vehicles can have some economic benefits for society. They can reduce infrastructure investments because narrower car lanes are required, protection measures can be abandoned, and signage can be removed (Silberg et al., 2012; Wagner, Baker, Goodin, & Maddox, 2014). Furthermore, costs associated with vehicle crashes and congestion can be greatly reduced (Fagnant & Kockelman, 2015). Automated vehicles can also influence the health of people. Firstly, they can reduce emissions, which has been mentioned before. This has health benefits for both users of the vehicle and people surrounding the vehicle. Secondly, AVs can help reduce the amount of vehicle crashes. AVs can also negatively influence health though. Their convenience can induce more vehicle use which can lead to more emissions.

Furthermore, the encapsulated nature of AVs can disconnect users from their surroundings, leading to social isolation.²⁴

Finally, congestion. Fagnant and Kockelman (2015) state that automated vehicles can reduce congestion but Litman (2015) notes that this effect might be curbed by an induced demand.

2.2.2 Resulting Vehicle

As has been shown in section 2.2.1, automated vehicles have many possible implications. In the rest of this report, a more extreme automated vehicle will be assumed for the sake of exploration. This vehicle, through more extreme, is based entirely on the literature research. Apart from this assumed vehicle, another important assumption has been made, namely that **all** vehicles will be automated vehicles. This has been assumed because this is an exploratory project and assuming all cars are replaced by automated vehicles allows the most space for exploration. For the vehicle itself, the following assumptions have been made.

Firstly, all vehicles will be fully automated and will not need human intervention at any point in time. Secondly, all vehicles are electric vehicles and thus more environmentally friendly and less noisy. Thirdly, all vehicles are interconnected and connected to the cloud and infrastructure. They both receive and send information about the city and its traffic. This means that every car is always aware of the position of all other cars, traffic incidents, events, available parking spots, weather, congestion of other modalities, and other relevant factors. Fourthly, AVs will be able to drive extremely precise. GPS is already able to locate up to a centimeter accurate (Chen, Zhao, & Farrell, 2016) and AVs are expected to profit from this. Lastly, cars will not cause accidents but might get involved in accidents sporadically. All these assumptions will be taken into consideration while conducting the exploratory research and the final design.

2.3.1 Scenarios

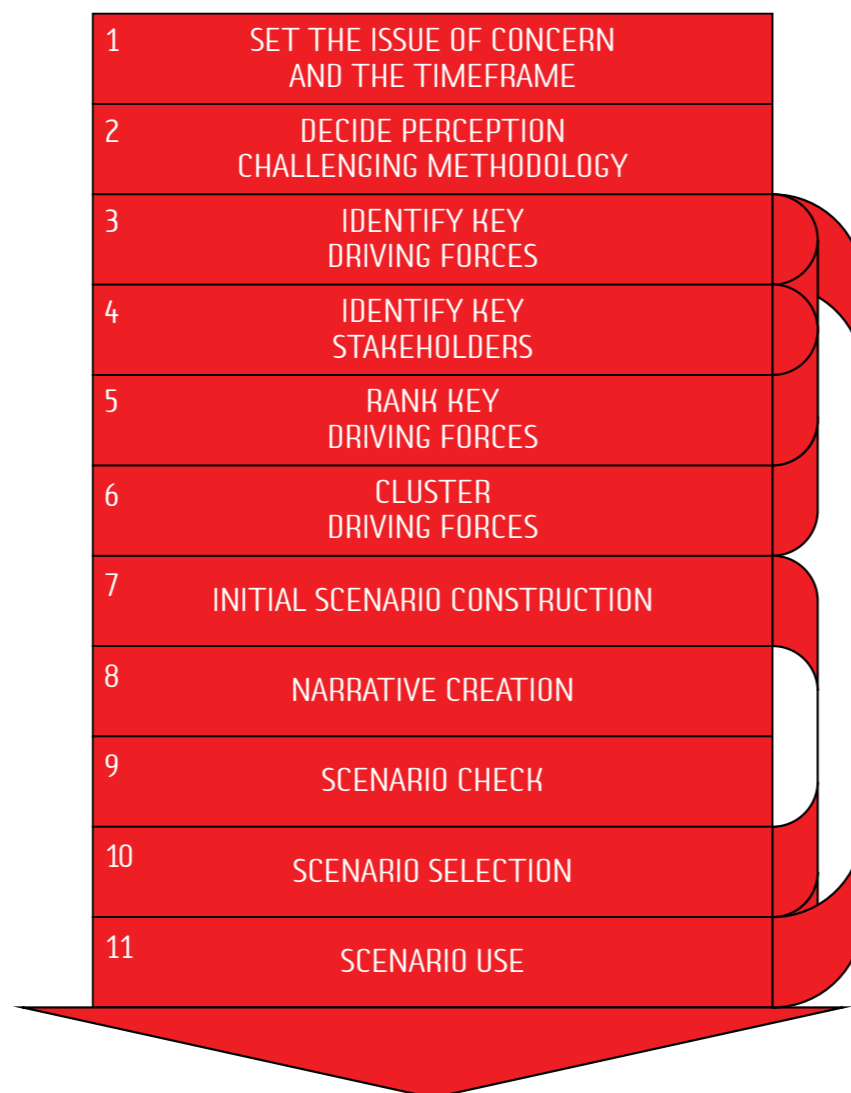
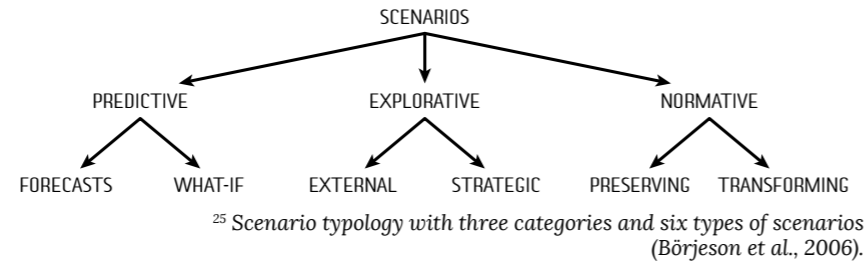
According to Börjeson, Höjer, Dreborg, Ekvall, and Finnveden (2006), three scenario categories can be distinguished. These are predictive scenarios, exploratory scenarios, and normative scenarios. Within each category, they distinguish two types. The first category, predictive scenarios, can be either forecasts or what-if scenarios. The second category, exploratory scenarios includes external scenarios and strategic scenarios. The last category, normative scenarios, includes preserving and transforming scenarios.²⁵ Each type of scenario has different uses and when using scenarios it is thus important to first establish which type of scenario is most useful for the intended purposes. For this graduation project, we need to understand what impact mobility can have on public space at a specific point in the future. The most useful type of scenario to do this is the external scenario. According to Börjeson et al. (2006), external scenarios are useful when one is trying to find an answer to a question in the form of 'what can happen to the development of external factors?'. This is what we are looking for, we want to know how external factors can influence the demands regarding mobility and how this influences public space. Having established the type of scenarios we will be building, we can now move on to creating a methodology for building the scenarios. This will, of course, be done based on scenario building theory.

2.3.2 Scenario Building Methodology

Based on literature, a scenario building methodology has been established.²⁶ For each step of the methodology we will shortly describe what it is and what its relevance is for the process.

The first step is to set the issue of concern (Chermack, 2007; Godet, 2000; Ratcliffe, 2002; Schwartz, 1991; Wright, Bradfield, & Cairns, 2013; Wright & Goodwin, 2009) and the time frame (Schoemaker, 1995; Wright et al., 2013). In this step, it needs to be made explicit what the purpose of building the scenarios is and what the time frame will be in which the scenarios are constructed. Failing to properly address the issue of concern can lead to failure of the entire exercise (Perrow, 1999). Explicitly mentioning the time frame can help guiding the process. Longer time frames relate to larger uncertainties and thus they result in more 'extreme' scenarios.

The second step of the scenario building process is to challenge the perception of scenario building participants, as Wright and Goodwin (2009) describe, people often have



²⁶ Scenario building methodology.

overly narrow or wrong perceptions of the issue of concern. Introducing a method to liberate the creativity of the human mind can (partially) overcome this, which makes the scenarios more diverse and thus more 'reliable'. This is because the principal behind building scenarios is to explore an array of possible futures as broad as possible. Possible techniques to challenge perceptions are to introduce the theory behind espoused theories to make participants aware of their subjective perception (Chermack, 2007; Uotila, Melkas, & Harmaakorpi, 2005); the inclusion of 'remarkable people', or people who have a different expertise, who offer different views on the issue of concern (Chermack, 2007; Wright & Goodwin, 2009); the introduction of systems thinking throughout the process to stimulate participants to think more holistically (Chermack, Lynham, & Ruona, 2001; Mietzner & Reger, 2005); role-play, or making people act out roles of actors who would be involved in the scenarios to imagine how they would influence the issue of concern (Wright & Goodwin, 2009); the introduction of a pluralistic present, making participants individually create scenarios, reasoning from their own, subjective, image of the present (Vervoort, Bendor, Kelliher, Strik, & Helfgott, 2015); and drug-induced scenario building, hallucinogenic drugs can open up new pathways in the brain, liberating the creativity of participants (Salewski, 2012).

The third step is to identify the key driving forces influencing the issue of concern (Arcade, Godet, Meunier, & Roubelat, 1999; Chermack, 2007; Godet, 1987; Phelps, Chan, & Kapsalis, 2001; Ratcliffe, 2002; Schoemaker, 1995; Schwartz, 1991; Wright et al., 2013). Driving forces can be trends or events that would influence the issue of concern. According to Börjeson et al. (2006), this is an especially important step when constructing external scenarios because it is this step in which the external factors that influence the issue of concern are established. The driving forces together form the basis of the eventual scenarios. As can be seen in image 26, it is possible to iterate back to this step after continuing to the next step when more driving forces are found.

The fourth step is to identify the key stakeholders (Chermack, 2007; Schoemaker, 1995). In this step, stakeholders are identified who have an influence on the issue of concern or the identified driving forces. When

constructing external scenarios a broad range of stakeholders can be identified because both directly and indirectly involved stakeholders can be relevant when establishing the development of external factors.

The fifth step is to rank the driving forces (Chermack, 2007; Schwartz, 1991; Wright et al., 2013; Wright & Goodwin, 2009). This means they should be judged on both likelihood and impact (Schwartz, 1991). High impact, high probability driving forces should be present in all scenarios, low impact driving forces will only appear in scenarios if they fit in by chance, and high impact, low probability driving forces determine the basis of the scenarios.

The sixth step is to cluster the driving forces (Wright et al., 2013). Here, synergies or causal relations are sought between driving forces to form clusters. Driving forces that are ranked as having a high degree of certainty will likely appear in more clusters while driving forces that are unlikely to happen will likely be limited to one or few clusters.

The seventh step is the initial construction of the scenarios (Arcade et al., 1999; Chermack, 2007; Wright et al., 2013; Wright & Goodwin, 2009). Here, the clusters are clustered together to form internally coherent scenarios.

The eighth step is to construct a narrative structure for the scenarios (Chermack, 2007; Ratcliffe, 2002). The scenarios are further elaborated and a narrative structure is created. Driving forces are added to complete causal chains if necessary.

The ninth step is to check the scenarios for plausibility (Chermack et al., 2001; Heinecke & Schwager, 1995; Wilson, 1998), differentiation (Chermack et al., 2001; Heinecke & Schwager, 1995; Wilson, 1998), consistency (Börjeson et al., 2006; Von Reibnitz, 1992; Wilson, 1998), decision-making utility (Chermack et al., 2001; Heinecke & Schwager, 1995; Wilson, 1998), and novelty (Chermack et al., 2001; Heinecke & Schwager, 1995). Plausibility here means that it should be actually possible for the scenario to unfold as is described. Differentiation means that all scenarios should be different with respect to the issue of concern, is their outcome really different or are they just variations of each other? Consistency means that the combination

of logics on which the scenarios are built should form a coherent whole. Decision-making utility means that the scenarios should be helpful in addressing the issue of concern. Novelty means that the scenarios should shed a new light on the issue of concern. The scenarios should show possible outcomes that are likely not to have been considered fully.

The tenth step is to flesh out scenarios that do not perform in all checks from step nine. After this step, there is again an option to iterate part of the process if necessary.

Finally, the scenarios can be used. Using the scenarios, again can lead to an iteration of the process because new possibilities might arise when using the scenarios.

SCENARIOS

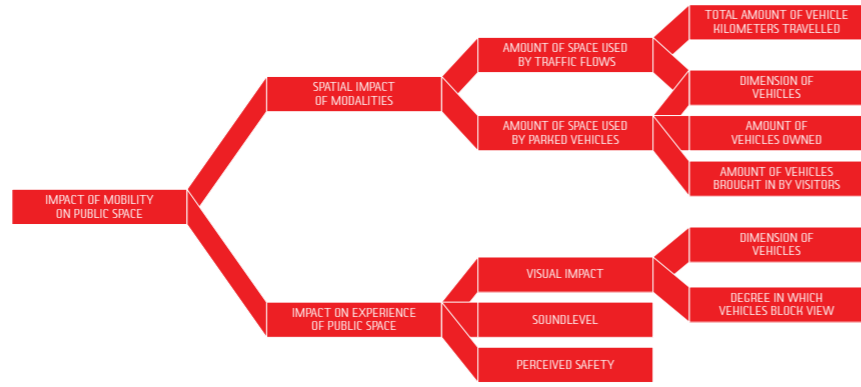


“It could be that if one clung too closely to reality, the result might well be far from realistic.”

Kōbō Abe (1966)

3.1.1 Step I: Setting the Issue of Concern

The issue of concern here is the impact mobility will have on public space. The timeframe is between now and the point in time where automated vehicles will be ubiquitous. The impact of mobility on public space depends on a range of factors.²⁷ In image 27, the issue of concern itself can be seen on the left side and from there it is dissected into smaller aspects. The third column shows the desired outcomes of the scenarios. Scenarios should reflect information about the amount of space used by traffic flows, the amount of space used by parked vehicles, the visual impact of vehicles from public space, the sound level experienced in public space caused by vehicles, and the perceived safety of public space.



3.1.2 Step II: Decide Perception Challenge

For this process, because of the limited amount of available time, two techniques are selected that can be used in a relatively short time. These are the use of remarkable people and systems thinking. The scenarios will be constructed by the author, who employs a systems thinking approach and conversations and interviews will be conducted with 'outsiders' to create broader scenarios. This will be done in an informal way because this saves time and in order for the subjects not to hold back on 'weird' answers which are the kind of answers that can actually broaden the scenarios.

3.1.3 Step III: Identify Key Driving Forces

In this step the driving forces are identified. Image 28 contains a visual representation of the driving forces. Changing mobility can be caused by changing demographics, changing reasons for travel, and modal shifts. These three categories then can have subcategories wherein the driving forces are shown. These driving forces were established through many conversations, interviews, and brainstorm sessions with peers, experts, and friends.

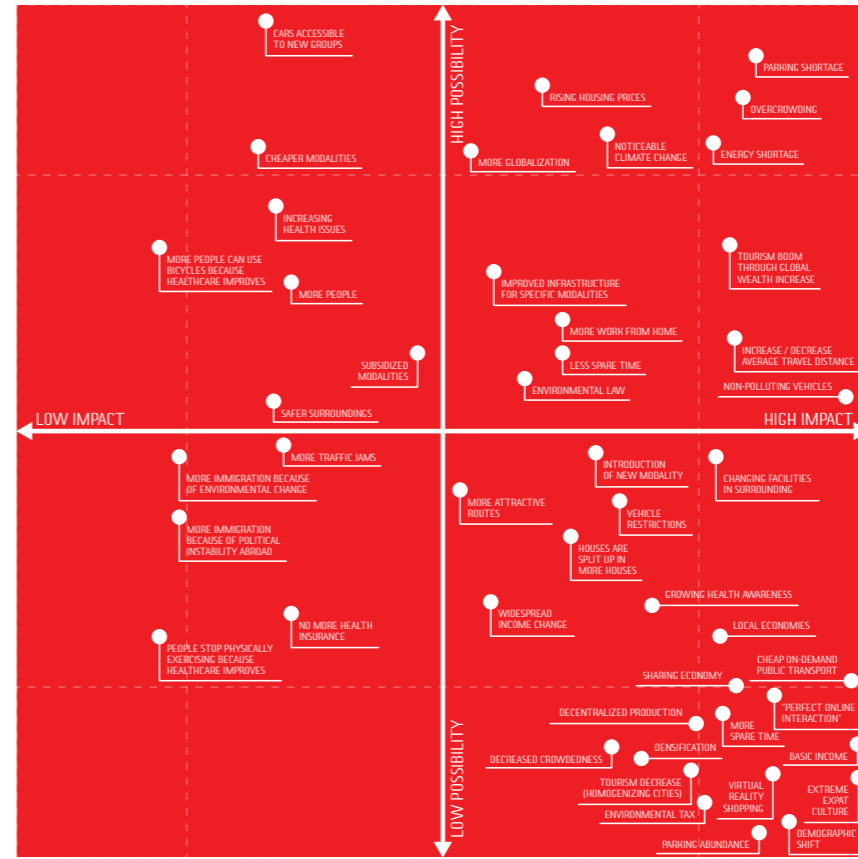
3.1.4 Step IV: Identify Key Stakeholders

Key stakeholders that were identified are long-time residents, new residents, entrepreneurs, the public transport sector, highly educated, tourists, students, expats, travellers, elderly, young families, and the governmental institutions influencing mobility policy. These groups all influence mobility on different scales and as such their decisions and behaviour will impact the way mobility will influence public space in possible futures.

²⁷ The issue of concern dissected into sub-aspects.

ISSUE OF CONCERN	ASPECTS OF ISSUE OF CONCERN	SCENARIO OUTCOMES	DRIVING FORCE DOMAINS
CHANGING MOBILITY	MODAL SHIFT	FINANCIAL REASONS	BASIC INCOME / SUBSIDIZED MODALITIES / ENERGY SHORTAGE / PRICE REDUCTION OF MODALITY / ENVIRONMENTAL TAX / SHARING ECONOMY / WIDESPREAD INCOME CHANGE
		CONVENIENCE, DISTANCE & TIME	VEHICLE RESTRICTIONS / TRAFFIC JAMS / PARKING SHORTAGE / PARKING ABUNDANCE / INCREASE AVERAGE TRAVEL DISTANCE / MORE LOCAL "DESTINATIONS" / IMPROVED INFRASTRUCTURE / NEW MODALITIES
		ENJOYMENT	MORE SPARE TIME / MORE "ATTRACTIONS" / SAFER SURROUNDINGS / DECREASED CROWDEDNESS
		PHYSICAL LIMITATIONS	TECHNOLOGICAL IMPROVEMENTS OF MODALITIES / IMPROVED HEALTH SECTOR
		ENVIRONMENTAL CONCERN	NON-POLLUTING VEHICLES / NOTICEABLE CLIMATE CHANGE / ENVIRONMENTAL LAW
	CHANGING REASONS FOR TRAVEL	MORE / LESS "GOING OUT"	INCOME CHANGE / CHANGING AMOUNT OF SPARE TIME / IMPROVED ONLINE INTERACTION / CHANGE IN FACILITIES
		MORE / LESS PHYSICAL EXERCISE	CHANGING HEALTH SECTOR / CHANGING HEALTH AWARENESS / CHANGING HEALTHCARE SYSTEM
		MORE / LESS SHOPPING	CHANGE IN ONLINE SHOPPING / DECENTRALIZED PRODUCTION / CHANGING CONSUMPTION PATTERNS
		MORE / LESS COMMUTING	BASIC INCOME / LOCAL ECONOMIES / GLOBALIZATION / LOSS OF JOBS / MORE JOBS / IMPROVED WORKING-FROM-HOME-FACILITIES
		AGEING POPULATION	IMPROVING HEALTHCARE / BASIC INCOME / GROWING HEALTH AWARENESS
CHANGING DEMOGRAPHICS	MIGRATION / IMMIGRATION	GLOBALIZATION / CLIMATE CHANGE / POLITICAL INSTABILITY / TECHNOLOGICAL ADVANCEMENT	
	MORE / LESS TOURISM	TECHNOLOGICAL ADVANCEMENT / GLOBALIZATION / CHANGING POLICY / HOMOGENIZATION OF CITIES / LOCAL LIFESTYLES	
	APPEAL TO OTHER DEMOGRAPHIC GROUPS	OVERCROWDING / GLOBALIZATION / CHANGING HOUSING PRICES / CHANGING FACILITIES / CHANGING LIVING ENVIRONMENT / CHANGING SAFETY	
	POPULATION GROWTH	DENSIFICATION / SMALLER HOUSING UNITS / FUNCTION CHANGE / CHANGING HOUSING PRICES	

²⁸ Identifying of driving forces, left the issue of concern, right the driving forces that influence them specifically named.



²⁹ Ranking of the driving forces according to possibility and likelihood.



³⁰ Clustering of the driving forces.

3.1.5 Step V: Rank Key Driving Forces

In this step key driving forces were ranked according to likelihood and impact.²⁹ Both rankings are based on average estimations of the author and participants. It must be noted that the gravity of the impact is specifically the gravity of the impact on the mobility and public space for the city centre of Amsterdam. So, while the event in which people stop exercising physically because of improving healthcare might have a large impact on society as a whole, the impact on the mobility and public space of the city centre of Amsterdam is relatively small. Possibilities are based on the assumption that automated vehicles are already ubiquitous, because this assumption has been made in section 2.2.2.

3.1.6 Step VI: Cluster Driving Forces

In this step, causal relations and synergies between driving forces are explored and clusters are made accordingly.³⁰ In the scheme, driving forces that are either causally related or between which synergy exists are connected by lines.

3.1.7 Step VII - X: Initial Construction, Narrative Creation, Check, and Selection

The last steps running up to the initial use of the scenarios, step seven, eight, nine, and ten have been conducted through a heavily iterative process. Many iterations were made and after each iteration, the resulting 'scenarios' were reflected upon, often through conversations with peers. Scenarios is put between quotation marks here because many times the results would not actually be full scenarios but rather large clusters of driving forces or incomplete stories about the future. Even though the steps were followed during the scenario building exercise, describing each iteration in retrospect makes no sense and would obscure the important outcomes of the scenario building exercise. For this reason, instead of describing step seven, eight, nine, and ten separately, a summary of the process will be shown in which simplified versions of the iterations and their limitations will shortly be described.³¹

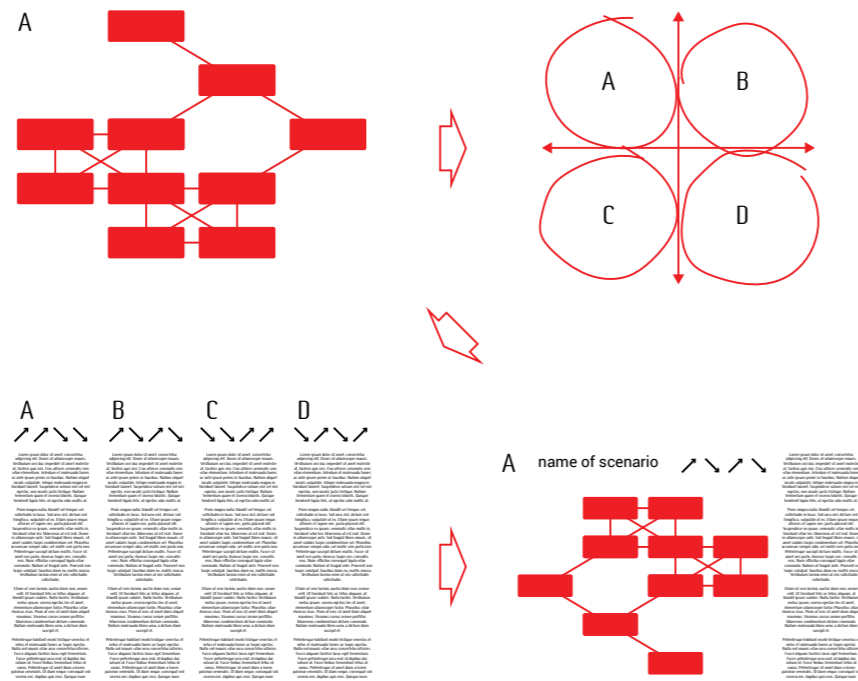
The first iterations focused on simply clustering the clusters that were found in step six. This led to partial stories that were mainly missing consistency. The 'scenarios' were missing important driving forces that were needed to create a coherent story that is plausible to unfold based on just the combination of the driving forces that they were composed of. However, they did provide a range of possible starting points to expand

from further.

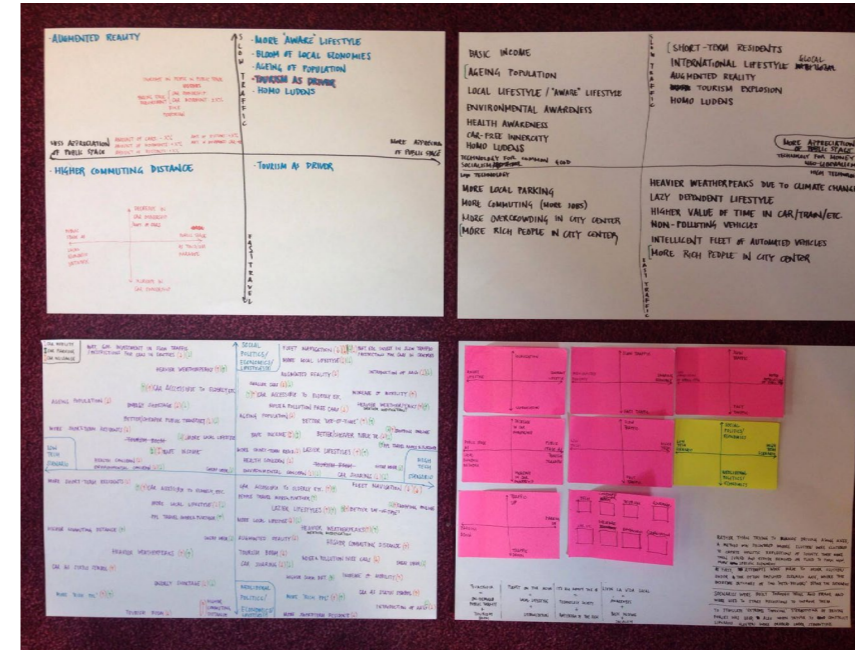
After a while, attempts were made to order the scenarios along axes.³² This is a popular form of creating scenarios. In it, meta-drivers are chosen which function as an umbrella for other drivers. For example, economic growth could be such a meta-driver because when there is economic growth, it is likely that there is also more consumption, more jobs, more commuting, etc. When working with this method, two meta-drivers are positioned along axes and this leads to four scenarios where scenario B is the extremely positive outcome of both metadrivers, scenario C is the extremely negative outcome of both meta-drivers and scenarios A and D are the other two possible combinations. Worth noting here is that positive and negative do not necessarily reflect good or bad. For example, an extremely positive traffic growth might be a bad thing depending on one's perspective. While trying to create scenarios along axes, often a method was employed to think in stereotypes to stimulate the process of organisation ("People who do this probably also do this and this"). Probably because of this, it was found that scenarios that were created according to this method were often overly simple, they did not reflect the holistic nature of the issue of concern. Meta-drivers that were tried were Local-Global; Awareness-Ignorance; Slow Traffic-Fast Traffic; Individual Economy-Sharing Economy; Public Space Appreciation-Public Space Depreciation; Car Ownership Increase-Car Ownership Decrease; Locally Focused Public Space-Tourism Focused Public Space; High Tech-Low Tech; Socialism-Neoliberalism; Traffic Increase-Traffic Decrease; and Parking Increase-Parking Decrease.

This method was succeeded by a method where all meta-drivers that were tried during the previous phase were combined in different ways and scenarios were then constructed around these combinations if possible.³³ This was quickly found to be too complex and the issue of concern itself was often lost in the large amount of outcomes belonging to each scenario. However, it did embrace the holistic nature of the issue of concern.

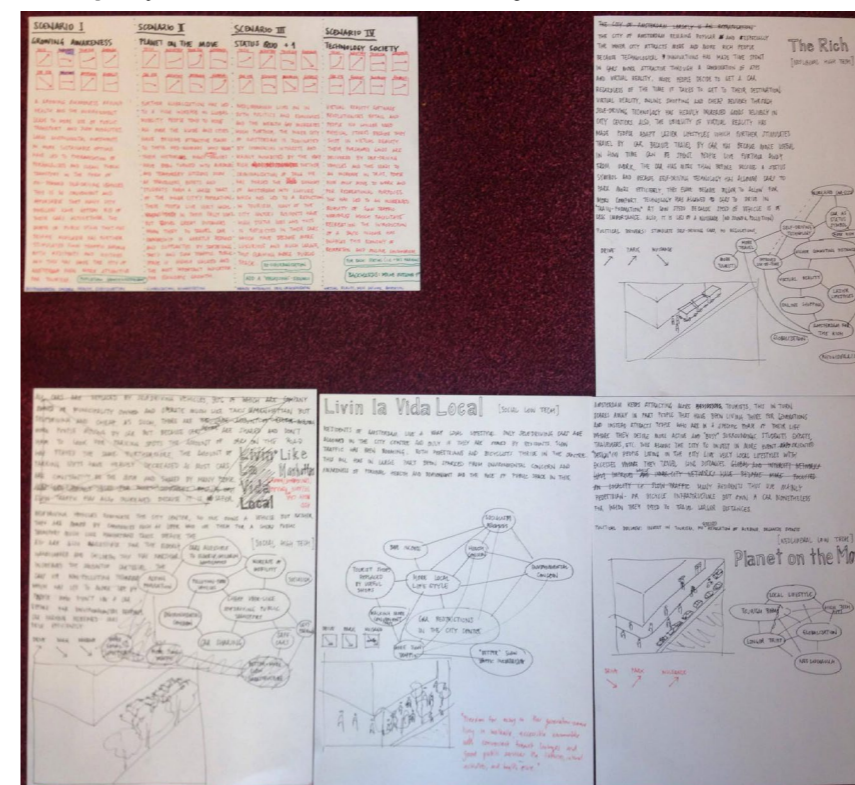
Finally, a combination of the previous methods was employed. The clusters of driving forces were combined and through systems thinking attempts were made to create narrative structures around these clusters of clusters. Here, the clusterings found through the axes method were also helpful. The scenarios found through this last method were refined during a few final iterations. Some scenarios



³¹ Different iterations that were gone through during steps seven to ten.



³² Examples of some iterations that were made using the 'axes method'.



³³ Examples of some iterations using the 'meta-driver method' and the 'combined method'.

were combined into more holistic scenarios, some were fleshed out, and some were just elaborated further. It was after this point that it became apparent that the scenarios could still be organised along axes, namely axes containing a growth or decline of traffic on one axis and growth or decline of parked vehicles on the other axis. These are the most important outcomes of the four scenarios that were found with respect to the issue of concern. However, immediately placing these long axes would not have resulted in the same richness of the scenarios which were hypothesized to be supportive for the design phase of the project. It is concluded that there is not one right or straightforward way of establishing the scenarios. Rather, it is a fuzzy process much resembling a design process in which the result will eventually become apparent after much trial and error and critical reflection.

3.1.8 Step XI: Scenario Use

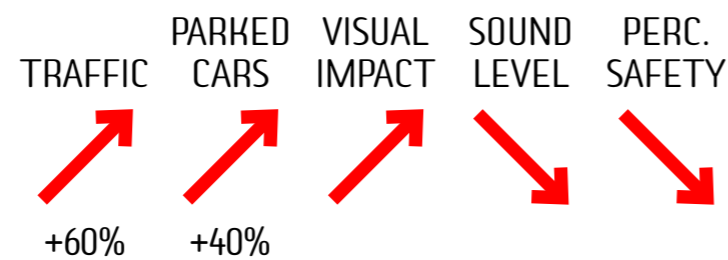
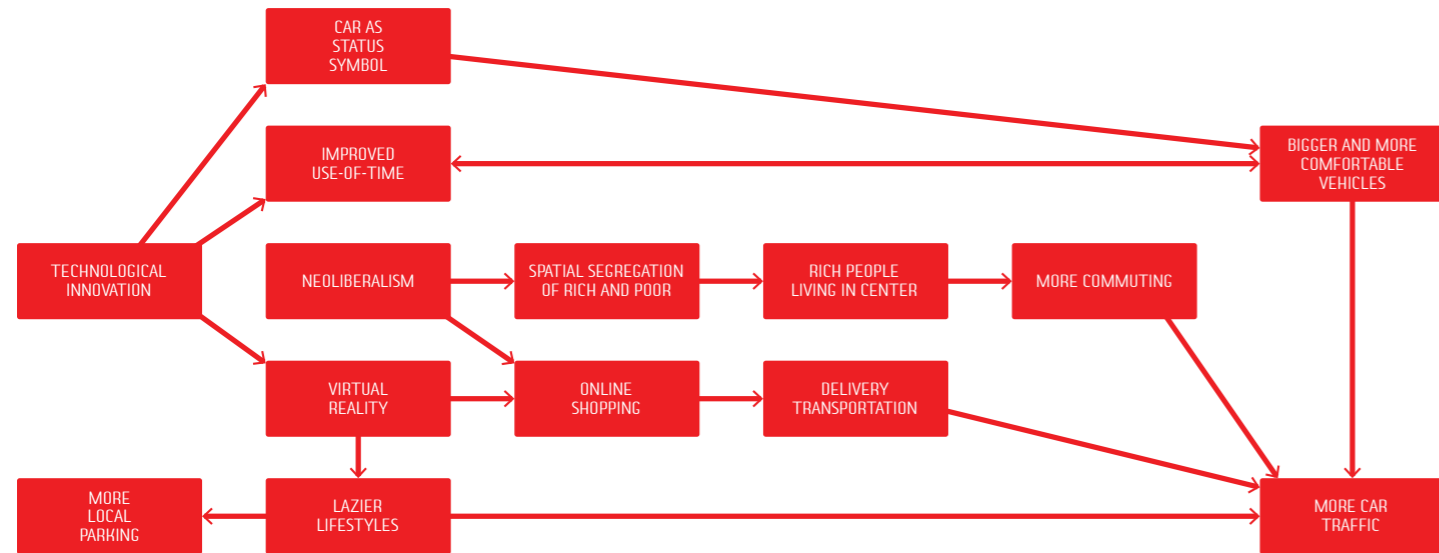
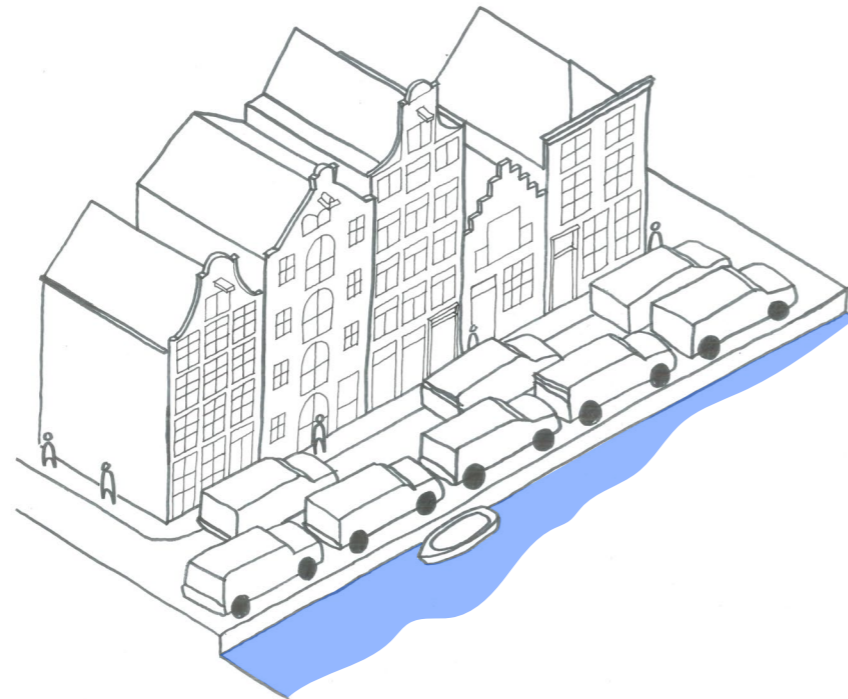
The scenarios that were established will be discussed in section 3.2, these scenarios formed an initial starting point for design. However, through designing for the scenarios, new insights were found which helped shape the scenarios further in a direction which served the final design more adequately. These final scenarios, called perspectives, which will be elaborated upon in section 3.3, abandon specific properties of the initial scenarios for the sake of free exploration because ultimately, this is what the scenarios were meant for.

In this scenario, large technological innovations guide development largely in line with developments of the past decades. Especially virtual reality has a huge impact. People shop in virtual reality and have their purchases delivered. A select few make a lot of money and it is these people who live in the city centre of Amsterdam. They have jobs all through the country and their own private office vehicles which have grown in size to accommodate office space and room for virtual reality hardware. Large commuting distances are seen as less of a problem because the time travelled can be spent well with virtual reality technology. People have adapted lazier lifestyles because of new technology which has further decreased slow traffic.

Demographics
highly educated
entrepreneurs

Political catalysts
laissez-faire politics

SCENARIO 1 IT'S ALL ABOUT THE MONEY



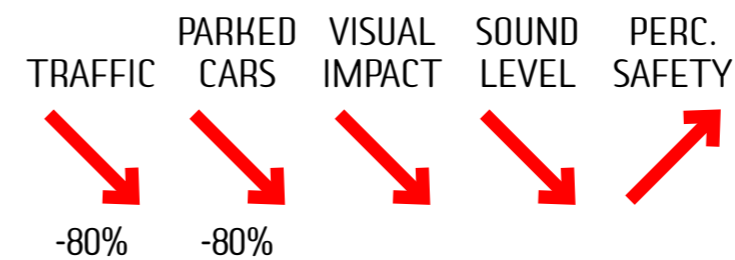
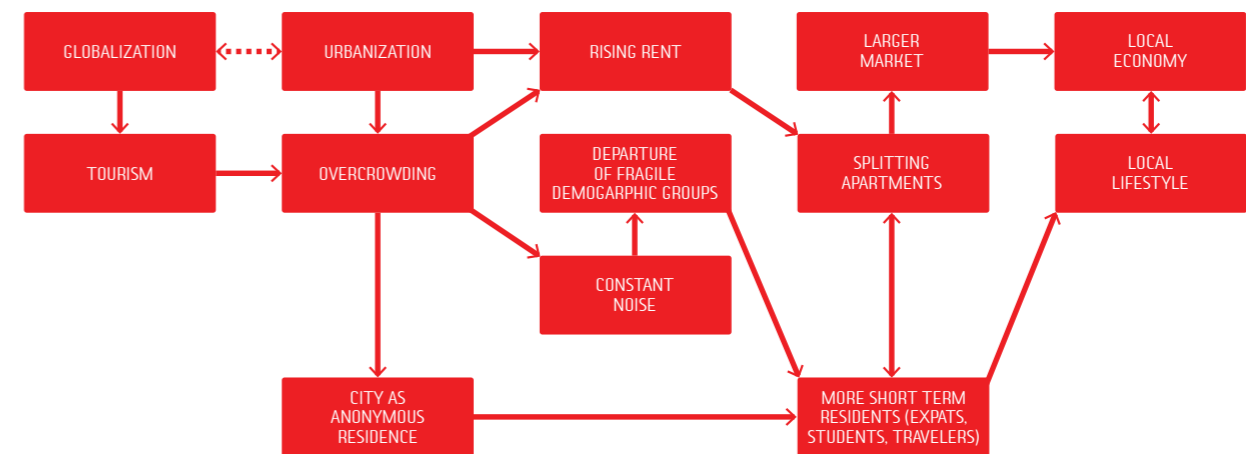
SCENARIO 2 PLANET ON THE MOVE



In this scenario Amsterdam keeps attracting more and more tourists. This leads to overcrowding and related nuisance. This sparks a demographic shift where the city centre gets occupied mainly by demographic groups who settle in the city centre temporarily for a specific phase of their life (students, expats, travellers, etc.). These groups live relatively local lifestyles with some exceptions where they travel large distances to visit family or to travel the world. Most of these people mainly move around with bicycles, by public transport or on foot. The amount of cars thus greatly decreases. At the same time, local economies flourish, both in the creative sector and in the service sector. The city centre keeps its mixed use character and even improves on it. The density increases as more houses are split up to answer to the high housing demand at 'reasonable' prices.

Demographics
students
expats
travellers
tourists

Political catalysts
stimulation of slow moving traffic
tourism stimulation
attractive living environment



In this scenario global tourism booms and historical city centres are an important destination. Technological progress has sparked the use of Uber-like public transport that shows up on demand and drives towards a destination of choice for a price similar to bus fares. Privately owned vehicles are largely replaced by this public transportation system. Because this automated public transport is so accessible, more people are using it than ever before and at any given moment, more vehicles are on the road than ever before. However, because these vehicles don't park, more space has become available in the city centre. Also, because children can now use the cars and cars have become very safe and clean, the city centre has become a popular place to live for young families.

- Demographics**
 entrepreneurs
 tourists
 long-time residents
 young families
- Political catalysts**
 stimulation of tourism
 public transport investment

SCENARIO 3 TOURISTOPIA

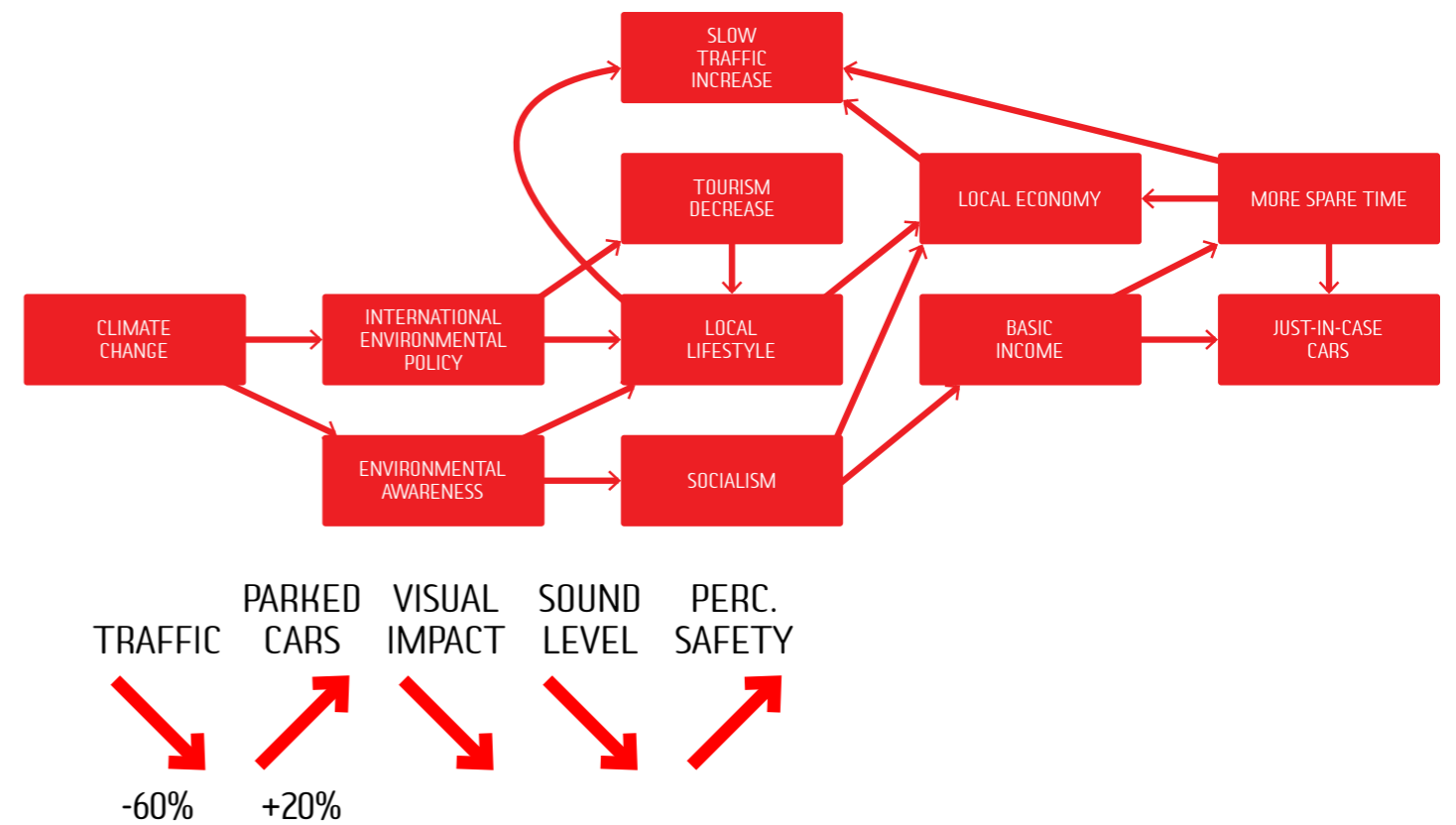
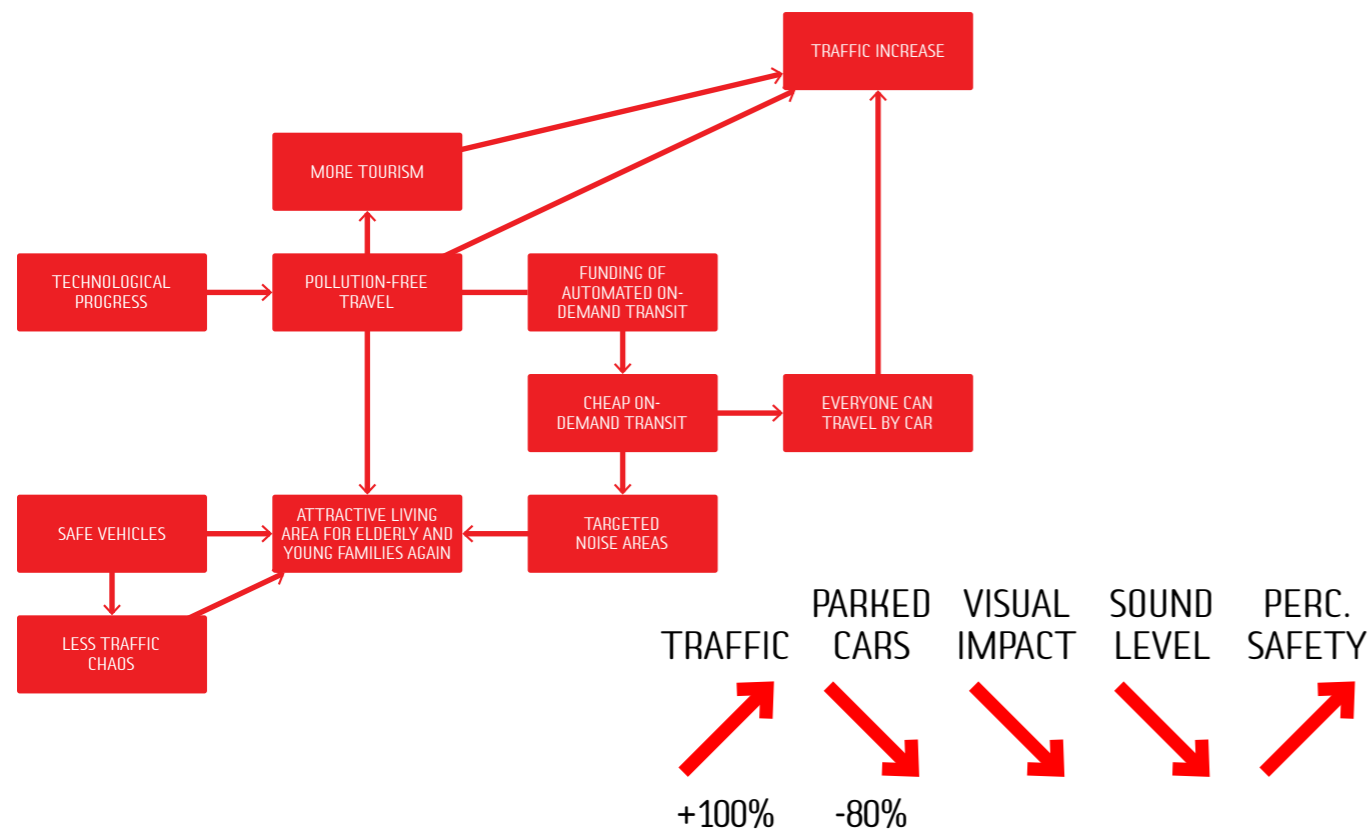


SCENARIO 4 LIVIN' LA VIDA LOCAL



In this scenario, climate change instigates international restrictions on mobility. As a result, slow traffic becomes more popular and local economies thrive. People still own cars but they are restricted to limited use and so they mainly catch dust along the road. Tourism also sharply decreases as a result of international mobility restrictions and the monotony of Nutella-shops is replaced by a more mixed-use network tailoring the needs of locals. The political movement that has sprung from the climate change has marked the beginning of a new socialism and this has led to a basic income for everyone. This basic income has further induced a need for slow traffic and recreational public space where people can meet each other.

- Demographics**
 long-time residents
 entrepreneurs
- Political catalysts**
 car restrictions
 slow traffic stimulation
 tourism reduction policies





3.3.1 Perspective I

This scenario is based on a future in which the centre of Amsterdam keeps attracting highly education rich people. Breakthroughs in the field of virtual reality incited lazier lifestyles in which people shop from home and often meet friends in virtual reality. AVs have become virtual reality rooms in which people disconnect from their surroundings and travel time is no longer an issue.

Mobility

People travel around mostly in their privately owned vehicles. Their vehicles are parked close to their house and will always be available within a minute. Rather than experiencing travel as a trip, people get in at one point and exit at another. The time in between is spent completely shut off from the surrounding space, engulfed in virtual reality. This has made travel much less inconvenient because it has become more productive.

Virtual Reality

Virtual reality has completely changed society, people shop, work, and meet friends in virtual reality. Most vehicles are outfitted specifically for virtual reality use and as a result AVs have become much more separated from their surroundings than regular cars used to be.

Subcanal Parking

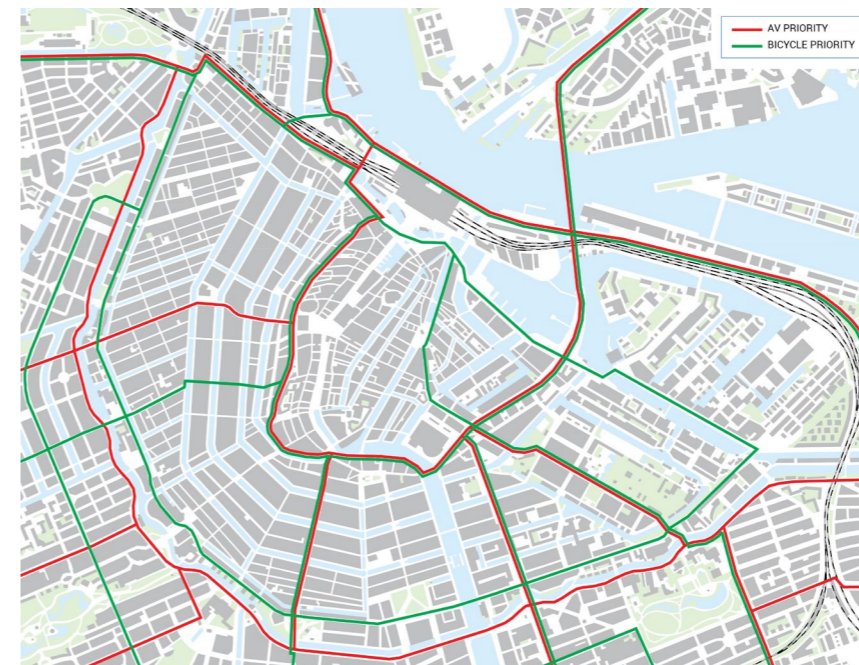
Because the centre's residents are rich, and more space was needed to harbour all parked vehicles. Large parking garages have been built under the canals.³⁴ These garages are large enough to provide space for most parked cars and as such, much space has been opened up along the centre's canals.

Priority Networks

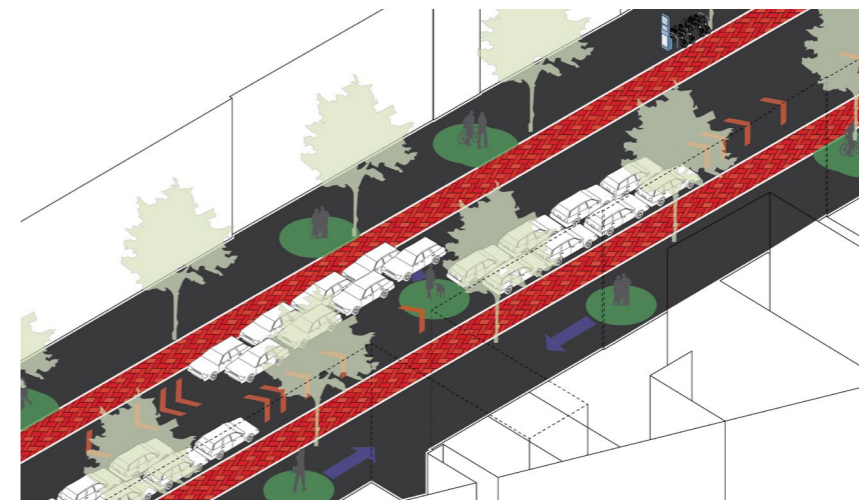
Because travel time has become much less of an issue, shared space has been introduced throughout the city centre. Pedestrians and cyclists are prioritised over AVs here. This leads to an increased travel time for AV-users and to compensate for this, priority networks were introduced for AVs and bicycles where they are prioritised.³⁵ On these priority lanes, AVs drive in convoys, this leaves space open that can be used by pedestrians to cross.



³⁴ Subcanal parking can provide ample parking space without taking up any surface space.



³⁵ Priority networks can facilitate fast travel for specific modalities.



³⁶ Digital infrastructure indicate to pedestrians and cyclists where they can walk safely and helps them predict the behaviour of AVs.

Digital Roads

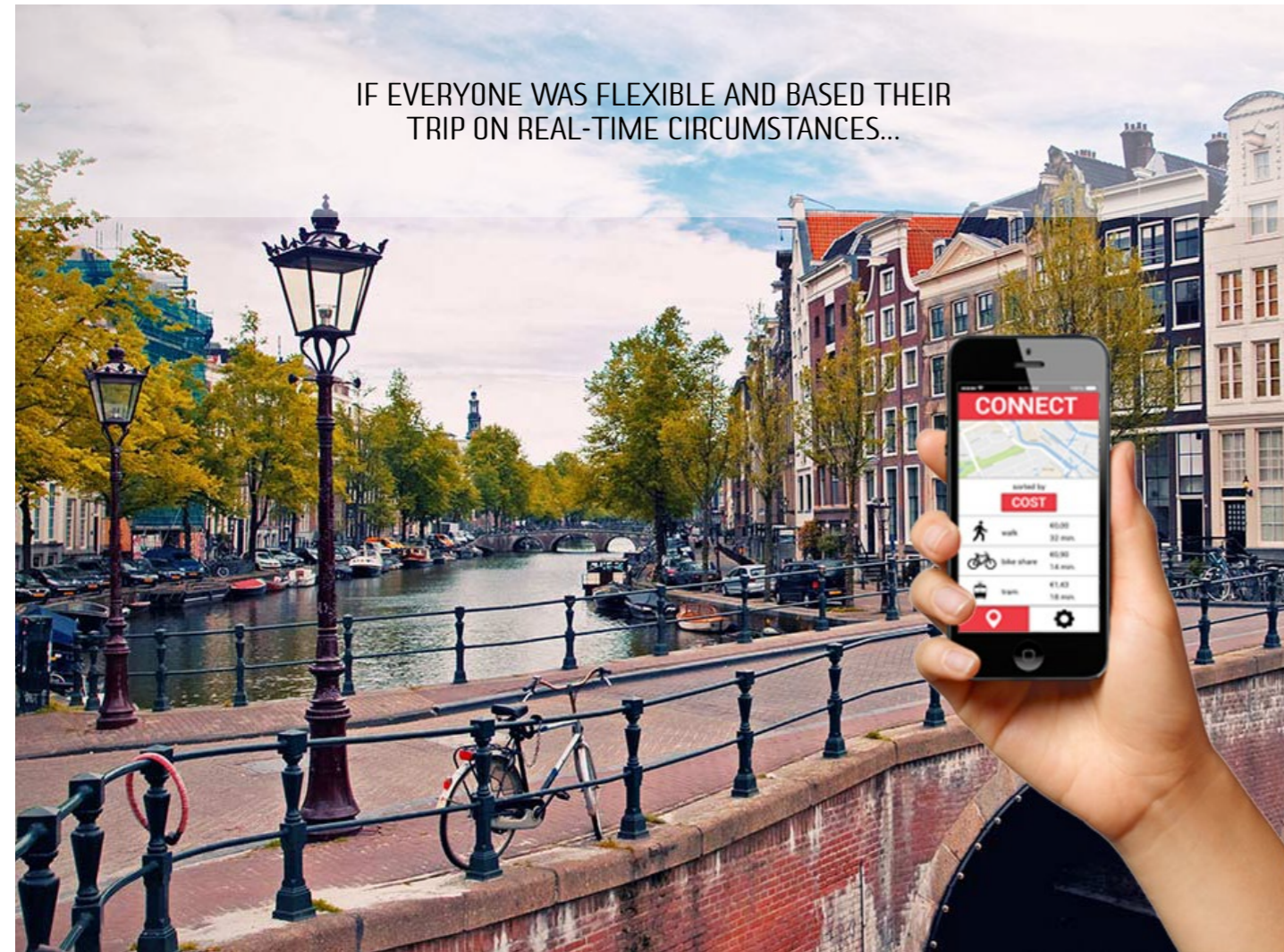
All of the centre's roads have been replaced by a digital screen surface which displays in real-time the positions of vehicles, pedestrians, cyclists and other moving things. The infrastructure also charges vehicles while they drive over it through induction. It furthermore updates pedestrians and cyclists in real-time where they can and cannot walk and gives route information.³⁶ Commercial parties pay the municipality to make the infrastructure display commercials and suggest alternative routes passing their business.

Society

Even though much public space has opened up as a result of moving parking under the canals, city life has died out in many parts of the centre. Because AVs have become dominant and are completely disconnected from their surroundings, the activity of people-watching has become much less rewarding and many public spaces died out as a result. A new layer of society has formed in virtual reality though, so that's something.

Discovered Instruments

- Priority Lane
- Inductive Charging Road
- Digital Road Surface
- Convoy Driving
- Shared Space
- Subcanal Parking



IF EVERYONE WAS FLEXIBLE AND BASED THEIR TRIP ON REAL-TIME CIRCUMSTANCES...

3.3.2 Perspective II

This scenario is based on the premises that people do not necessarily always want to travel in the same manner. They use smartphone apps to decide which route they will take and what modality they will use based on what is convenient at that time and place.

Mobility

Mobility completely changes because of smartphones. People find out which modalities they are going to use by consulting applications that specialise in (multimodal) travel. These applications take into account the location of modalities owned by its users through GPS transmitters.³⁷ They also take into account the location of public transport stops and AV- and bicycle-sharing programmes. The apps can optimise routes based on different criteria such as travel time, price, ecological footprint of travel, route attractiveness, degree of crowdedness, or safety. This leads to personalised advice which always gives the best travel advice for the occasion.

Delivery Logistics

AVs owned by transportation companies have a special temperature-controlled compartment in the back which can be opened with a smartphone after

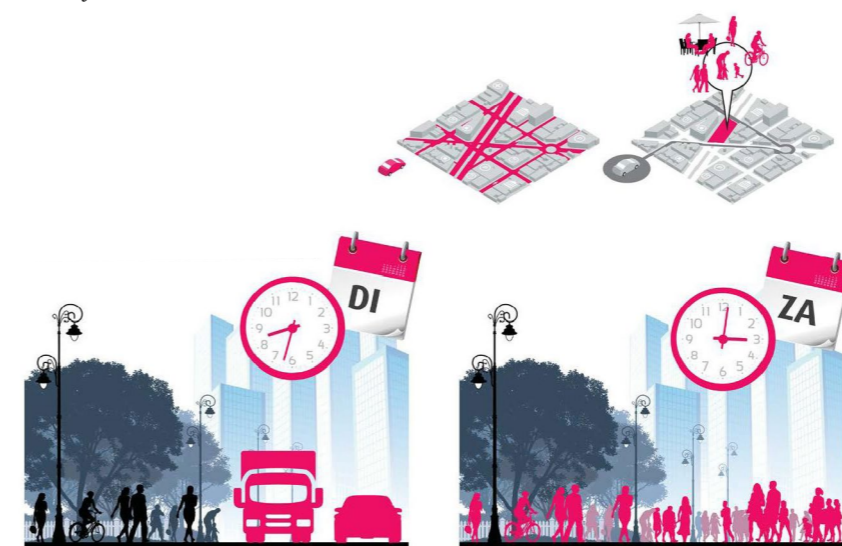
authorisation from the transportation company. This allows the vehicle to transport people, goods or people and goods at the same time. Because of the temperature control the compartment can also be used for delivery of food and other spoilables. For non-urgent deliveries, neighbourhood centres have been introduced which function as a place where people pick up packages, drop off packages, and drop off their recyclables and garbage. This allows for efficient transportation. Vehicles both drop off packages and take back garbage and never drive without cargo. Residents can use a smartphone application to manage the logistics of all their flows of goods.³⁷

Infrastructure

Because people base their travel on advice based on real-time situations, streets are made accessible and inaccessible to AVs at different times by the municipality.



³⁷ Smartphone applications for travel and logistics of goods can help optimise urban mobility.



³⁸ Time-dependent infrastructure can help manage traffic flows.

AVs automatically adapt and change route as soon as a road is made unavailable.³⁸ These time-dependent roads, for example, allow the municipality to remove AVs from residential areas during off-peak hours, when the main roads have enough capacity.

Street Life

To stimulate a decrease of car ownership, the municipality offered residents the opportunity to help redesign parking spaces next to their house if they gave up their parking permit. This has led to diverse streets with all kinds of new functions such as urban gyms, barbecue spots, small terraces, micro parks, and bicycle parking.

Society

Street life has increased and improved. Residential areas are more lively and pedestrians and cyclists are no longer bothered by bulky cars. More people than ever are using public transport because it has become so easy to use. Bicycle use and walking have also increased and this has brought back many qualities to the city. Logistics nodes have become important meeting points where neighbours can meet up and discuss day-to-day life over a cup of coffee while picking up their groceries and dropping off their garbage.

Discovered Instruments

- Multimodal App
- Logistics App
- Multi-Use Vehicles
- Logistics Node
- Time-Dependent Infrastructure
- Bicycle Share Smart Lock
- Bicycle GPS Transmitter

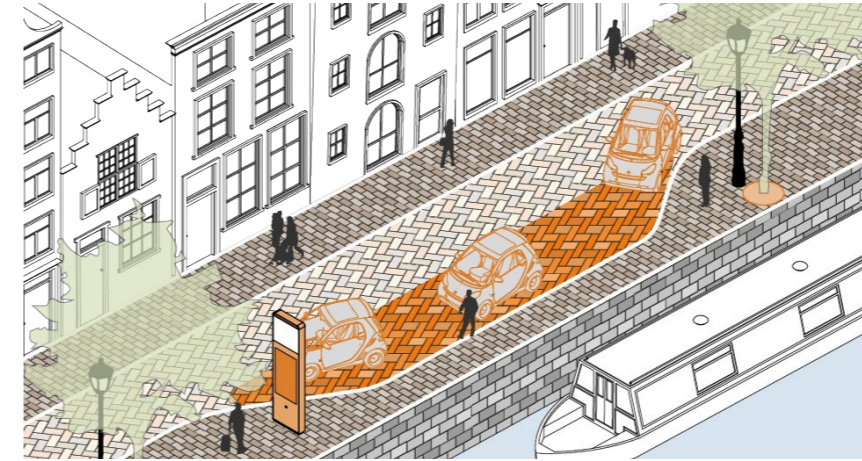


3.3.3 Perspective III

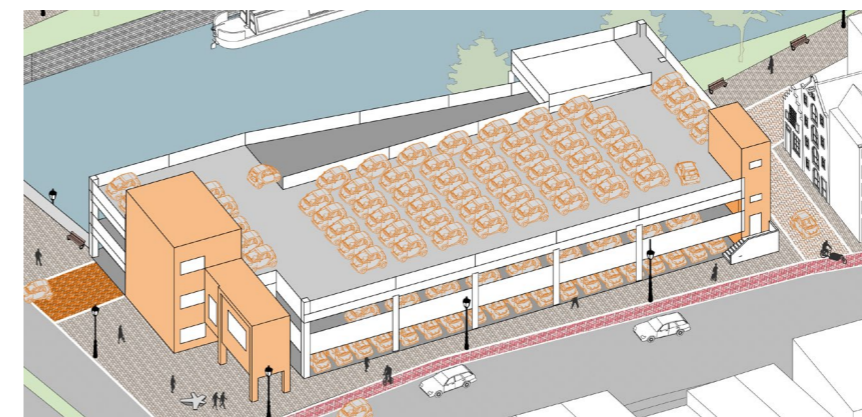
This scenario shows a future in which tourists dominate the city centre of Amsterdam and all privately owned vehicles, taxicabs, buses, and trams have been replaced by on-demand vehicles provided by transportation companies.

Mobility
 Mobility has been severely simplified by removing taxicabs, buses, trams, and privately owned vehicles from the city centre. All trips are made either by bicycle, on foot, or by an on-demand AV which is owned by a transportation company with the exception of one tram line for tourists between touristic hotspots. The AVs can be summoned from hop-on-drop-off-spots (hodosses) and can drive to any other hodos in the city. The hodos network is laid out approximately over a grid of 300 by 300 meter so a hodos is always within short walking distance and often within sight. The hodosses guarantee efficient use of space and optimal flow of traffic by removing moments of stopping from the road. They are easily recognisable because they are outfitted with a coloured road surface and a totem which can be used to summon vehicles and stay up to date on its arrival time.³⁹

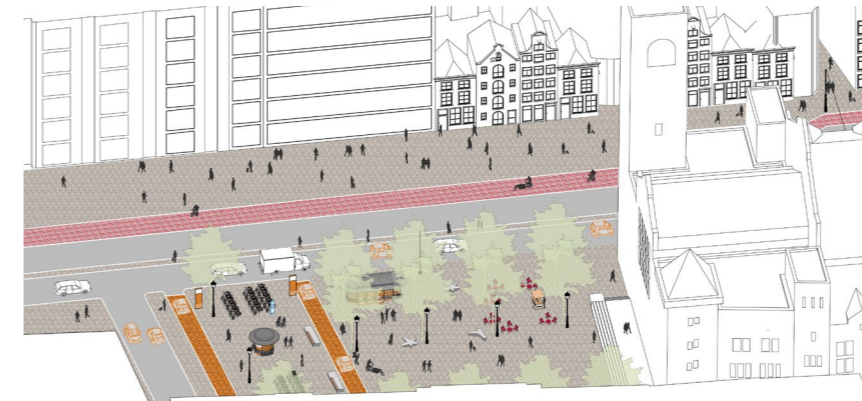
Park & Charge
 Because the AVs are all part of a centrally owned fleet, they are interchangeable and as a result they are parked in a row from which the vehicle in front drives away when a vehicle is summoned and the rest of the vehicles move one place forward. This means parking is much more efficient. While waiting to be summoned, vehicles can be charged through induction and because the fleet is centrally owned, its batteries can be used to store excess green energy during off-peak hours, especially at night when wind energy generation is peaking while mobility is at a low point. This park and charge system has been retrofitted into existing indoor parking facilities by simply adding inductive charge layers on top of existing floors.⁴⁰ This decreases the floor height slightly but because people no longer have to enter the parking hubs, this does not form a problem.



³⁹ A hodos allows efficient flow of traffic while reducing required parking space.



⁴⁰ A Park & Charge hub charges accomodates and charges a fleet during off-peak hours.



⁴¹ Hotspots at busy spots such as the Beursplein accomodate large amounts of traffic.



⁴² New developments such as terraces have popped up in place of former parking spots.

Hotspots
 To facilitate tourists, hodosses have been implemented at important touristic spots. Here, more people can summon AVs and be dropped off at the same time. These hotspots can be configured in different manners, such as on a square or in line. They allow high numbers of drop offs and hop ons in an efficient manner.⁴¹ The hotspots have been outfitted with extra elements such as a card-machine where tourists can join the system, waiting space, small-scale commerce, and iconic decorations such as statues of local heroes which give identity to the hotspots.

Roadside Developments
 Parking has become much more efficient, AVs take up much less space both because they can park more precise and because they can park in a row rather than having to be accessible individually. Furthermore, because the system needs only one vehicle for every five that were used before the transition, most parking has been moved to indoor garages. This has led to redevelopment of the roadside. Commercial functions have been placed along roads along with many other facilities such as micro parks, urban nature, bicycle parking, public seating, and fishing spots along the canals.⁴²

Society
 Even though many public functions have been implemented along roads, public life is not what it used to be. Many people move around exclusively by AVs because they are cheap, fast, reliable, and people have become unable to find their way by themselves. Furthermore, street life has become boring because capsular movement* has become the norm and this does not allow for interaction between people.

- Discovered Instruments**
- Car Fleet as Battery
 - Centrally Owned Fleet
 - Hodos
 - Park & Charge Hub
 - Replace Tram with AVs
 - Tourist Tram Line

* Translated from the Dutch term 'capsulaire versnelling', coined by Dutch philosopher Henk Oosterling (2008). Capsular movement indicates moving around in an enclosed 'bubble' which separates people from their surroundings. A car is an example of this but AVs will facilitate capsular movement much more dramatically.



3.3.4 Perspective IV

This scenario is based on a future in which climate change has motivated governments to heavily discourage motorised traffic. This has caused people to live much more local. The municipality of Amsterdam has banned cars from the city centre altogether, further stimulating local lifestyles.

Mobility

People move around with public transport, bicycles, and on foot. The tram network has been expanded with a few lines and a new subway line reaching from the centre to the western part of town has been implemented as well. Though public transport has become more popular, cycling and walking have skyrocketed in popularity. Properly dimensioned networks for both walking and cycling accommodate the new traffic flows perfectly and the removal of cars from the centre makes the experience of walking and cycling feel more safe and relaxed for residents and visitors alike.

Supply

Because the city is no longer accessible to cars, shops are supplied over the canals by autonomous boats. Packages for residents are brought to distribution points by the boats from which they are delivered by postmen assisted by

delivery assistance vehicles which carry the packages and automatically follow the postman, guided by self-driving technology.⁴³

Edge Nodes

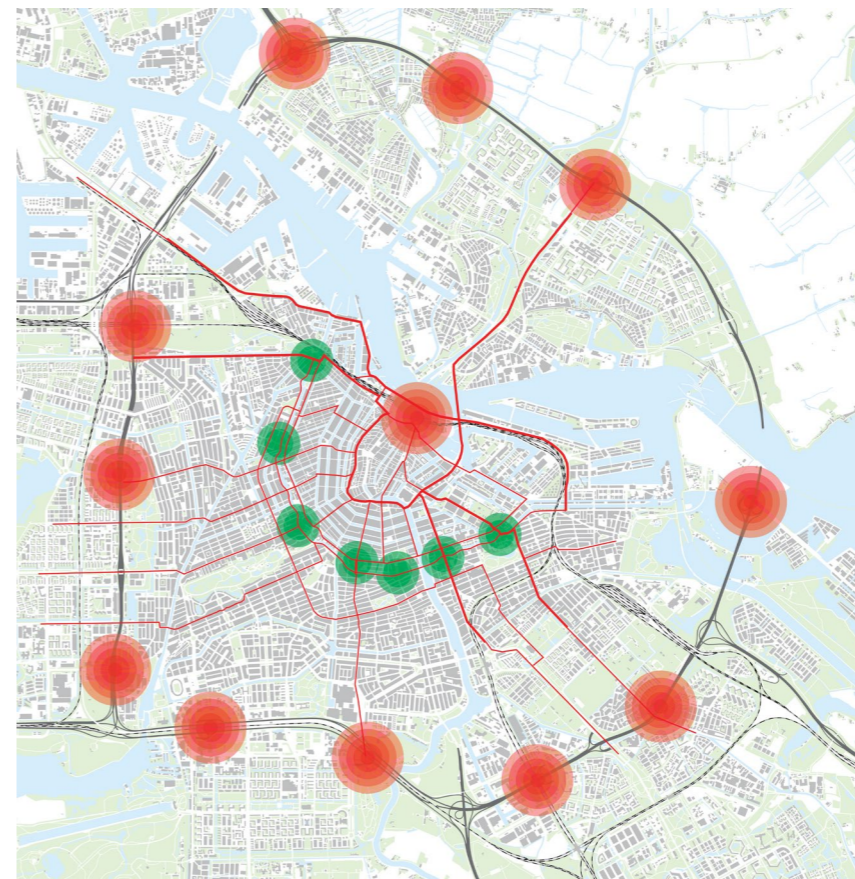
At the edges of the city centre and at the A10 ring road, infrastructural multimodal nodes smoothly facilitate intercity travel. The edge nodes guarantee smooth transfers between train, subway, tram, AV, and bicycle.⁴⁴

Bicycle Infrastructure

Bicycle infrastructure can easily handle peak bicycle traffic. Because of the lane width, tourists riding a bicycle for the first time, daredevil Amsterdammers, and the elderly on electric bicycles can all share the same lane without much problems. Much space opened up by removing cars and thus car parking from the city centre has been transformed into bicycle parking. The city has also implemented



⁴³ Delivery assistance vehicles can be used for supplying stores and home deliveries.



⁴⁴ Multimodal nodes can facilitate smooth transfers between different modalities.

a bicycle rental programme which makes it possible to rent bicycles throughout the city.

Emergency network

While AVs are banned from the city centre, some exceptions have been made. Emergency vehicles such as those owned by the police, and the fire department have been granted special access. This access is integrated in the vehicle and automatically detected by the city centre's infrastructure, which responds by opening up to the vehicles in question.

Society

The local lifestyle people live has created more lively neighbourhoods with stronger social networks. The centre's residents have become healthier because of the car ban. They no longer breathe polluted air, no longer experience stress caused by car noise, and get more physical exercise because they walk and cycle more often. The centre's society has lost some of its diversity though because car-dependent residents have moved elsewhere.

Discovered Instruments

- Delivery Assistance Vehicle
- Supply over Water
- Autonomous Boat
- Multimodal Node
- Bicycle Parking
- Bicycle Sharing Programme
- Conditional Access Road



CATALOGUE OF INSTRUMENTS

“A pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem in such a way that you can use this solution a million times over, without ever doing it the same way twice.”

Christopher Alexander (1977)

The findings from the scenarios have been properly catalogued to make them usable during the design phase. To create a catalogue, an approach has been created based on 'A Pattern Language' by Christopher Alexander (1977). The pattern language aims to make certain solutions for problems replicable. While Alexander's invention has been used as a starting point, the catalogue presented here deviates from the work of Alexander in both its form and application. Rather than trying to find the optimal solution for a specific problem, the catalogue presented here merely aims to present possible instruments for improving the built environment, either directly or combined with other patterns. The unifying factor in this catalogue is that all instruments are made possible by automated vehicles or become more interesting when combined with automated vehicles. In the next section, all instruments that were derived from the scenarios will be elaborated upon individually. They will first be explained and their relation to automated vehicles will be clarified. After that, precedents will be discussed which help explore the instruments. Using the information obtained from analysing these precedents, an explanation will be given on how each pattern can be implemented in the centre of Amsterdam. In some cases, a generic implementation strategy will be discussed which can be helpful when applying the instruments to other cities. Finally, the advantages and disadvantages of the instruments will be discussed. In section 4.3, a syntax will be provided for the use of the catalogue. This syntax is provided in the form of a diagram showing different interactions between the instruments. Subsequently, clusters are taken out of this diagram that show interacting groups of instruments. These clusters can form a base for the design and thus they will shortly be discussed in terms of how they interact and what these interactions can achieve.

4.2.1 Priority Lane

Theory

A priority lane does exactly what one would expect. It prioritised its users, meaning that people using a priority network theoretically never have to stop. Priority lanes can be imagined for any modality. In the context of this project, priority networks can be implemented for pedestrians, cyclists, and automated vehicles. While priority networks are not made possible solely by automated vehicles, their usefulness increases upon the arrival of automated vehicles. Because automated vehicles can concert their arrival time at intersections, they can maintain a constant speed while allowing other modalities the same luxury.

Precedents

Priority lanes have been implemented under many conditions in many different contexts. Amsterdam's *plusnetten* are a notable example here because they focus specifically on Amsterdam (Gemeente Amsterdam, 2013a). The *plusnetten* are a concept showing which modalities are prioritised in which streets.⁴⁵ They serve as a starting point for future developments, i.e. when a street is transformed, the *plusnetten* show which modality should be prioritised in the transformation. The *plusnetten* respond to local needs, for example, in shopping areas, where pedestrians are prioritised. Each *plusnet* is positioned according to a set of criteria, creating a fine grained network which serves each modality according to its needs while guaranteeing optimal flow of traffic for other modalities. While the *plusnetten* provide an excellent starting point for designing priority lanes, automated vehicles have different needs than regular cars and as such, the placement of priority lanes can differ from the placement of the *plusnetten*.

Another project that can serve as an example is Copenhagen's PLUSnet project, which is planned for 2025. It is similar to Amsterdam's *plusnet* for cyclists but notably includes *bicycle superhighways*. Furthermore, the PLUSnet project aims to widen important traffic arteries for cyclists, to add bicycle tunnels and bridges where necessary, and to improve coherence of the network (City of Copenhagen, 2011).^{46,47}

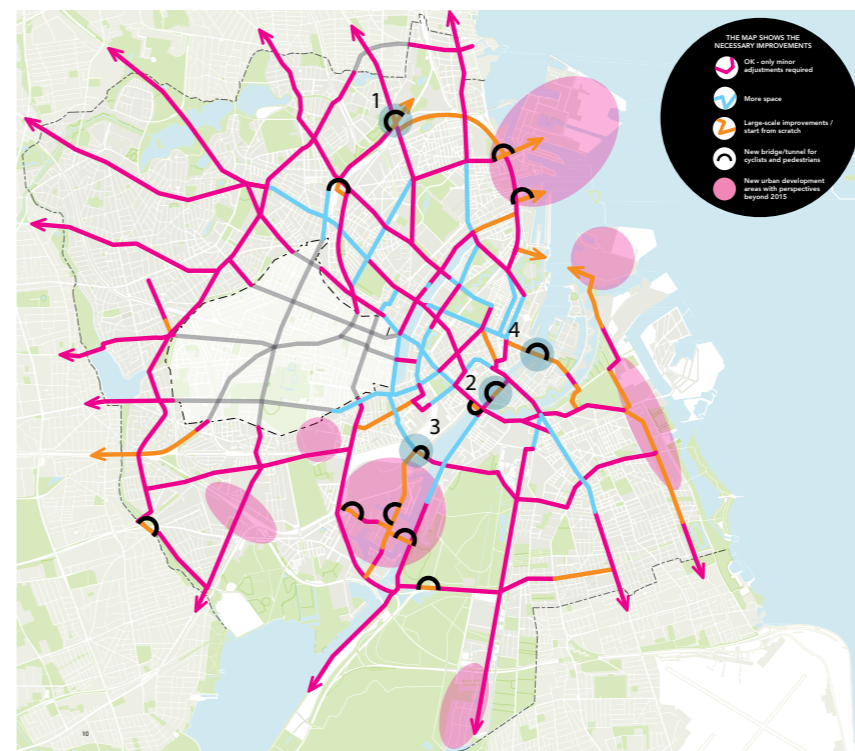
A final precedent that has been studied is the car-free promenade running around Münster's city centre in a ring shape. The promenade features priority lanes for cyclists and pedestrians. The ring connects the most important sights of the city and forms the most important connection through the city



⁴⁵ Amsterdam's plusnetten aim to give space to modalities where they need it most.



⁴⁶ This bicycle route in Copenhagen fully prioritises cyclists.



⁴⁷ Copenhagen's PLUSnet project map showing future network interventions.

for both cyclists and pedestrians (“Münster is well worth seeing”, 2016).⁴⁸ The success of the promenade lies in minimisation of intersections and optimisation of crossing speed at intersections through the implementation of underpasses and favourable traffic lights.

Implementation

Priority lanes can be implemented on many different scales, they can serve as national, regional, or local connections. Because this project focusses on Amsterdam’s city centre, implementation criteria will be discussed for a highly urbanised context. Criteria for implementation differ for different modalities. Placement of a priority network for pedestrians requires a spatial analysis of area functions, i.e. pedestrian priority networks are required in shopping areas because customers primarily move around on foot. Placement of a priority network for cyclists requires an analysis of wayfinding patterns in the form of paths, edges, districts, nodes, and landmarks (Lynch, 1960). Here, paths, nodes, and landmarks can be discovered by looking at current bicycle traffic densities, tourist densities, and the position of streets within the network, i.e. paths corresponding to streets positioned central in the network. Edges and districts correspond to structural elements such as rivers and roads that are hard to penetrate. Because Amsterdam’s centre already features an extensive bicycle network, the placement of bicycle priority lanes will have to correspond largely with current patterns of use to avoid unnecessary confusion. Finally, placement of a priority network for AVs requires an analysis of area functions. Optimally, AV priority networks need to steer clear of predominantly residential areas and areas which are used primarily for shopping. Furthermore, the network needs to connect the city’s important (touristic) sights. Notably, the AV priority network does not need to adhere to the wayfinding principles provided by Lynch (1960) because AVs do not need input from their surroundings to decide their route as they receive their information from an external communications network. All three networks require an analysis of street widths; priority networks require a minimum width and streets must be able to accommodate this width if a priority network is to be placed in them.

Pros

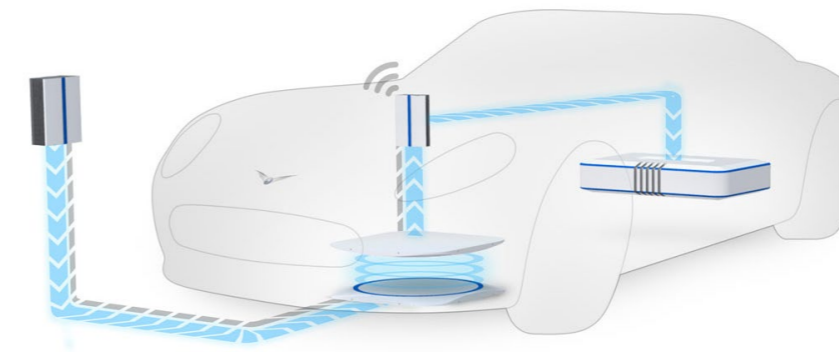
- Improves traffic flow.
- Responds to local requirements.
- Can be implemented independently.

Cons

- Large intervention.



⁴⁸ A bicycle promenade in Münster inaccessible to cars stimulates bicycle traffic.



⁴⁹ Vehicles can be charged through induction.



⁵⁰ Wireless charging station by Plugless Power.



⁵¹ Concept for wireless charging through a road surface by Foster + Partners and Nissan.

- Might create conflicting intersections which need tailor-made and expensive solutions.

4.2.2 Inductive Charging Road

Theory

An inductive charging road is able to wirelessly charge the battery of an AV through electromagnetic induction. Currently, the technology exists to charge vehicles this way while they are parked (Audi, 2015; Plugless Power, 2016; Primove, 2015)^{49,50} but research is already being conducted on creating a road which charges vehicles while they drive (Mearian, 2015). While this principle can be used with non-automated electric vehicles as well, automated vehicles will make implementation easier. Firstly, because they drive much more precise and can thus improve energy efficiency, and secondly, because automated vehicles are likely to be shared (Johnson & Walker, 2016), which incentivises the ability for cars to be able to drive without having to stop for charging. While automated vehicles improve the usefulness of inductive charging roads, it works the other way around as well. Charging vehicles through induction can ease the use of electric vehicles and thus be an important step in introducing electric automated vehicles to the public.

Precedents

Nissan and Foster + Partners have explored the possibilities of an inductive charging road in the project ‘Fuel Station of the Future’ (Foster + Partners, 2016).⁵¹ They suggest transforming parking space into wireless charging stations which are connected to privately owned renewable energy sources such as rooftop-mounted solar panels. In their concept, vehicles can charge when parked and the energy stored in the vehicle’s battery can then be used for driving and powering the home or office of its owner. The synergy between inductive charging, automated vehicles, and renewable energy is an important one, which does not necessarily correspond with the objectives of this graduation project but can be considered an additional benefit regardless.

Implementation

Inductive charging roads can be implemented in two notable ways, as parking spots and as roads. Because implementation can be expensive, the density of charging facilities should be minimised while maintaining a density of facilities that can guarantee continuous driving. In the context of Amsterdam’s centre this means that main arteries need to be outfitted with inductive charging while the neighbourhood streets

can be left out. Additionally, parking facilities can be outfitted with inductive charging to make sure AVs are also charged when only short distances are travelled which do not pass the main arteries of the network.

Pros

- Much more convenient than gasoline stations or current charging points.
- Less visual clutter than current charging facilities.
- Can theoretically keep vehicles driving until they or their batteries need to be replaced.

Cons

- Expensive.
- Less energy-efficient than cabled charging points.

4.2.3 Digital Road Surface

Theory

Digital road surfaces are road surfaces that can function as a digital screen. The content of the screen can be updated in real-time and can respond to its surroundings.^{52,53} This allows digital road surfaces to communicate information to observers. Such information includes the possibility to cross a road, the approach of a vehicle, and the speed at which a cyclist needs to travel in order to catch a green wave. Because of these possibilities, digital road surfaces can help optimise traffic flows, prevent waiting at intersections, and help avoid collisions.

Precedents

The Idahoan firm Solar Roadways has created a pilot installation of an adaptable modular digital screen surface (Solar Roadways, 2016).⁵² Their digital road has the additional benefit of generating energy. The generation of energy falls outside of the scope of this project but can present an additional benefit. The modularity of the system provides easier maintenance and as such can be important when implementing a digital road surface.

BIG and the Audi Think Tank have explored the idea of digital road surfaces combined with AVs (Ingels et al., 2010).⁵⁴ They suggest a full digital surface which shows the location of pedestrians, cyclists, and AVs, shows small areas around trees which cannot be accessed by automated vehicles, and can adapt to the changes of urban life in real-time.

Implementation

While implementation of a full digital surface allows the most flexible use and most precise communication of uncommon messages, it would be very expensive to construct and maintain and it would also



⁵² Solar Roadways pilot installation of a digital road surface that can be updated in real-time.



⁵³ Digital infrastructure responding to the movement of a user.



⁵⁴ Visualisation of a square outfitted with a digital road surface made by architectural firm BIG in cooperation with the Audi Think Tank.

have notable negative impacts on city life. Research shows that over-illumination and erroneous spectral composition of light may cause increased headache incidence, fatigue, medically defined stress, and increase in anxiety (Ayers et al., 2001; Burks, 1994; Knez, 2001). To avoid this, the area covered by digital road surfaces needs to be minimised. This can be done either by exclusive placement of digital surfaces at critical spots such as busy intersections or by reducing digital road surfaces from full surface to just a digital strip. In the context of Amsterdam's centre, the latter is preferable because it is able to provide the means for flexible road crossing, speed optimisation for cyclists and a warning system throughout the entire centre.

Pros

- Adaptive.
- Works well with same real-time information that is already used for AVs.
- Can optimise traffic flows.
- Can prevent waiting at intersections.
- Can help prevent collisions.
- Can replace most signs and traffic lights that are currently in use.

Cons

- Might cause negative effects related to over-illumination and erroneous spectral composition of light.
- Is energy-intensive.

4.2.4 Convoy Driving

Theory

Automated vehicles communicate with each other and can thus coordinate speed, acceleration, and braking to avoid inertial impedance (Fagnant & Kockelman, 2015; Musk, 2016). This allows them to drive in convoys very efficiently. Convoy driving is more energy efficient and leaves gaps between convoys which can be used for crossing.

Precedents

The Italian company Next has envisioned a modular automated transportation system which is linkable and can thus function as a really efficient convoy (Next, 2016).⁵⁵ This system, while being the most efficient form of convoy driving, relies on the ubiquity of one vehicle type. As such, it can be a valuable option for transportation and lease companies but not for privately owned vehicles.

Implementation

In the centre of Amsterdam, convoy driving is especially useful at roads which would otherwise be hard or impossible to cross. Making convoy driving mandatory for these



⁵⁵ Linkable modules can drive efficiently while providing interaction between users of different modules.

roads can provide a solution. In practice this would mean that vehicles would only be allowed to enter these roads after specific intervals. Vehicles can be made aware of these intervals, allowing them to anticipate their arrival time at the road entrance.

Pros

- Requires no physical transformations.
- Energy efficient.
- Creates more pedestrian crossings in real-time.

Cons

- Only makes sense at specific traffic densities.

4.2.5 Shared Space

Theory

Shared space is an urban design approach largely developed by Dutch traffic engineer Hans Monderman (Hamilton-Baillie, 2004). It aims to give greater priority to vulnerable road users and to minimise segregation between different modes of transport by removing kerbs, road surface markings, and signage (Pharoah & Russell, 1991). The concept, paradoxically, aims to make roads safer by removing safety measures. The success of this concept is due to the risk compensation theory, which dictates that people pay more attention when they perceive their surrounding as potentially unsafe (Adams, 2010). Automated vehicles can further improve the functioning of shared space because they are not prone to human error and can thus interact with other modalities more safely and efficiently.

Precedents

Shared space has been implemented many times. Three examples have been studied and will shortly be discussed. The first example is *Skvallertorget*, a major intersection in the Swedish town of Norrköping.⁵⁶ The intersection, which used to be controlled by traffic lights and signs was remodelled in 2004 because a university faculty relocated close to the square (Hamilton-Baillie, 2008). To cope with increasing volumes of pedestrians and cyclists, the intersection has been turned into a coherent plaza which has been stripped of signs, traffic lights, and height differences. Engineering firm Tyrens has monitored the intersection for three years and has concluded that traffic speeds have reduced, delays and congestion have fallen, and pedestrian volumes have increased (Hamilton-Baillie, 2008). Furthermore, surveys among drivers, cyclists, and pedestrians show that there is a high degree of satisfaction among users (Hamilton-Baillie, 2008).



⁵⁶ Shared space in the Swedish town of Norrköping.



⁵⁷ Shared space behind Amsterdam's central station.



⁵⁸ Shared space behind Amsterdam's central station.



⁵⁹ Shared space in Auckland's Fort Street.

Another precedent is the shared space that has recently been introduced in Amsterdam behind the central station.^{57,58} The shared space accommodates traffic flows of pedestrians, mopeds, and cyclists and includes the busy intersection between the connection running along the central station and the disembarkation space of the ferry. Before the shared space was introduced, a measurement counted one collision and fifteen incidents in three hours. After introducing shared space, two collisions and twenty incidents were counted over a period of 38 hours. Alderman Pieter Litjens has concluded that the amount of conflicts has, as a result of introducing shared space, been reduced by a factor of eight (Kruyswijk, 2016a).

The last transformation that has been studied is that of Auckland's Fort Street Area.⁵⁹ The area used to be a somewhat neglected part of downtown, mostly used to pass through to other places. In 2008 it was identified as having significant potential for transformation into a more user-friendly and attractive environment. A report evaluating the transformation found the following impacts: 91% of stakeholders and users were highly complimentary about the new shared space, 75% of property owners determined that being close or adjacent to the shared space was valuable, pedestrian traffic increased by 50% during peak hours, and vehicle presence decreased by 34% (Auckland Council, 2012). Notable for the Fort Street area is that street profiles feature a shared zone in the middle, an activity zone, and a pedestrian only zone at the edge. This allows extra fragile users such as the elderly and blind people to steer clear of the shared surface.

Implementation

Shared space does not work well under all circumstances. First off, it requires vehicular traffic speeds to be lower than that of normal streets. Karndacharuk, Wilson, and Dunn (2014) state that the speed disparity between motorised vehicles and low-speed users is one of the most important factors in determining the safety and success of shared space. This means that shared space is not a viable option for high capacity traffic arteries. Secondly, enough space is needed for users to be able to dodge other users (Kruyswijk, 2016a). Based on these criteria, shared space can be implemented in Amsterdam's centre in the neighbourhood streets and in shopping areas with moderate amounts of shoppers. Ideally, streets should feature a pedestrian only zone at the edge to accommodate blind people, the elderly, and other users who prefer not to use the shared space.

Pros

- Safe.
- Less visual clutter.
- Stimulates increased pedestrian volumes.
- Stimulates retail spending in shopping areas.
- Stimulates use of cognitive functions.

Cons

- Does not allow large volumes of car traffic to pass through.
- Potentially less safe for blind and deaf people.

4.2.6 Subcanal Parking

Theory

Parking consumes a lot of space. Creating parking garages under canals can save public space because it makes use of otherwise unused space. It removes vehicles out of sight, allowing more pleasant sights to reveal themselves. Subcanal parking facilities can also serve as water storage tanks during peak weather events. While subcanal parking is already possible, automated vehicles will improve their functioning for two reasons. The first reason is that automated vehicles can park themselves, as such the parking facility does not have to be accessible for humans, which means it can be designed much more efficiently. This can cut costs of an otherwise very costly undertaking. The second reason is that AVs are provided with information by an external source. This means that they can vacate a parking facility immediately when necessary. As such, actually using the garage as a water storage tank becomes much easier.

Precedents

A subcanal parking garage under the Boerenwetering canal is already under construction.^{60,61} The garage will provide 600 parking spots and 60 bicycle storage spots. The municipality of Amsterdam notes the location of the subcanal garage has been carefully selected to prevent unnecessary damage and additional costs (Gemeente Amsterdam, 2016b). From this, the conclusion can be drawn that subcanal parking can be applied sporadically but is not a viable option for all of the city's parking requirements.

Implementation

Subcanal parking has some major benefits but also has some important downsides. One of which is that they are very expensive. Another one is that constructing them is a huge undertaking. As such, subcanal parking might be a valid option for areas that do not form an important infrastructural connection or an important touristic spot.



⁶⁰ Planned parking garage under the Boerenwetering canal.



⁶¹ The parking garage under the Boerenwetering canal under construction.

Pros

- Efficient use of space.
- Removal of vehicles from street level.
- Multifunctional as water storage.
- Could double as bicycle parking facility.

Cons

- Major construction project.
- Expensive.
- Construction could damage surrounding structures.
- Additional parking facilitates car use.

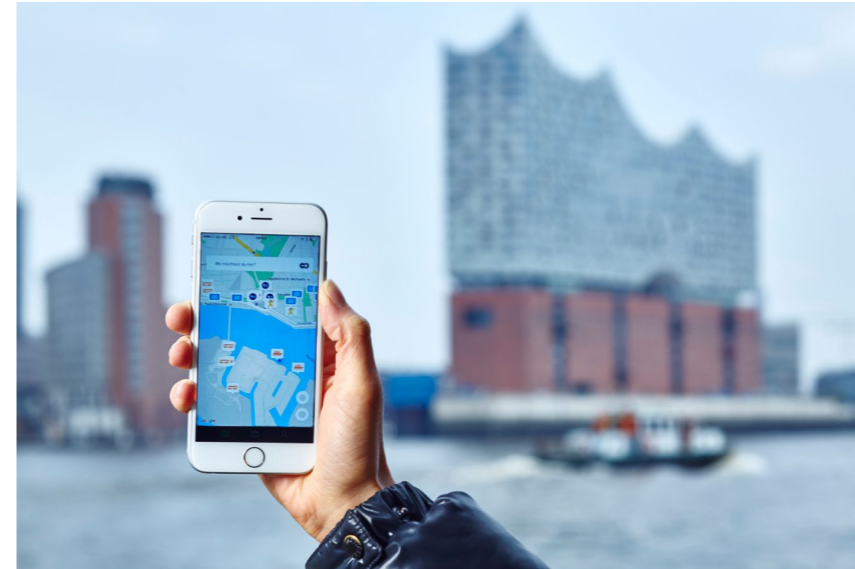
4.2.7 Multimodal App

Theory

Every modality has its own strengths and weaknesses. Depending on the context, a different way of travelling can serve the needs of a traveller in the optimal way. This, by extension, means that switching between different modalities can be a helpful way of optimising the trip with respect to specific criteria. Multimodal travel can, in theory, optimise cost, comfort, attractiveness, duration or other aspects of trip by combining the use of different available modalities. The crux here is that finding this optimal combination is a seemingly wicked problem. Contexts change all the time and 'optimal trip' is a subjective term. Multimodal apps, however, might be able to solve the problem. Media platform CityLab has called the smartphone the most important transportation innovation of the decade (Goldwyn, 2014). Research has shown that availability of real-time travel information affects the choice of modality users make (Brazil & Caulfield, 2013; Tseng, Knockaert, & Verhoef, 2013). While companies such as Google and Moovel are already working on multimodal apps⁶², the 'perfect' app is still impossible to make, mainly because car traffic is too unpredictable (Manwaring, Carter, Romijn, Van der Lans & Soetendal, 2013). Because AVs are not subject to human unpredictability, this problem becomes solvable and a perfect multimodal app becomes possible.

Precedents

Amsterdam's department of infrastructure, traffic and transport (DIVV), has commissioned a report called 'Towards a multimodal API' in which the feasibility of developing a multimodal API (Manwaring, Carter, Romijn, Van der Lans & Soetendal, 2013). The report concludes that creating a multimodal app requires some data that is unavailable at the time of writing the report. This data mainly relates to the unpredictability of cars and taxicabs but also includes unpredictability and absence of data about public transport (Manwaring, Carter, Romijn, Van der Lans &



⁶² The Moovel app, which is currently in beta testing in Amsterdam, aims to integrate all forms of mobility into one app.

Soetendal, 2013). While the unpredictability of cars and taxicabs can be solved by AVs, the unpredictability and absence of data about public transport requires close cooperation between transportation companies and developers of multimodal apps.

Implementation

Adequate implementation would integrate all different modalities. This means that cooperation is required between the developer and transportation companies. If the municipality takes an active role in development of a multimodal app, additional benefits can be reaped. First, the app can provide important travel data that can assist in infrastructural development. Second, the app can be used for crowd control. Third, the city could more easily provide changed travel information during events. And last, the app can be used to promote new forms of travel when they are introduced. As such, it is recommended that the municipality takes an active role in the development and management of the app.

Pros

- Convenient for users.
- Stimulates use of different modalities.
- Easy to implement new means of transportation.
- Useful for traffic distribution when operated by the municipality.
- Efficient use of resources.
- Gives insight in movement through the city.

Cons

- Needs an initial investment.
- Works better when implemented nationally or even globally.
- Does not stimulate using cognitive abilities for wayfinding.

4.2.8 Logistics App

Theory

A large portion of vehicular trips in Amsterdam's centre is related to logistics. Supply of stores and home deliveries generate vehicular traffic and thus it is important to take logistics into account for this graduation project. Currently, logistics are managed very inefficiently. Vehicles often drive around while not at full capacity or even while empty. A logistics app can support more efficient logistics, especially when combined with automated vehicles, which can theoretically transport goods without human assistance. A logistics app can furthermore make logistics more convenient for consumers by showing them exact delivery times and giving them the power to change these times in real-time.⁶³ This further assists in making logistics



⁶³ A smartphone application for managing logistics can contribute to efficient use of resources.

more efficient as it will reduce the number of times a delivery has to be carried out more than once because a consumer is not at home at the time of delivery. Logistics apps can thus contribute to a more efficient use of resources and a reduction of traffic.

Implementation

Implementing the application would require close cooperation between post offices, couriers, and software developers. If done by a municipality, a logistics app can help mediate peak traffic densities and optimise use of resources rather than exclusively optimising cost. As such, active involvement of the municipality in development of the app is recommended.

Pros

- Can help mediate peak traffic.
- More flexible mobility of goods.
- More efficient use of resources.
- User-friendly.

Cons

- Complex to implement.
- Might stimulate more home shopping.

4.2.9 Multi-Use Vehicle

Theory

Because AVs can drive by themselves, they can be used for transporting both people and goods. Vehicles can for example transport people during the day and goods during the night but it is also possible to transport people and goods simultaneously.

Precedents

German firm Rinspeed has recently presented its concept car "Oasis", which boasts a code-protected drawer that can be both cooled and heated (Rinspeed, 2016).⁶⁴ This allows vehicles to deliver consumable goods while transporting people at the same time.

Implementation

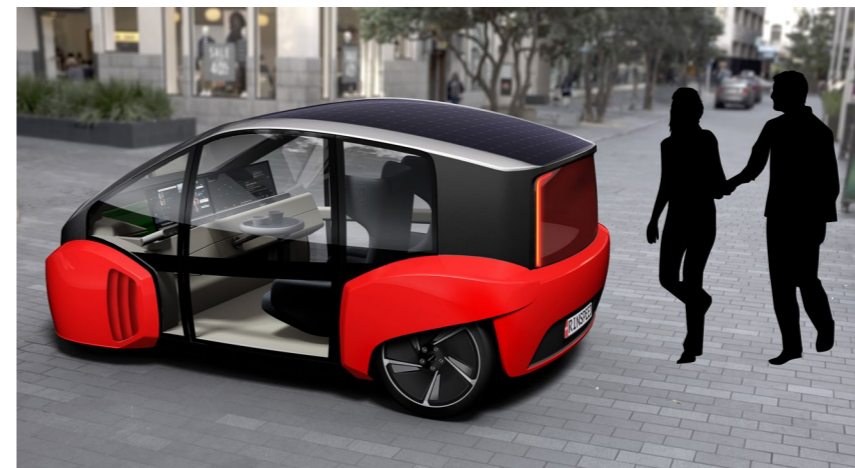
Using this kind of multi-use delivery vehicles requires vehicles to be well-informed about the destination of goods, people, and other vehicles. If it is implemented so that the vehicle is either transporting people or goods, it will probably lead to more mobility. Effective logistics are thus required to make multi-use vehicles actually beneficial for the city.

Pros

- Can decrease traffic density.
- Can contribute to smooth logistics of delivering goods and people.

Cons

- Can increase traffic density.



⁶⁴ Rinspeed's concept car Oasis, which features a code-protected and temperature-controlled compartment that can be used for delivering goods and food.

4.2.10 Logistics Node

Theory

A logistics node can serve as a local centre for sending and delivering goods. It can double as a recycling station. This means people can drop off their garbage and take their orders back home. Delivery companies on the other hand can drop off packages and take back recyclables, this means their vehicles are driving around empty much less often. Logistics nodes thus stimulate efficient use of energy and vehicles. The node could function not just as a logistics centre but also as a neighbourhood centre. Automated vehicles can support the functioning of logistics nodes because they can supply the node in a *smart* way, allowing a fine-grained logistics system.

Precedents

DHL and PostNL have created package take-away machines which serve as a pick-up point for packages, these fulfill one function of a possible logistic node.⁶⁵ One such machine has been tested by PostNL at the train station of Almere. 89% of users reported being very satisfied or even extremely satisfied. 95% of users would use the machine again in the future (PostNL, 2014).

PostNL and the municipality of Delft have launched 'Stadslogistiek Delft'. An initiative aiming to "offer tomorrow's logistics services today" (Stadslogistiek Delft, 2015).⁶⁶ The initiative supplies retailers and other parties, distributes retail orders, and even picks up certain types of garbage. The project aims to reduce traffic in Delft's historical centre by aggregating logistics trips.

Implementation

When implementing a logistics node, a central position is favourable. However, if the node focuses solely on logistics without forming a neighbourhood centre, a peripheral location can be more beneficial. In the case of Amsterdam's centre however, nodes can be implemented close to multimodal nodes to stimulate the neighbourhood function of the node. The position of the nodes must be selected carefully in a way that it is conveniently accessible both for consumers and suppliers. In practice, this means at intersections of traffic arteries and neighbourhood streets.

Pros

- Efficient use of resources.
- Can stimulate social networks in residential areas.
- Can help reduce vehicles on the road during peak hours.
- Stimulates recycling.



⁶⁵ PostNL package take-away machine.



⁶⁶ Launch of the Stadslogistiek Delft initiative by PostNL chairwoman Herna Verhagen and alderman Stephan Brandligt.

Cons

- Takes up space.
- Requires cooperation between many involved parties.
- Would need government investment and involvement.

4.2.11 Time-Dependent Infrastructure

Theory

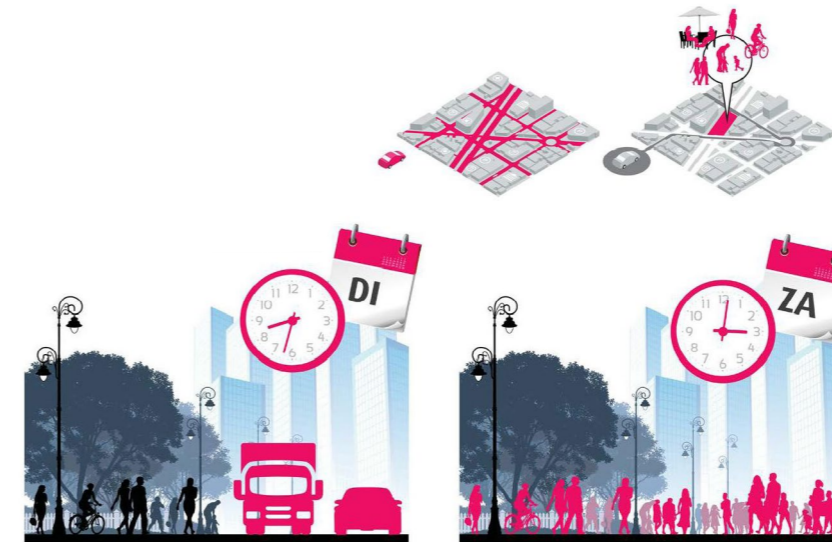
A city is a dynamic entity. It is used in many different ways at many different times and this means that changing infrastructure over time can make it facilitate different patterns of use at different times. A street can be used for commuting in the morning and evening, a market during the day, and a social gathering space during the evening. Time-dependent infrastructure already exists in Amsterdam, during running events for example, when specific streets are temporarily unavailable to cars and bicycles. Currently however, this generates a lot of disruptions because not all users are aware of this temporary change. Because AVs are automatically informed by a central source, they can immediately respond to such changes.

Precedents

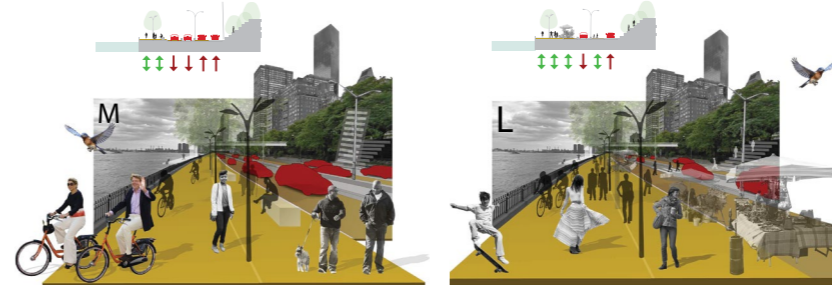
Goudappel Coffeng has explored the possibility of assigning different uses at different times to roads (Goudappel Coffeng, 2015).⁶⁷ Their project 'Flexway' aims to make optimal use of Manhattan's scarce public space by assigning different uses to infrastructural space at different times (Goudappel Coffeng, 2011).⁶⁸ Their suggestion is that New Yorkers have the ability to suggest alternative uses for the space and that they can vote on these suggestions. This means that New Yorkers decide when the space is used for recreation and what kind of recreation this will be. Such a system empowers the users of public space and creates support for the space.

Implementation

Many different implementations are conceivable, ranging from seasonal use, to weekend use, to event use, to different uses throughout the day. An important criterion for implementation is to take into account the importance of connections. Main traffic arteries need to stay accessible and back-up routes need to stay available at all times for safety and accessibility reasons. Temporal functions that can be assigned to time-dependent infrastructure can be decided upon in cooperation with residents and other involved parties such as local entrepreneurs and interest groups.



⁶⁷ Time-dependent infrastructure can be used to manage traffic flows and create new recreational spots during off-peak hours.



⁶⁸ The Flexway allows different uses of public space at different times.

Pros

- Efficient use of space.
- Responsive to patterns of use.
- Can prevent chaos during events or accidents.
- Can be used for crowd control.
- Can be used to stimulate city life in low density areas.

Cons

- Can disorient pedestrians and cyclists.

4.2.12 Bicycle Share Smart Lock

Theory

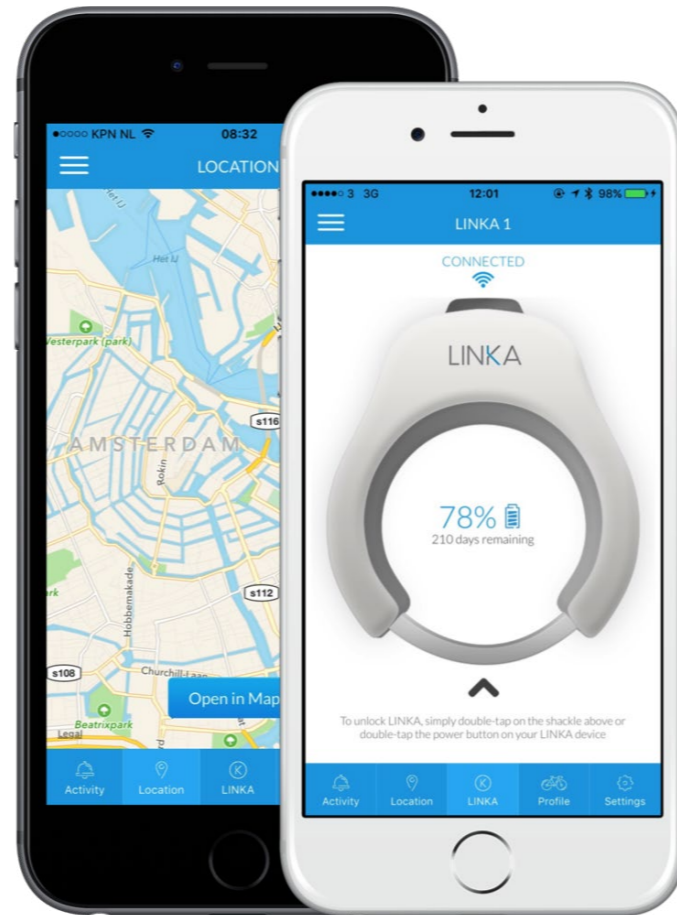
Smart bicycle locks are nothing new. Companies like LINKA are already selling them.⁶⁹ These locks open as the owner comes close to his or her bicycle. These type of locks can also be used for shared bicycles. The bicycles can be rented through a smartphone application which gets permission to open the bicycle. This can facilitate an easily accessible bicycle sharing system that does not require ubiquitous expensive storage facilities. The bicycle share smart lock is supportive of multimodal travel and only interacts with automated vehicles indirectly through multimodal apps and nodes.

Precedents

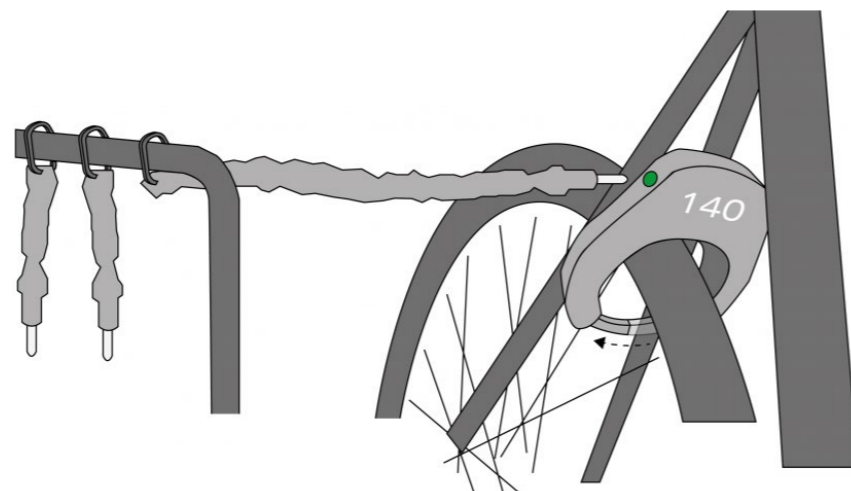
De Natuurlijke Stad has researched a smart lock in combination with a bicycle sharing programme in their plan 'Haagse Fietsen' (De Natuurlijke Stad, 2016).⁷⁰ The plan aims to reduce stray bicycles and give an impulse to bicycle usage. The plan proposes high-tech locks combined with fixed chains throughout the city which can be attached to the smart locks. This creates a system more flexible than the OV fiets because it allows bicycles to be returned not just at a small amount of fixed locations.

Implementation

To make smart locks advantageous for the city, they need to be complemented at least with a bicycle sharing programme. In this case, different possibilities are conceivable. One is to make the lock automatically register when it is locked or unlocked. This allows most flexibility for users. Another option is to place locking spots throughout the city, chains which need to be connected to the bicycle in order for the rental period to end automatically. This gives the owner of the system the power to restrict bicycle parking to certain spots. If the owner is the municipality, this will obviously lead to better control of bicycle parking and less clutter. Another possibility is to employ a combination which renders both possible but stimulates return to specific spots by financial or other means.



⁶⁹ LINKA smart bicycle lock smartphone interface.



⁷⁰ Smart lock proposed by De Natuurlijke Stad.

Pros

- Easy for users.
- Allows control of bicycle distribution.
- Reduces amount of bicycles.

Cons

- Needs an update for existing bicycle parking when used with chains.

4.2.13 Bicycle GPS Transmitter

Theory

Outfitting bicycles with GPS transmitters has several advantages. Companies such as Sherlock aim to bring GPS transmitters to bicycles to make them traceable in case of theft or loss. This is one advantage but an advantage that could be more interesting for Amsterdam is that privately owned bicycles can be traced by multimodal smartphone apps. This makes it possible for such apps to perfectly integrate bicycles into multimodal travel recommendations. The same principle can also be used for bicycles belonging to bicycle sharing programmes, integrating these better into multimodal travel. Similar to the bicycle share smart lock, a bicycle GPS transmitter only has an indirect interaction with automated vehicle through multimodal apps. Nevertheless, when used in tandem with a multimodal app and automated vehicles, accessibility can be improved through a synergy between these instruments.

Precedents

The company Sherlock is developing a GPS transmitter that can be traced through a smartphone.⁷¹ It shows that GPS transmitters can be retrofitted into existing bicycles.

Implementation

The municipality could implement GPS transmitters combined with a bicycle sharing programme and a multimodal application. Furthermore, residents can be encouraged to outfit their bicycle with a GPS transmitter and add the bicycle to their multimodal app for integration. This would also stimulate multimodal travel and bicycle use.

Pros

- More comfortable bicycle use for users.
- Can prevent stray bicycles.

Cons

- Privacy sensitive.

4.2.14 Car Fleet as Battery

Theory

More and more energy is being generated from renewable sources. The problem with this type of energy production is that it cannot be generated on demand when



⁷¹ Easily integrable GPS transmitter as visualised by Sherlock.

energy use is high. This means that it needs to be stored in batteries when energy production is high, to be used when the energy demand is high. But storing energy can be expensive when batteries have to be made exclusively for this purpose. Here, automated vehicles come into play because they are likely to be electric vehicles (Johnson & Walker, 2016), in part because car batteries are rapidly decreasing in price. Nykvist and Nilsson (2015) show that battery prices have dropped by 59% between 2007 and 2014 and predict that this trend will continue. Tesla is currently in the process of constructing a Gigafactory which is predicted to produce more lithium ion batteries annually by 2018 than were produced worldwide in 2013 (Tesla, 2015).⁷² This mass production will further reduce the cost of batteries and improve their capacity. Black and Strbac (2006) show that systems relying on wind energy require a complementary system which is able to store excess energy during peak energy generation. The Netherlands focusses on wind energy (SER, 2013) and thus requires such a complementary system. Automated vehicles can fill this position if a large enough fleet is connected to the energy grid.

Precedents

Foster + Partners and Nissan have researched what using a city's car fleet as its battery could look like and how it can change the user's experience (Foster + Partners, 2016).⁷³ Their research shows that using a car fleet as a battery for the city can make optimal use of renewable energy and even stimulate private investments into renewable energy sources. Their vision however fails to take into account the cost of energy and renewable energy sources. An alternative would be to employ a centrally owned fleet with a central charging facility.

Implementation

Implementing the city's car fleet as a battery would require ample vehicle charging facilities throughout the city. These can be placed at parking spots or in the road itself when combined with inductive charging. Furthermore, policies can be introduced to stimulate private storage of renewable energy at peak energy production, or a centrally owned fleet of vehicles can be used for storing energy.

Pros

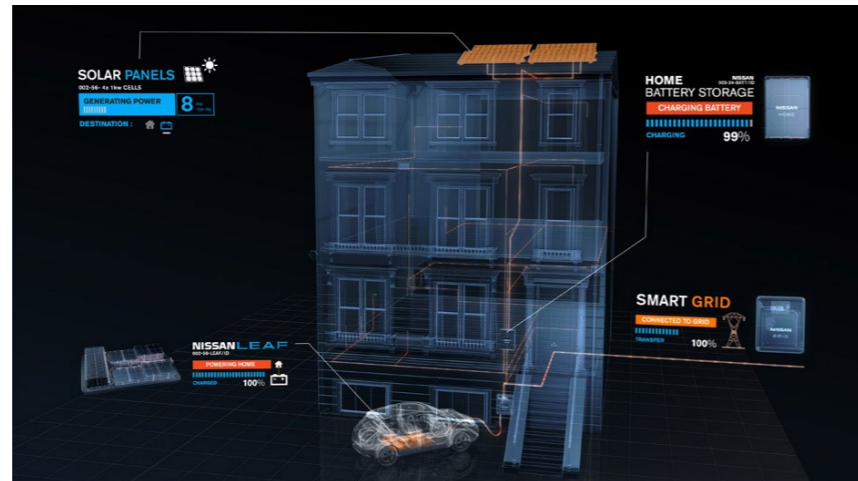
- Stimulates energy from renewable sources.
- Makes vehicle charging more convenient.

Cons

- Large scale project.



⁷² Tesla's Gigafactory.



⁷³ Synergy between electric vehicle and energy generation from renewable source conceptualised by Foster + Partners



⁷⁴ Minister of transport Irene Vorrink and alderman Brautigam make the first journey in a witkar along the Prinsengracht in Amsterdam, 1974, March 21.



⁷⁵ A fleet of vehicles owned by car2go on Amsterdam's Dam Square.

4.2.15 Centrally Owned Fleet

Theory

A centrally owned fleet simply means that a large amount of vehicles is owned by one party. This party then rents out the vehicles and offers mobility as a service to consumers. In Amsterdam, such a system was first introduced in 1974 under the name *Witkar*.⁷⁴ When all cars are owned by a central organisation, this offers many benefits for a city and its residents. First and foremost because it stimulates vehicle sharing and this can lead to a reduction in the number of vehicles in a city by 80 percent while still bringing everyone to their destination in time (Claudel & Ratti, 2015). This means much less parked vehicles, not just because there are less vehicles but also because those vehicles are driving for a much larger proportion of the time. But even when people refuse to share a vehicle, a centrally owned fleet can offer benefits. Car-buyers tend to buy large vehicles for full-family excursions which only make up a small fraction of trips. A centrally owned fleet allows users to pick a vehicle by the trip, which allows them to *right-size* their vehicle. This alone can cut energy consumption by 20 to 40% (Hopper, 2016). Another advantage lies in behavioural economics. Car ownership requires a large initial investment but allows driving at a marginal cost while a centrally owned fleet almost has no up-front cost but charges more per trip. According to Grabar (2016) this will push vehicle travel down. Finally, a centrally owned fleet can give important insights into patterns of use. It can show the municipality of Amsterdam how often and when roads are used. This data could help improve accessibility. While some companies already own a fleet and offer mobility as a service, automated vehicles can revolutionise such services because they do not require drivers and thus can pick up users autonomously rather than users having to travel to the location of a vehicle they would like to use. This greatly improves their convenience and this is considered an important criterion for any mode of travel (Filarski, 2008).

Precedents

Companies such as car2go are already offering mobility as a service by renting out vehicles.⁷⁵ A report commissioned by the municipality of Amsterdam concludes that the initial introduction of car2go in the city has had a positive impact on mobility, parking pressure, and the environment (Suiker & Van den Elshout, 2013). While car2go has made a huge step in making mobility as a service convenient, as of yet, it is not as convenient as owning a vehicle but automated vehicles might allow the final step in this direction.

Implementation

Introducing a centrally owned fleet can be done in two ways by the municipality. It can be done by introducing an AV fleet owned and operated by the municipality or it can be done in cooperation with a transportation firm. The former would be preferable in many ways because it offers the possibility for crowd control, it gives direct access to traffic data, and it allows tweaking of prices to stimulate or discourage travel by AV. The latter however, requires less maintenance by the municipality and as such can be a viable option. Transportation companies such as Uber and Lyft are already exploring AVs and will start offering on-demand mobility services as soon as possible (Kasteleijn, 2016; Zimmer, 2016). Cooperation with these companies would be preferable over giving them freedom to implement as they please because it would open up possibilities for crowd control, and would make usage data accessible to the municipality. Furthermore, strict regulations can prevent excessive AV use through the city.

Pros

- Gives insight into patterns of mobility use.
- Can facilitate crowd control.
- Can be used to encourage or discourage AV use.
- Can reduce the amount of vehicles.

Cons

- Can increase the amount of rides.
- Can make users vulnerable to companies when not owned or properly regulated by municipality.

4.2.16 Hodos

Theory

Hodos is an acronym for hop-on-drop-off-spot, it is essentially a spot where people can summon and get picked up by an AV or can get dropped off by an AV (De Waart & Nap, 2016). A hodos consists of two base elements: alternatively coloured pavement parallel to the road which vehicles can use to pick up and drop off users and a totem which indicates vehicle arrival times and can be used to summon a vehicle by users who do not own a smartphone.⁷⁶ The added value of hodosses as compared to getting picked up and dropped off at any place lies in optimisation of traffic flow. Getting in or out of an AV would strain traffic if done on the street while a hodos is positioned parallel to the street. To improve the usefulness of hodosses, the totem can be outfitted with additional functions such as USB ports for charging of devices, free Wi-Fi, and a display for route information and recommendations.



⁷⁶ A hodos along one of Amsterdam's canals.



⁷⁷ Hodosses implemented at the touristic location of Amsterdam's Westerkerk, close to the Anne Frank house.



⁷⁸ Possible functions that can replace parking spaces.



⁷⁹ LinkNYC poles are equipped with Wi-Fi, phone service, advertisements, city services, and USB ports.

Furthermore, additional functions can be placed adjacent to the hodos at hotspots⁷⁷: benches, bicycle rental facilities, or even information desks and machines for signing up for the system at busy hodosses.

Precedents

De Waart and Nap (2016) have explored the concept of implementing a network of hodosses in an urban area in the project 'Auto Correcting'. They suggest a fine-grained network of hodosses which aims to make on-demand vehicles more attractive than privately owned vehicles. They conclude that the hodos can unlock parking spaces which can be retrofitted into public functions such as barbecue spots, urban gyms, allotment gardens, retail, bicycle parking, public seating, terraces, playgrounds, or other functions.⁷⁸ Their project suggests that these new functions can be decided upon through cooperation between municipalities, residents, local entrepreneurs and other local parties.

New York's LinkNYC programme aims to create a network of poles through the city with Wi-Fi, USB ports, city services, and free phone use (LinkNYC, 2016).⁷⁹ The LinkNYC poles function similar to the totems integrated in the hodos. An important feature of the LinkNYC system is that they are paid for by advertising. This allows them to bring a public service at no direct cost for the public.

Implementation

A network of hodosses should be implemented throughout the city on a grid that guarantees a hodos is always in walking distance. Only then do hodosses become useful because getting dropped off three kilometers from one's destination ignores the possible benefits of AVs. Alternatively or additionally, hodosses can be combined with multimodal nodes, this can stimulate AVs as part of multimodal travel. When implementing the hodosses, the displays on the totems can be used to display commercials which can be used to pay for the project.

Pros

- Stimulates car-sharing.
- Saves parking spots compared to regular parking.
- Makes AV traffic easily accessible.
- Easily applicable.

Cons

- Stimulates AV traffic.

4.2.17 Park & Charge Hub

Theory

The park and charge hub is a parking garage that can charge AVs. Other than regular parking garages though it does not have to be accessible for people because AVs can drive in and out by themselves, this makes it possible to use space much more efficiently.

Precedents

In their project 'Auto Correcting', De Waart and Nap (2016) have explored park and charge hubs in combination with hodoses. Here, the hub takes over the vehicle storage function of parking spots while the hodoses take over the function of forming an entrance point to the city. Because vehicles are centrally owned and driving most of the time, hubs are only active during off-peak hours and can be located in peripheral areas that are well-connected to the infrastructural network.

Implementation

Because AVs need to be able to drive quickly to as many locations as possible from the hubs, its location should preferably be at an accessible point in the infrastructural network. Hubs can be implemented by retrofitting existing parking garages throughout the city.⁸⁰ Currently, approximately one in four parking spots in Amsterdam's centre are positioned in a garage (Gemeente Amsterdam, 2013b). If all privately owned vehicles were to be replaced with centrally owned rentable vehicles, a reduction of 80% in vehicles would be possible (Claudel & Ratti, 2015), combine this with the premises that automated vehicles will require less space for parking (Fagnant & Kockelman, 2015) and it could become possible to position all parking needs in existing garages if enough people choose to exchange their car for mobility as a service.

Pros

- Can open up parking at highly prized places.
- Much more efficient use of space.
- Relatively cheap.

Cons

- Only useful for people who want to summon vehicle from a distance.

4.2.18 Replace Tram with AVs

Theory

Automated vehicles can come in many forms. Because automated vehicles can drive in convoys very efficiently or can even connect to form one vehicle while driving (Next, 2016), they combine the efficiency and capacity of trams with the flexibility of cars because they do not require a specialised infrastructure



⁸⁰ A park and charge hub with cars belonging to a transportation company parked in a row to save space.

and can thus change route during disruptive events. Tesla recognises that the role of high passenger-density urban transport will need to be filled by automated vehicles and is currently in the process of developing such a concept (Musk, 2016).

Implementation

Replacing trams with automated vehicles is extremely risky because removing tramrails is quite hard and costly to reverse. Furthermore, the static nature of trams helps guide traffic flows and allows transit oriented development. These factors need to be taken into account when replacing trams with AVs. High capacity automated vehicles can still be used to drive a set route which would in theory still be able to support transit oriented development but the unfixed nature of AVs might create trust issues among developers. When implementing this concept in the centre of Amsterdam, high capacity vehicles can use existing tram stops as their stopping point or hodos (see 4.2.16). These stops can be upgraded into multimodal nodes which strengthens their position and creates a more permanent character which then allows transit oriented developments around the nodes. Implementation would have to be done gradually and pilot projects would have to be conducted in which the concept is tested.

Pros

- More flexible.
- More efficient use of resources.
- More responsive to actual patterns of use.
- Does not require specialised infrastructure.

Cons

- Risky with regard to transit oriented development.
- Hard to reverse.

4.2.19 Tourist Tram Line

Theory

A touristic tram line can take tourists along touristic hotspots, preferably in an authentic tram. This can move tourists through the city in an efficient manner while offering them an enjoyable experience. Such a tram line can serve as sort of a wink to Amsterdam's past if AVs were to take over the function of trams.

Precedents

The Hague already has a touristic tram line called Tourist Tram running along the city's touristic hotspots.⁸¹ The tram line was a suggestion by entrepreneurs and connects retail and the city's important sights (Westerduin, 2016).

Implementation

In Amsterdam, a tourist tram line can be implemented between important hotspots. Implementation could be considered for busy routes with entertaining views typical for Amsterdam. Implementing a tram line could be considered if regular tram line were replaced by automated vehicles (see 4.2.18).

Pros

- Efficient use of space.
- Can become nice sight in the city.

Cons

- Can attract more tourists.
- Requires tram infrastructure.

4.2.20 Delivery Assistance Vehicle**Theory**

Online shopping has grown exponentially since the mid-1990s (Rotem-Mindali & Weltevreden, 2013) and is likely to keep growing. It follows that there will be more deliveries and this requires some sort of mobility. Many deliveries are now done with cars or vans. In busy areas, this can contribute to congestion. With self-driving technology, a new solution in the form of delivery assistance vehicles can become reality. A delivery assistance vehicle provides space solely for deliverable goods. It is outfitted with a follow-me function which allows it to autonomously follow a deliverer around. The deliverer can take out packages from the vehicle and deliver these to the door. He does not have to enter the vehicle between every delivery made to drive the vehicle. This saves time and also makes the vehicle smaller.

Precedents

Maximilian Bakalowits has suggested an automated vehicles which can double as a delivery vehicle (DHL, 2015). Although the described vehicle is actually more similar to the multi-use vehicle (see 4.2.9), the visualisation shows a vehicle that seems to be made for deliveries and thus inspired the delivery assistance vehicle.⁸²

Implementation

Use of delivery assistance vehicles can be stimulated by the municipality for busy areas. Actual implementation would have to be done by delivery companies though.

Pros

- More energy efficient.
- Can operate in car-free areas.
- Can be used both for residential deliveries and supplying shops.

Cons

- Not implementable by municipality.



⁸¹ The Hague's tourist tram takes tourists along the city's attractions.



⁸² A self-driving vehicle that can transport both people and goods.



⁸³ Marnixmarkt at the Lijnbaansgracht around 1930.



⁸⁴ A DHL packet boat in one of Amsterdam's canals.

4.2.21 Supply over Water**Theory**

For centuries, transport of goods and to a lesser extent people was the most important function of Amsterdam's canals.⁸³ This is no longer the case. Functional transport of people is limited to the IJ and transport of goods is largely limited to the IJ, the port, the Amsterdam-Rijnkanaal and the Kostverlorenvaart (Gemeente Amsterdam, 2015c). In Amsterdam's vision for the water for 2040, the will to partially bring back transport of goods over the water is shared (Gemeente Amsterdam, 2015c). This could help take away transport of goods over land, unburdening overcrowded roads. Some companies, such as Mokum Mariteam, Rederij Kees, and DHL, are already delivering goods over the water but currently this is limited to a tiny fraction of less than 1% (Gemeente Amsterdam, 2015c). Supply over water can complement an autonomous logistics system which makes use of self-driving technology.

Precedents

Mokum Mariteam, Rederij Kees, and DHL are already delivering goods over Amsterdam's canals.⁸⁴ While the percentage share of deliveries that are made over water is low, supply over water currently already fills an important niche. Brewery De Prael states that supply over water is essential to their operation (Dijkhuizen, 2016). Unloading takes two hours and blocking the street for this long with a van would cause major local congestions.

Implementation

Bringing back transport over water is mainly relevant for supplying locations that are located directly along the water. Implementation would require the municipality to address the lack of berths in the centre.

Pros

- Removes car traffic from overcrowded roads.
- More environmentally friendly than supply over land.
- Unburdens small bridges from heavy transport.
- Strengthens Amsterdam's identity.
- Dutch people love a *pakjesboot*.

Cons

- Requires transformation of expensive space along canals.

4.2.22 Autonomous Boat

Theory

Autonomous boats are, strictly speaking, also automated vehicles. They do however operate differently. Because water has a central role in Amsterdam's centre, introducing autonomous boats only makes sense.

Precedents

Currently MIT, AMS, TU Delft and Wageningen University are already collaborating to develop a fleet of autonomous boats, which they call roboats.⁸⁵ According to MIT, the fleet of roboats can be used for transporting goods and people and for creating temporary floating infrastructures, such as self-assembling bridges and concert stages (MIT News, 2016).

Implementation

Ideally, the municipality would cooperate with logistics companies to achieve the use of autonomous boats. This cooperation could also give the municipality access to the boats for specific events, when they are needed to construct temporary bridges or other structures above water.

Pros

- Can facilitate efficient transport of goods and people over water.
- Can be used to construct structures above water.
- Has possible additional benefit of providing environmental data about water quality.

Cons

- Can clutter the canals if overused.

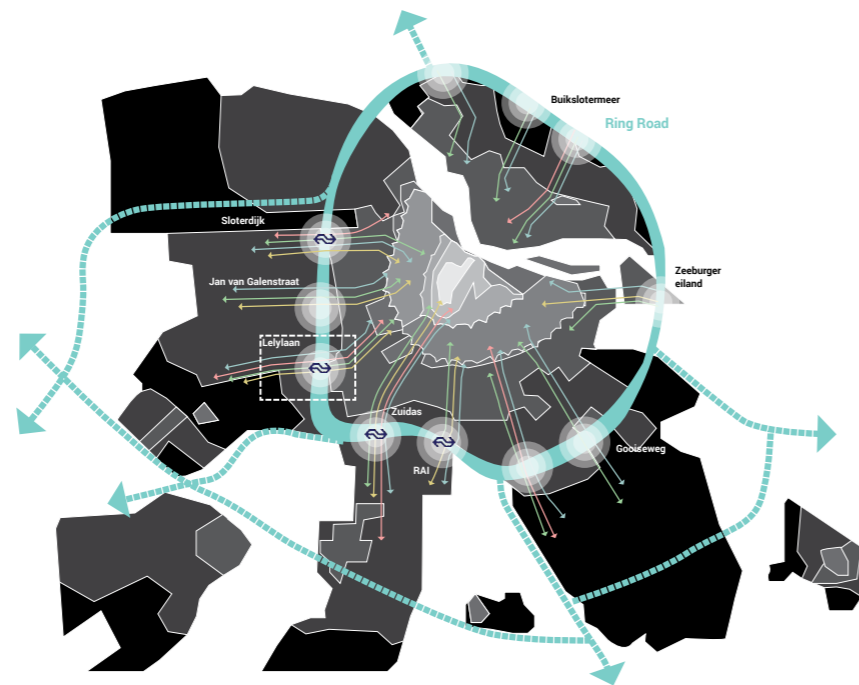
4.2.23 Multimodal Node

Theory

Multimodal travel can help bridge the gap between inner- and intercity travel. The former benefits primarily from cyclists and pedestrians while the latter should facilitate high speed travel. Research has shown that multimodal travel, using shared mobility services, reduces car ownership and car use, stimulates a healthier lifestyle, and reduces transport cost for users (American Public Transportation Association, 2016). To stimulate multimodal travel, transfer points are a solution. These smoothen the transfer between different modes of transport. Train stations are a good example of multimodal nodes, they often offer the possibility to transfer between train, bus, car, bicycle, and/or tram. Improving this transfer often leads to success for both modalities involved in said transfer (Kager, Bertolini, Te Brömmelstroet, 2016). The Dutch OV-fiets, for example, has



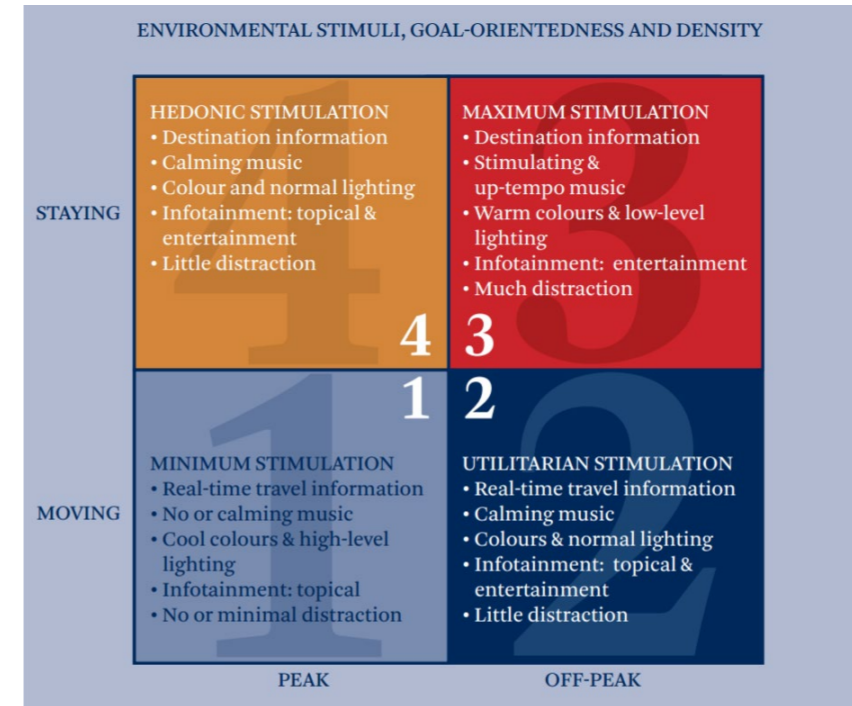
⁸⁵ An autonomous boat, the roboat, as imagined by AMS and MIT.



⁸⁶ Eleven multimodal hubs positioned along the A10, taken from the report 'Amsterdam A10: Case Study Lelylaan'.



⁸⁷ A vision for a large scale multimodal node along the A10 at Station Lelylaan, as visualised by Goudappel Coffeng.



⁸⁸ Required cognitive stimulation for reducing perceived transfer time during different moments (Van Hagen, 2011).

proven to be a great success and stimulates use of both bicycle and train (Fietsersbond, 2015; Van Lieshout, 2016). Automated vehicles have a major advantage over regular cars for multimodal nodes, namely that they do not necessarily require to be parked when used in a multimodal chain (also see 4.2.7 and 4.2.15).

Precedents

Goudappel Coffeng, Geophy, 2getthere, and UNStudio have collaborated to research the possibilities of implementing a multimodal node along the A10 highway at Station Amsterdam Lelylaan (Goudappel Coffeng, 2016).^{86,87} Their project aims to create a transition between long distance and short distance travel. The project shows the importance of making transitions between different modalities convenient. It also shows that transformations of multimodal nodes can be financed by transit oriented development. While this is not equally true for every type of multimodal node, it should be taken into consideration when implementing multimodal nodes.

Implementation

Multimodal nodes can be implemented on many different scales. As soon as two different modalities come together in one spot, this spot can be called a multimodal node. This ranges from a neighbourhood node, which grants pedestrians smooth access to their parked bicycle, to a complex train station, where an array of modalities come together. Smoothening transfers, in practice, comes down to minimising perceived transfer times. This means having parking space available where necessary, and making the actual transition comfortable for users by providing clear instructions and information. Furthermore, the perceived transfer time at multimodal nodes can be shortened by altering cognitive stimulation through time (Van Hagen, 2011).⁸⁸ Van Hagen states that providing different types of music, light, and visual stimulation during peak- and off-peak-hours can reduce perceived transfer times. On top of smoothening existing nodes, additional nodes can be created or nodes can be expanded by adding the possibility to transfer to more different modalities. Here, placement of networks needs to be taken into consideration. For example, if a new bicycle priority lane were introduced, this could be complemented by adding new multimodal nodes at intersections between the bicycle network and other networks. Also, the implementation of hodosses (see 4.2.16) can done in a way that makes them part of a multimodal node.

Pros

- Can help reduce car travel.
- Contributes to a healthier lifestyle.
- Cheaper for users.
- More efficient use of resources.

Cons

- Makes users depend on functioning of transport companies.

4.2.24 Bicycle Parking

Theory

If AVs are to facilitate a shift from cars to slow traffic, more bicycle parking is needed. Many bicycle parking spots are already present, many of which around station areas.⁸⁹ As of yet, it appears to be insufficient though, notably at important infrastructural nodes such as the central station and station Zuid (Borren, 2015). In 2015, 37,383 bicycles were removed in Amsterdam because they were parked wrong (Dienst Verkeer en Openbare Ruimte, 2015). Simply put, more parking facilities for bicycles are already needed and even more are going to be needed.

Precedents

Amsterdam is already in the process of constructing additional bicycle parking facilities. Between 2015 and 2020, 40,000 bicycle parking spots are to be realised, many of which around the important train stations (Borren, 2015).

Implementation

Where car parking can be removed, this space can be transformed into bicycle parking. This will create a more fine-grained network of bicycle parking throughout the centre. Furthermore, additional bicycle parking garages need to be realised at important multimodal nodes. These can be placed in buildings, underground or along streets, depending on the scale of the node.

Pros

- Facilitates bicycle use.
- More efficient use of space than car parking.

Cons

- Takes up a lot of space.
- Expensive.

4.2.25 Bicycle Sharing Programme

Theory

Bicycle sharing programmes have been around for a while. The idea was first pitched in 1965 by the Dutch Provo movement under the name *witte fiets*. The idea was not realised until much later in 2000 when it was implemented under the name *depo*.



⁸⁹ Bicycle parking facility at Amsterdam central station.



⁹⁰ OV-fiets rental at Amsterdam central station.



⁹¹ Shared electric bicycle 'Urbee' by Amsterdam-based start-up Urbee.

It turned out to be too vulnerable to theft and was discontinued. Recently, with new technologies the idea has again surfaced. This time implemented as the now well known *OV-fiets*. This project has been a great success and now more programmes are on their way (Kruyswijk, 2016c; Van Lieshout, 2016). Bicycle sharing programmes can reduce the amount of parked bicycles in a city and thus contribute to more efficient use of space.

Precedents

The *OV-fiets* offers rental bicycles at train stations and other busy spots in Amsterdam.⁹⁰ The success of the *OV-fiets* lies partly in its convenience. The bicycle can be rented with the same card that is used for other modes of public transport. Furthermore, it is affordable and reliable. These qualities are central to operating a successful bicycle sharing programme.

Amsterdam-based start-up Urbee aims to offer shared electric bicycles for fast and environmentally friendly travel through the city.⁹¹ While similar in approach to the *OV-fiets*, it offers electric bicycles and focusses on offering transport for longer trips than the *OV-fiets* does.

Implementation

Implementation of a bicycle sharing programme in the case of Amsterdam's centre would mean expanding existing bicycle sharing programmes that are already successful. These programmes could be adapted such that they provide coverage for the entire centre by creating additional rental spots or by allowing bicycles to be returned anywhere, similar to the car2go rental system (see 4.2.15).

Pros

- More efficient use of resources.
- More efficient use of space.
- Offers environmentally friendly and faster alternative to AVs.

Cons

- Requires maintenance and enforcement.

4.2.26 Conditional Access Road

Theory

A road that can only be accessed under certain conditions can manifest itself in many ways. It responds to the personalised nature of AVs. Roads can, for example, be accessible only to residents of that road, people with disabilities, emergency services, movers, delivery vehicles, or high capacity public vehicles. Roads can also become accessible under specific circumstances, e.g., during

heavy rainfall neighbourhoods could be made accessible to visiting vehicles because streets are not used for recreation during this weather anyway.

Precedents

The historic centre of Delft is only accessible with a permit.⁹² Permits can be requested from the municipality for an array of reasons. Such reasons include loading and unloading, dropping off someone with a physical limitation, or supplying a store. For residents and regular suppliers of stores, it is also possible to obtain a permanent permit (Gemeente Delft, 2016).

Implementation

Because automated vehicles can be fed real-time information, the conditions under which a vehicle is allowed to enter roads can be changed at any time. Implementation requires a thorough examination of possible conditions under which vehicles should be allowed to access areas so that an exhaustive list exists which can be used to guide vehicles in real-time. Furthermore, a clear hierarchy in streets should be present in which different levels within the hierarchy indicate different conditions for access, e.g. neighbourhood streets should require different permits than connecting traffic arteries.

Pros

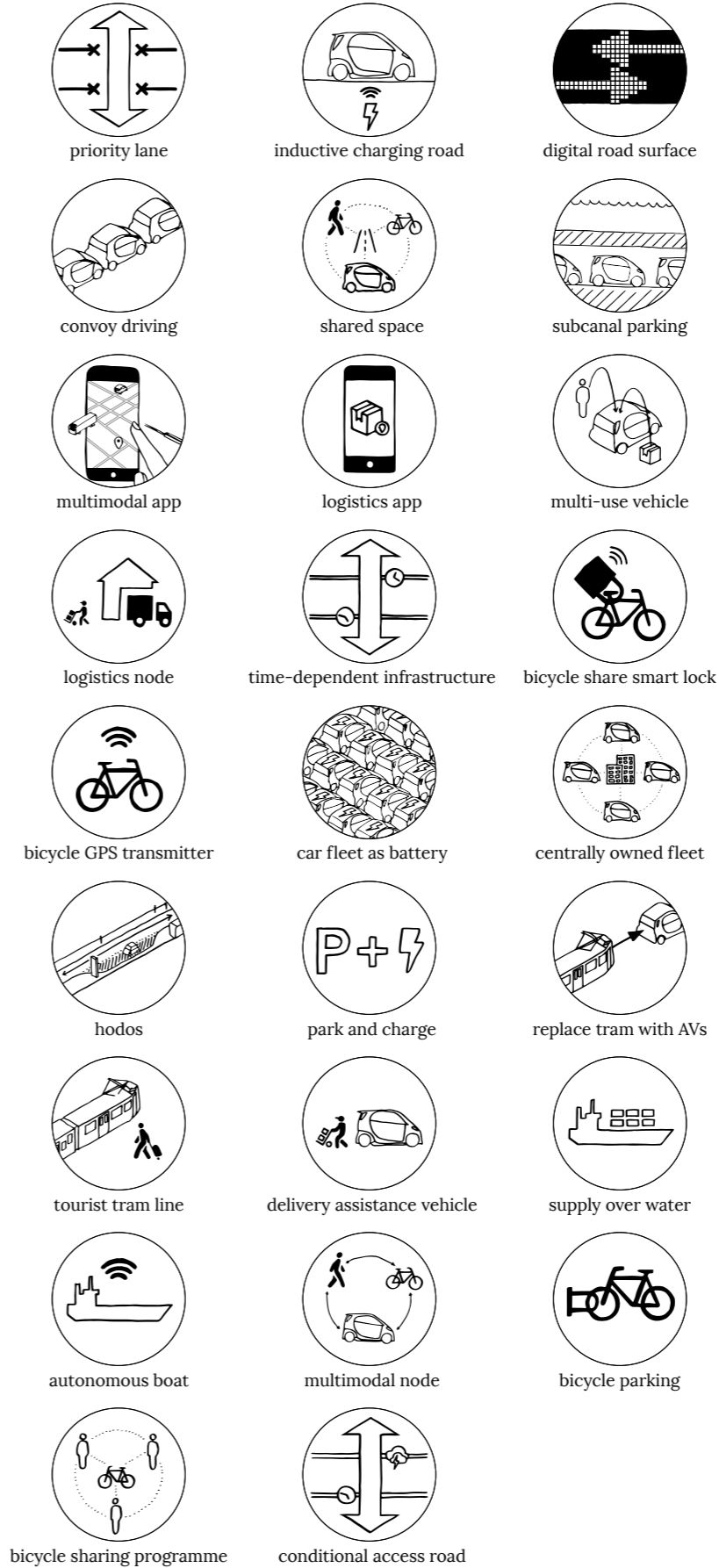
- Can be used for crowd control.
- Can create low density car traffic areas.
- Responsive to real-time events.

Cons

- Reduces accessibility for visiting AV users.
- Requires very complex computing.



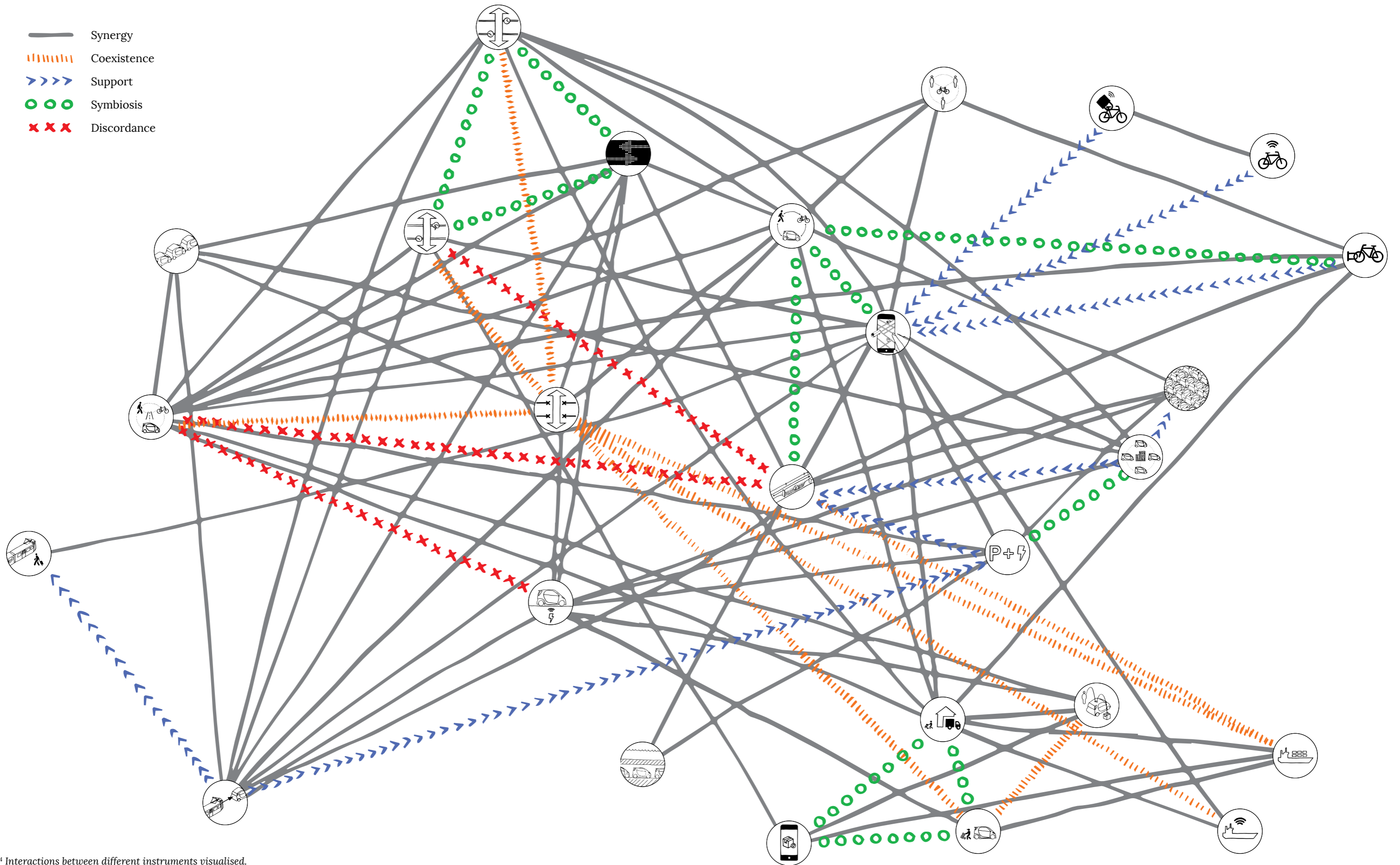
⁹² Delft's downtown area is car-free under normal conditions but exemptions can be requested online.



⁹³ The complete catalogue of instruments shown in icons.

The instruments can be implemented individually but they often synergise with each other. This makes it useful to research which instruments interact and in which way. To do this, every possible pair has been researched and their relation has been classified as one of six types of interactions. These interactions are *synergy*, *coexistence*, *support*, *symbiosis*, *discordance*, and *no interaction*. The nature of these interactions will shortly be discussed and on the next page, all interactions between the instruments are shown in a diagram. The synergy interaction indicates that two instruments both work better if they are implemented together. The coexistence interaction denotes that two instruments work well together but not in the same spot. Here, implementing both can be beneficial but some extra consideration must be given to prevent that the instruments will compete instead of cooperate. The support interaction points out that one instrument's success depends on the presence of another supportive instrument. Here, both can still be implemented individually but the supported instrument might not nearly be as successful without the supporting instrument. This is the only interaction that denotes a hierarchy in instruments. The symbiosis interaction expresses that two instruments reinforce each other to a degree that implementing either one without the other would be a wasted opportunity. The discordance interaction indicates that two instruments cannot be implemented together. They can still both be implemented but not in the same place and they do not improve each other. The last interaction is no interaction. This simply means that instruments do not interact, they strengthen nor weaken each other.

- Synergy
- ||||| Coexistence
- >>> Support
- ○ ○ Symbiosis
- × × × Discordance



⁹⁴ Interactions between different instruments visualised.

4.3.1 New Parking

One cluster that can be derived from the field of interactions is a cluster that revolves around a new parking typology. This cluster includes the *Hodos*, the *Park & Charge Hub*, the *Inductive Charging Road*, the *Centrally Owned Fleet*, the *Subcanal Parking*, and the *Car Fleet as Battery* instruments.⁹⁵ These instruments synergise into a new way of parking where people do not actually park their own car but they are dropped off at a convenient hodos and the car then goes on to serve other people. During off-peak hours, the car automatically parks itself in a (subcanal) park & charge hub where it is then charged.

4.3.2 Mobility as a Service

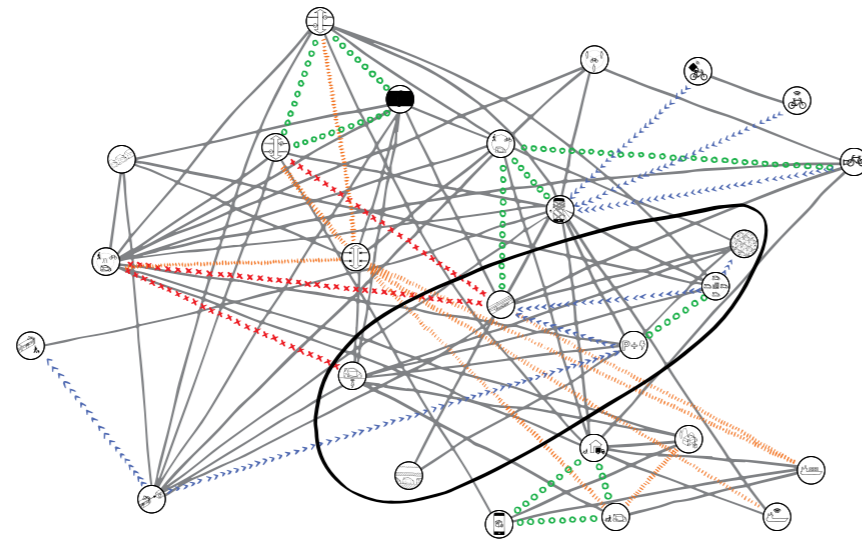
A second cluster is the mobility as a service cluster. This cluster includes the *Multimodal App*, the *Centrally Owned Fleet*, the *Hodos*, the *Bicycle Sharing Programme*, the *Multi-Use Vehicle*, the *Autonomous Boat*, the *Multimodal Node*, and the *Replace Tram with AVs* instruments.⁹⁶ The synergies in this cluster could offer travellers easy, convenient, and affordable mobility without having to actually own any vehicles.

4.3.3 New Logistics

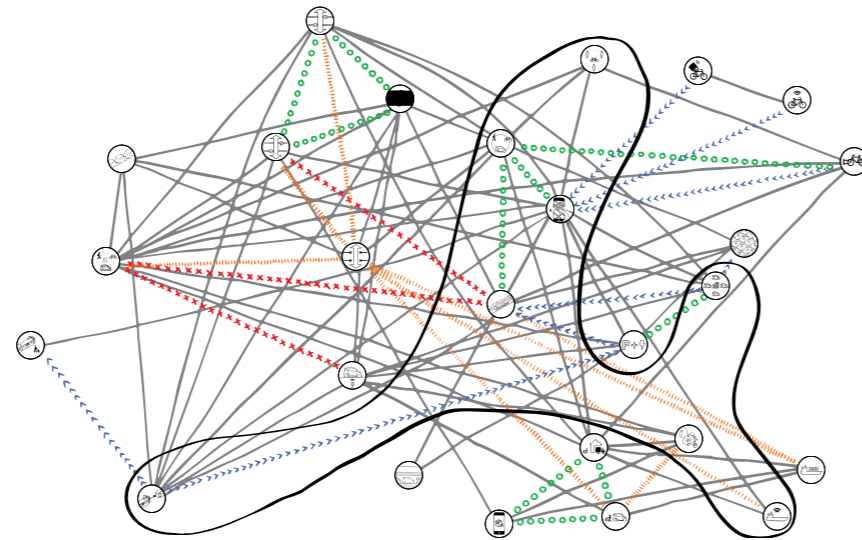
Another cluster is the new logistics cluster. This cluster includes the *Multi-Use Vehicle*, the *Logistics Node*, the *Autonomous Boat*, the *Supply over Water*, the *Delivery Assistance Vehicle*, the *Logistics App*, the *Centrally Owned Fleet*, the *Shared Space*, and the *Conditional Access Road* instruments.⁹⁷ This cluster mediates the difficulties raised by having car-free areas. It makes use of the possibilities offered by self-driving technology in the form of multi-use vehicles, autonomous boats, and delivery assistance vehicles while introducing logistics nodes and a logistics app for smartly managing the new logistics system.

4.3.4 Multimodal Travel

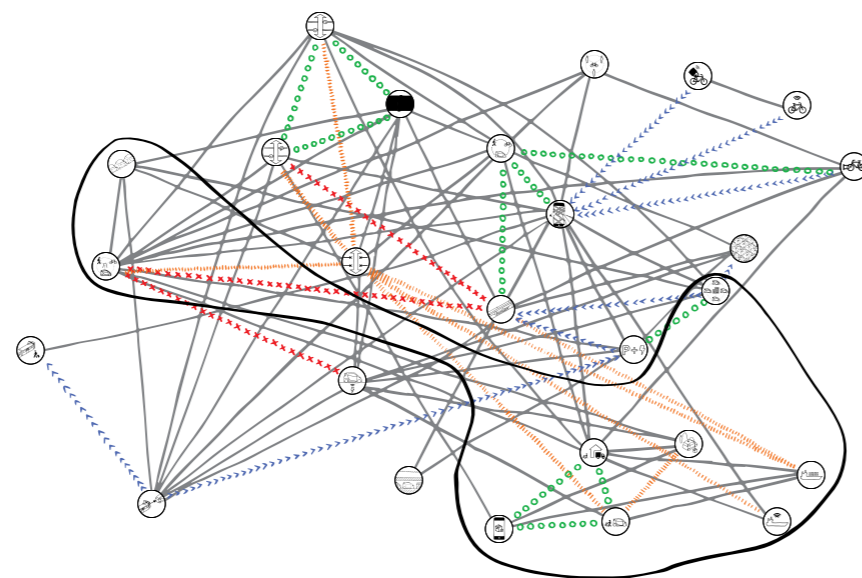
A fourth cluster that was found is a synergy of patterns into multimodal travel. The cluster includes the *Bicycle GPS transmitter*, the *Multimodal Node*, the *Multimodal App*, the *Bicycle Share Smart Lock*, the *Bicycle Sharing Programme*, the *Priority Lane*, the *Multi-Use Vehicle*, the *Bicycle Parking*, and the *Autonomous Boat* instruments.⁹⁸ The cluster makes use of the predictable nature of AVs to make multimodal travel clearer and more convenient. It adds additional spatial and non-spatial interventions to create a coherent multimodal travel experience.



⁹⁵ The New Parking cluster.



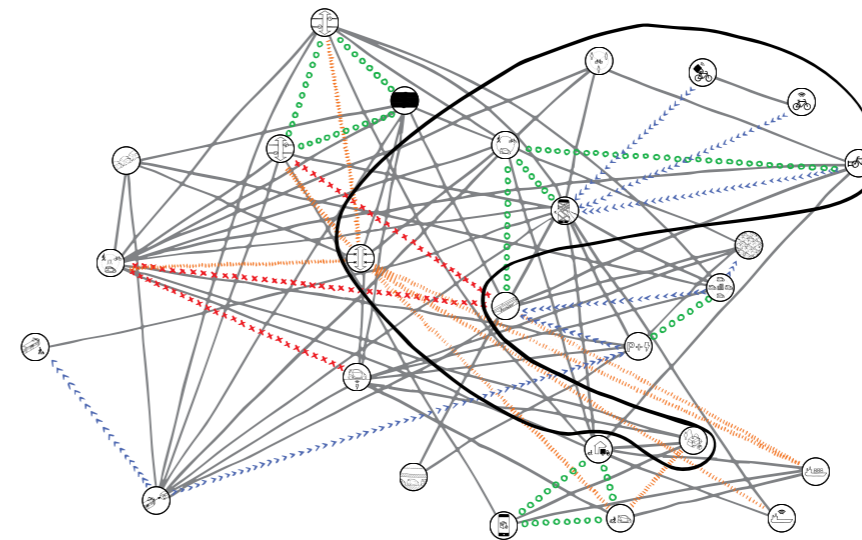
⁹⁶ The Mobility as a Service cluster.



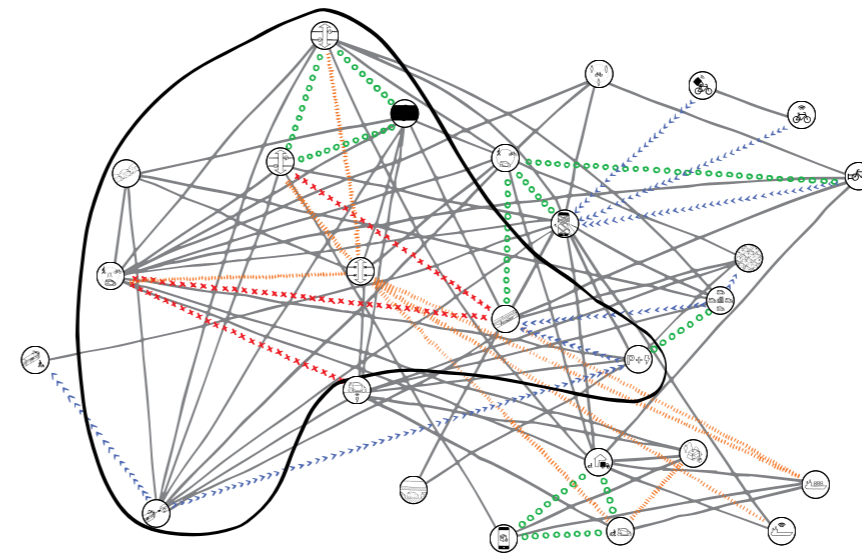
⁹⁷ The New Logistics cluster.

4.3.5 Network Principles

The Network Principles cluster includes the *Convoy Driving*, the *Time-Dependent Infrastructure*, the *Priority Lane*, the *Conditional Access Road*, the *Digital Road Surface*, the *Replace Tram with AVs*, the *Shared Space*, the *Hodos*, and the *Park & Charge Hub* instruments.⁹⁹ The synergy in this cluster defines a new principle for accessing areas. Rather than adhering to a static principle, it proposes a dynamic principle which changes through time and under different circumstances.



⁹⁸ The Multimodal Travel cluster.



⁹⁹ The Network Principles cluster.



DESIGN

**“If one does not know to which port one is sailing,
no wind is favourable.”**

Seneca the Younger

Before starting the actual design, Amsterdam's centre was analysed with regard to walkability and cyclability. Or, to put it otherwise, its spatial lay-out has been studied and held against the pillars of walkability and cyclability that were established in chapter two. The goal of this analysis is to find which aspects of walkability and cyclability need to be improved most, this knowledge can then help decide which interventions should be prioritised during the design phase.

5.1.1 Mixed Uses

Amsterdam's centre has a high density of functions (Van den Hoek, 2008). As such, a majority of Amsterdammers undertake leisure activities and do their groceries by foot or bicycle (Gemeente Amsterdam 2016a). This means that this pillar is already in place, which comes as no surprise, seeing as Amsterdam is already world famous for its bicycle culture.

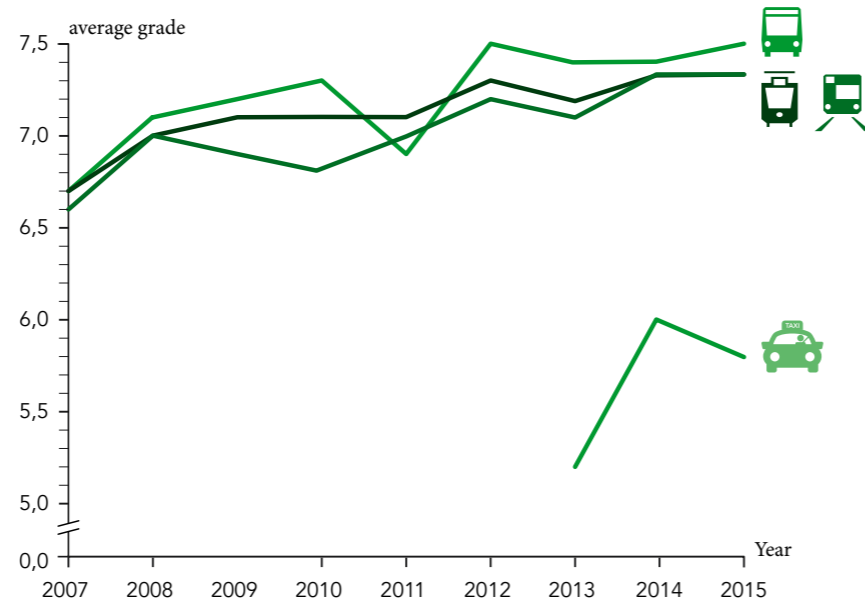
5.1.2 Network Coherence

Amsterdam's centre currently features coherent networks for pedestrians, cyclists, and cars alike. However, because many of the connections in this network have reached their capacity, they sometimes become unusable for efficient movement from A to B. The current plan for implementation of *plusnetten* aims to prioritise specific modalities in specific locations (Gemeente Amsterdam, 2013a), but executors must be careful not to undermine the coherence of the networks of other modalities in the process. In *The Mobility-Livability Revolution*, pedestrians and cyclists are prioritised, so while AVs are an important part in the solution, network coherence for pedestrians and cyclists must be maintained during the design phase. Public transport currently functions well and residents are increasingly satisfied by buses, trams, and subways (Gemeente Amsterdam, 2016a).¹⁰⁰ This must at least be maintained, either by keeping the same networks in place or by replacing them with better alternatives.

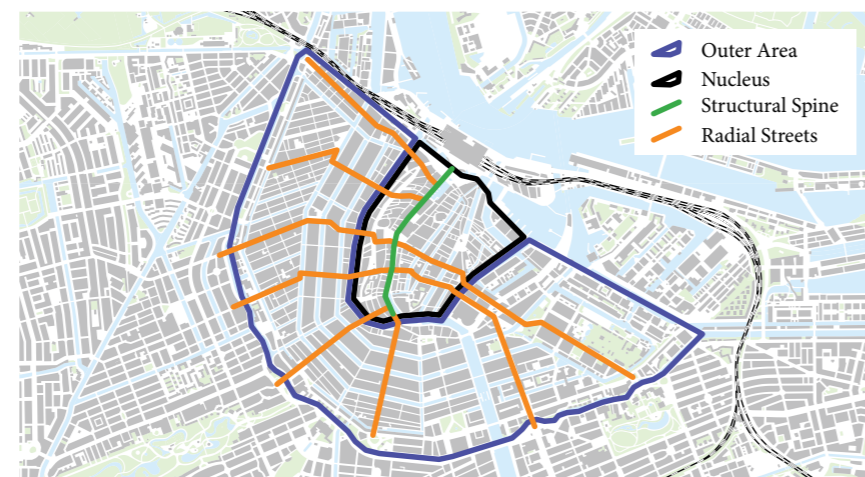
5.1.3 Legibility

The centre has a clear hierarchy. There is the old centre, which is the nucleus of the structure, the old centre has the Damrak and the Rokin as its spine, connecting the central station to the Munt Square. From this spine, streets go outward towards the edges of the nucleus.¹⁰¹ These streets then proceed

¹⁰⁰ translated from the Dutch term 'grachtengordel', which denotes the area of the centre along the four main canals: Singel, Herengracht, Keizersgracht, and Prinsengracht. The canal belt starts at the Brouwersgracht and gradually bends in southeastern direction towards the Amstel.



¹⁰⁰ Satisfaction rate for Amsterdam's public transport (Gemeente Amsterdam, 2016a).



¹⁰¹ The structure of Amsterdam's centre.



¹⁰² Amsterdammertjes protect pedestrians from street traffic.

through the newer parts of the centre, among which is the canal belt.* This area is clearly structured. It features the radial streets originating from the nucleus and function as connectors of the city, and the cross streets, which are mostly residential. While this hierarchy is clearly present, it can be emphasised in materialisation and by making the function of the canals as residential areas more explicit through banning cars.

5.1.4 Protection

Amsterdam's pedestrians are often well protected. The typical street posts called *Amsterdammertjes*¹⁰² separate pedestrian traffic from other traffic. This works well in theory but because sidewalks are often too narrow, people have to divert to the road, which poses potential safety risks. Shared space has been proven to create safe conditions for pedestrians and cyclists, but banning car traffic from areas might be a better solution if space is tight.

5.1.5 Dimensioning

Dimensioning is the key to this project. Overcrowding has caused many streets to become too narrow and other streets have been too narrow since the introduction of a car lane in the profile. The design will have to focus for a large part on establishing appropriate distribution of street profiles. This could include, as was mentioned in the last subsection as well, removing car traffic from some streets. As such, this step will require reevaluating of Amsterdam's networks as well as the profiles of different types of streets.

5.1.6 Presence of Green

While Amsterdam's centre is not short of trees, many of these are positioned in inner courts, parks, and neighbourhood streets. Where possible, radial streets could be complemented with additional trees. Smaller forms of vegetation, such as plants and flowers, could further embellish neighbourhood streets. This can be achieved either by putting in place planters or stimulating appropriation of public space among residents. Appropriation of public space can be stimulated by making neighbourhood streets more reclusive through banning outsider cars (Lankester & Polito, 2010). It can also be stimulated by subtly guiding pedestrian traffic through a street in a way which leaves a small stroke of semi-public space along the houses.

5.1.7 Visual Stimulation

With regard to visual stimulation, one main criterion has become apparent and it is the effect of parked cars blocking the view on the city's canals. This means cars parked along the canals have to be moved elsewhere. They have to be replaced with something worth seeing. Another improvement can be to replace parked cars in neighbourhood streets with other, more visually stimulating, functions. This, again, can be done by employing methods that stimulate public space appropriation.

5.1.8 Connect Attractors

Amsterdam's main attractions are all positioned within the old centre or easily accessible from its radial streets.¹⁰³ This means that they are currently easily accessible. A feature that makes the city very appealing, and must therefore be maintained, specifically for pedestrians, cyclists, and users of public transport. In some cases, radial street profiles must be optimised so they can accommodate larger traffic flows. Again, pedestrians and cyclists should be prioritised.



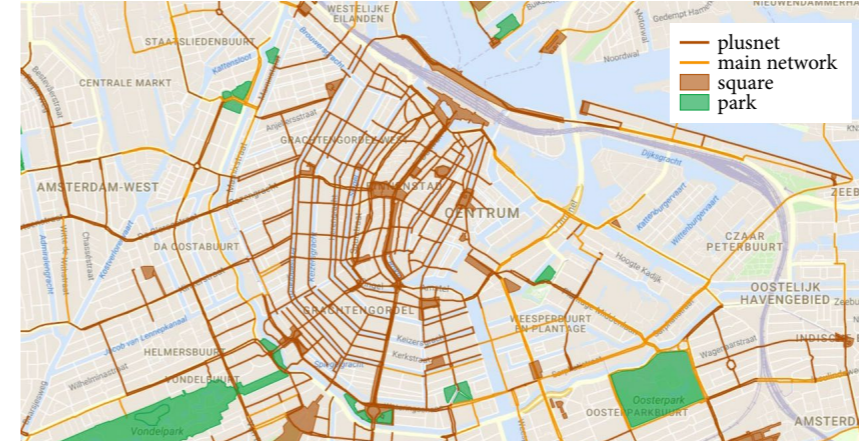
¹⁰³ Amsterdam's most visited touristic hotspots and the most popular touristic routes, abstracted from geodata coupled with Flickr uploads (Van der Drift, 2015).

5.2.1 Network Development Principles

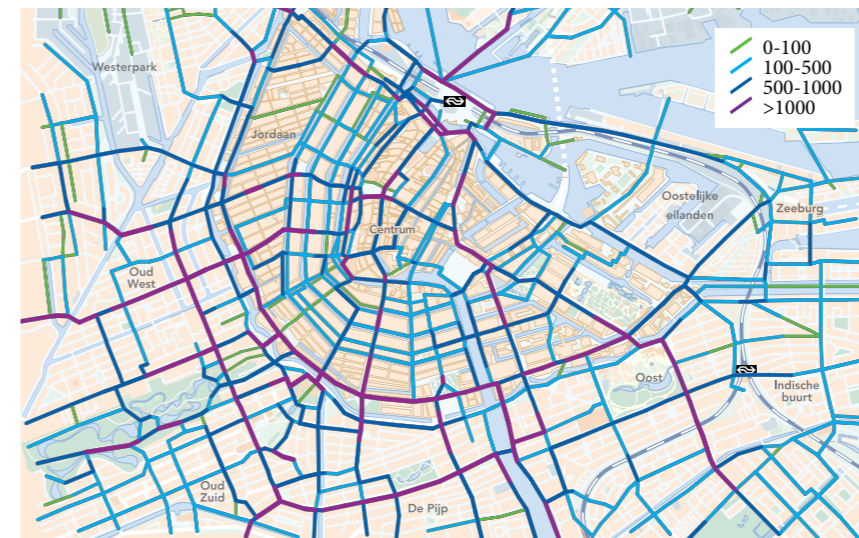
When defining infrastructural networks, several criteria have been used to decide which modalities should be present where. When designing streets, one often faces one major difficulty, namely how both people using the street as a place for recreation and people using the street as a means to get from A to B can both be satisfied. People using the street as a place for recreation often want the street to be safe, attractive, and active, while people using the street to get from A to B want to get through as fast as possible. These uses conflict because fast movement creates unsafe conditions, loud noise and unhealthy surroundings. Because the infrastructural network needs to serve both groups, some streets mainly function as a place for recreation, while others function mainly as a connection.

Areas that function mainly as a place include shopping areas, residential areas, and in the case of Amsterdam, centre areas. These type of areas have been defined by the municipality as areas where pedestrians should be prioritised (Gemeente Amsterdam, 2013a). This pedestrian network is the most important network for the city centre because it facilitates commerce, recreation, and city life. The pedestrian network has the finest grain and reaches everywhere in the city centre. It consists of a priority network which favours pedestrians over other modalities at intersections, a network of shared space where all modalities use the same surface but pedestrians have the most rights, and a network of sidewalks along major arteries where other modalities are prioritised over pedestrians. The layout of the pedestrian network will be based upon the pedestrian *plusnet* defined by the municipality of Amsterdam¹⁰⁴, the position of shopping, residential and connecting areas¹⁰⁵, and a map of major touristic routes.¹⁰³

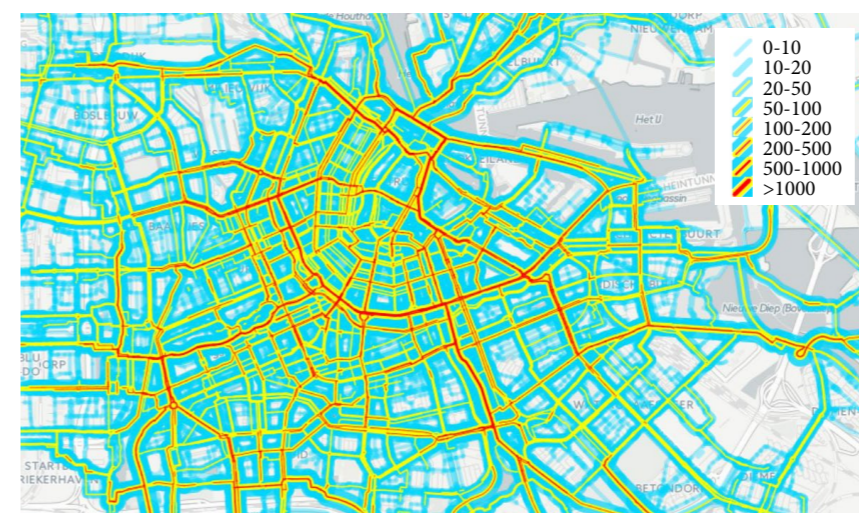
After determining a pedestrian network, a network for cyclists needs to be defined. This network provides a means for efficiently moving around through the city. It consists of a priority network in which cyclists are favoured over other modalities at intersections, a network of bicycle roads which don't have priority at intersections, and a network of shared space where bicycles have to share a surface with other modalities and have to give way to pedestrians. The layout of the bicycle priority network will be based upon frequency of use maps^{105,106} and the principle of using well-connected streets for improved wayfinding, this means using streets that are interconnected well according to the space syntax method.¹⁰⁷



¹⁰⁴ Pedestrian plusnet.



¹⁰⁵ Bicycle intensity of Amsterdam in 2008, according to the municipality of Amsterdam.



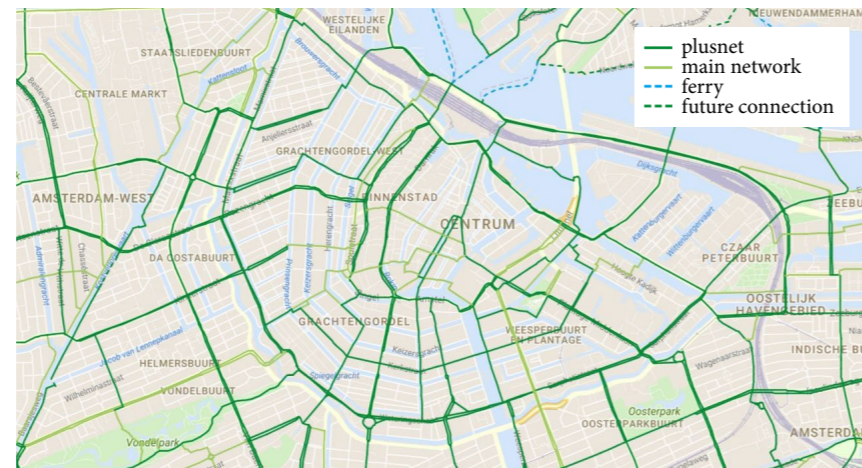
¹⁰⁶ Bicycle intensity of Amsterdam in 2015, according to a national bicycle count.

The regular bicycle network will be based upon the bicycle plusnet defined by the municipality.¹⁰⁸

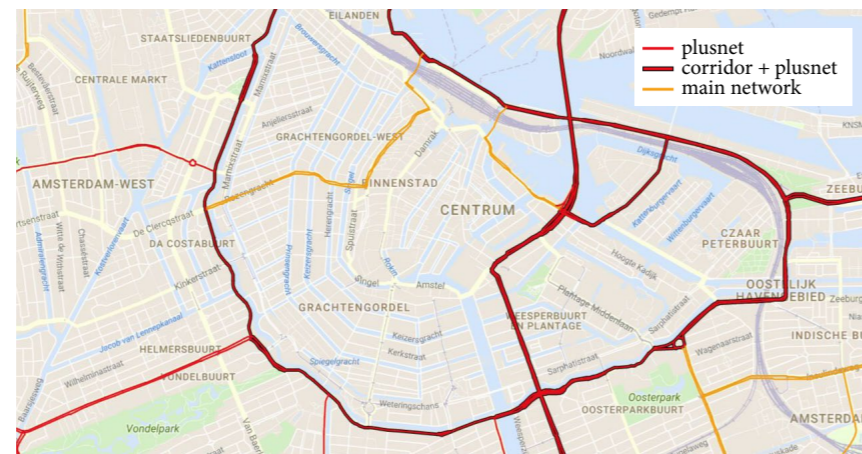
Since the car network will be converted to an AV network, it will be very different from the current car network. The disagreement between infrastructure as a space and infrastructure as a means to get from A to B discussed earlier is mainly based on the use of infrastructure by cars. Where pedestrians and cyclists can usually get from A to B while improving the quality of roads as a space for recreation, cars do the opposite. As such, in an ideal situation cars are only present where necessary, when necessary. Here, AVs offer a major advantage over regular cars. They can transmit information and be fed commands in real-time. This means that certain areas can be made inaccessible to certain vehicles. Residential areas can be made accessible exclusively to vehicles owned by residents, emergency services and other vehicles with (temporary) exemption privileges such as movers. Furthermore, because AVs get their route instructions from the cloud, they do not need visual cues for wayfinding. This means that an AV network can be placed where it fits without having to worry about how people will find their way. The AV network consists of a priority network where AVs have priority over other modalities at intersections and a network of roads that can be accessed by AVs but where they do not have priority rights at intersections. Furthermore, there is a fine-grained network of shared space where only specific vehicles are allowed (such as those owned by locals). The layout of the AV network is based on the car plusnet defined by the municipality¹⁰⁹ and the map of touristic hotspots.¹⁰³ It is created in a way that makes every part of the city accessible by car to anyone with a maximum walking distance of ten minutes. However, this walking distance does not apply to residents, because they can always get dropped off or picked up from their house. So while the car network is very minimalistic, its dynamic nature allows residents to travel like they do now, if not more efficient.



¹⁰⁷ Fractional Mean Depth Space Syntax of Amsterdam city centre showing the central position of radial streets in the network. The red and orange lines denote that streets are well-connected streets while the yellow to green lines indicate that streets are more secluded within the network.



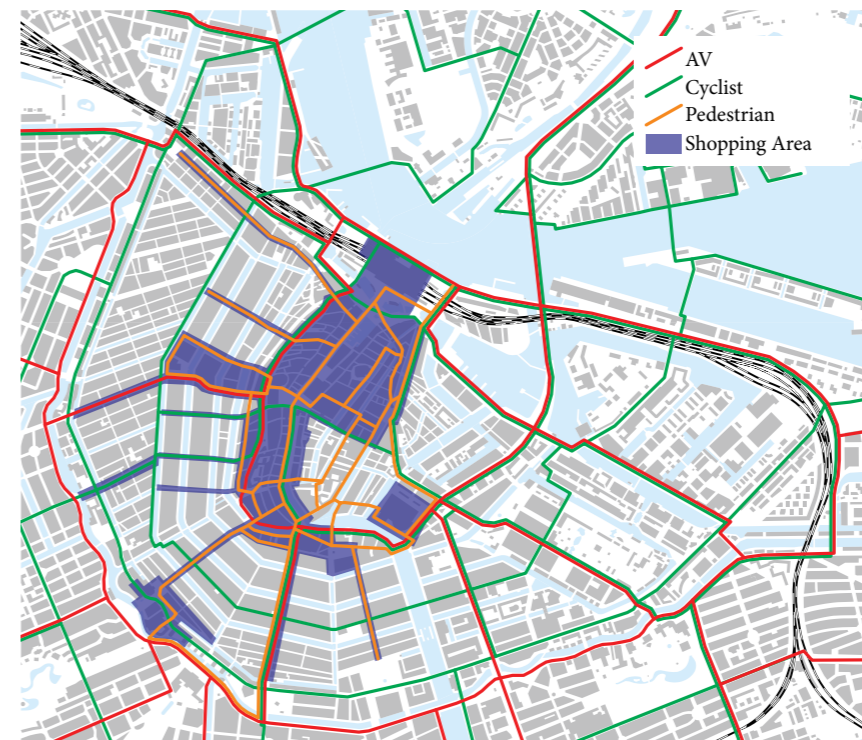
¹⁰⁸ Bicycle plusnet.



¹⁰⁹ Car plusnet.



¹¹⁰ Amsterdam's centre divided into different areas. Red demarking important infrastructural connections, yellow showing areas which mainly serve as a residential area, and blue showing primarily commercial areas.



¹¹¹ The priority networks, pedestrian priority network in orange, bicycle priority in green, and AV priority in red. Underneath, the commercial area is visible to show the overlap between pedestrian priority areas and shopping areas.

5.2.2 Networks

Developing the actual networks has been both a rational process based on the starting points developed through research and a process of trial and error. The networks have been drawn over and over and evaluated from a user's perspective. While the final lay-out of the networks can be developed further still, it can be seen as a starting point for discussion with involved parties such as residents, the municipality, commercial parties, and NGOs. This is important to note as making infrastructural adjustments is a costly and time consuming process. As such, all parties involved should support the change. The suggested networks can be seen in image 111. The bicycle priority networks includes the suggested bridges from the Houthavens and KNSM island (Borren & School, 2015), and a bicycle tunnel running from the Westerdokskade to the Van der Pekbrug suggested by Roland Haffmans (Kruyswijk, 2016b). Another important note is that the networks function differently, this has been explained earlier but will be repeated; the pedestrian priority network is an infrastructural network that guarantees right of way for pedestrians at intersections. This network is complemented by a coherent network of pedestrian prioritising shared space and regular pedestrian infrastructure. The bicycle priority network functions similar but is slightly less coherent, some shopping areas such as the Kalverstraat are inaccessible to cyclists. The AV networks functions completely different altogether. The functioning of the AV network will be explained in detail in section 5.2.4.

5.2.3 Nodes

In order for the networks to function optimally and cyclists and pedestrians to flourish, infrastructural multimodal nodes have been positioned along the networks, these nodes facilitate transfers between different modalities. The nodes are hierarchically structured according to the amount and type of modalities they harbour. Larger nodes facilitate more modalities and/or larger traffic flows.¹¹² Similar to the networks, the map is the result of both rational planning and trial and error followed by critical reflection from a user perspective. And again, it merely aims to open up a discussion between involved actors. The nodes are based on current nodes in the form of train stations, bus stops, tram stops, and subway stops. This has been done to soften the transition from the current system to the next system and make use of existing patterns of use. The nodes pictured here merely show the nodes that facilitate

public transport of some sort. Transfers between walking, cycling and regular AVs can be made practically everywhere and have thus been left out. While this suggests that AVs will have free rein in the city, this is not actually true because of the way the network functions, which will be elaborated upon in the next section.

5.2.4 AV Priority Network

The AV priority network is actually the complete default network for AVs, meaning that AVs cannot divert from this network.⁹⁹ This means that pedestrians and cyclists gain much more room and that the quality of this room improves. The AV network is positioned in a way that every place in the centre can be reached from the AV network within a reasonable walking distance. While the limited AV network has a large positive impact on walking and cycling, it creates some inconveniences which cannot just be ignored. An important example is that emergency services will still need to reach every spot in the city. Luckily, there is a solution for these inconveniences in the form of conditional access roads (see 4.2.26). AVs have the ability to respond to their context and external input in real-time and can make individual decisions based on their current use and their user. This makes it possible to allow specific vehicles to divert from the default AV network. Which vehicles can divert from the network can be decided by the municipality and can be changed at any time. The dynamic nature of the network has been visualised in image 113 to 115. Some possible reasons for being exempted from the default network will be discussed.

Emergency Services

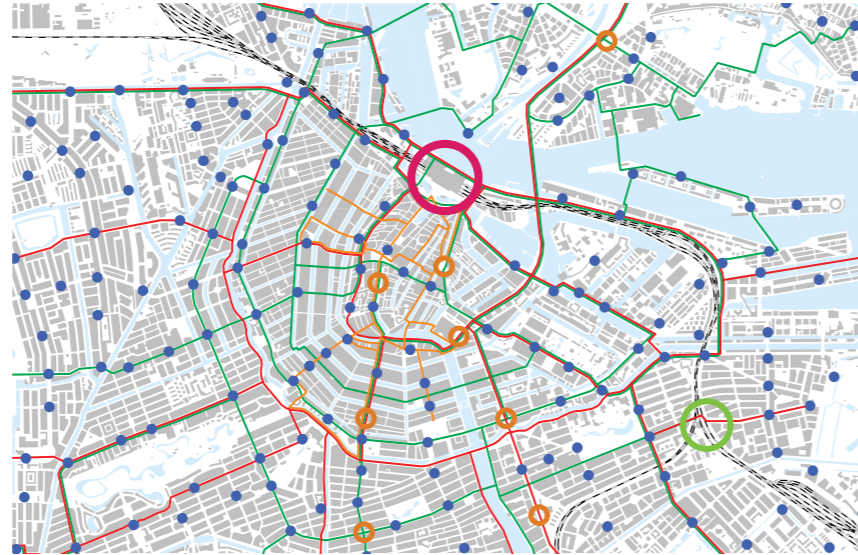
The most obvious and probably the most important exemption has to be made for emergency services. The police, fire department, and ambulance still need to be at the scene as fast as possible and their vehicles will thus have to be exempted at any time and any place.

Public Transport

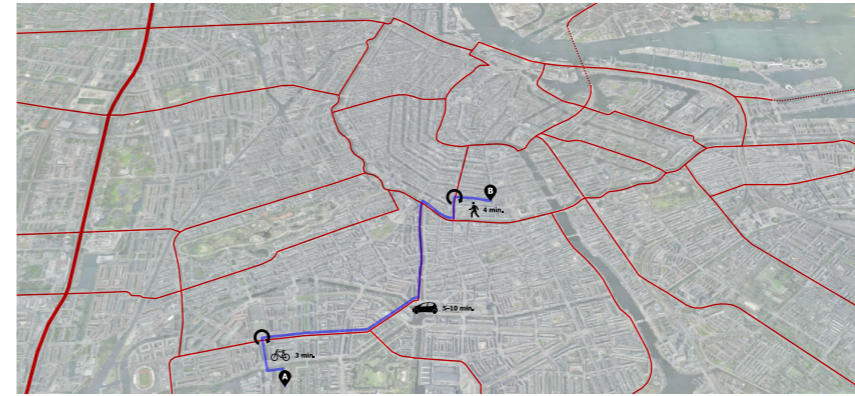
To stimulate the use of mass transport over individual transport, self-driving buses can be exempted from the default AV network. This creates more social interaction and uses space much more efficiently. As such, an exemption for public transport can be beneficial for the city.

Residents

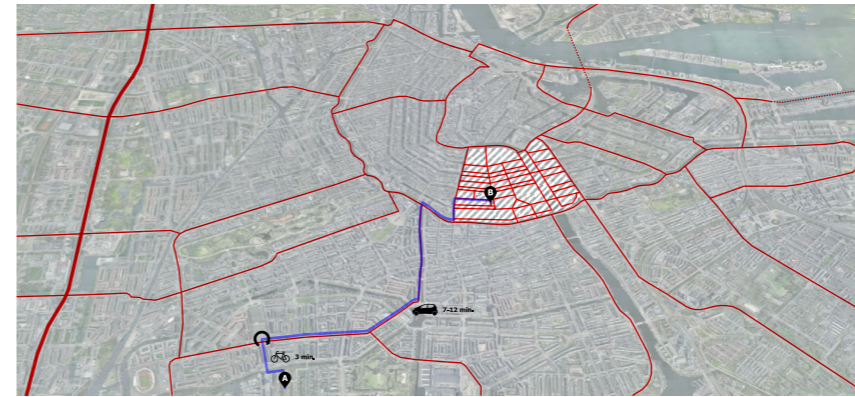
For residents who rely on their AV on a regular basis, having to walk upwards of five minutes from and to a vehicle every time becomes tedious. For these people, an exemption can



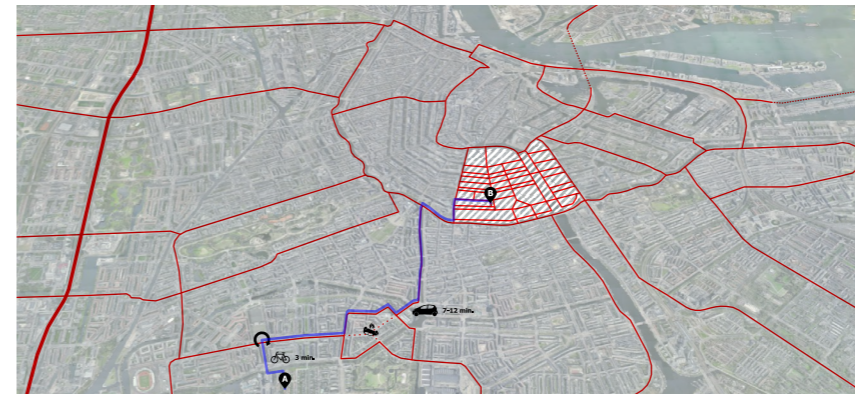
¹¹² A network of nodes. Pink nodes feature a train station, subway stop, hodos, and bicycle parking. Green nodes are similar but lack a subway stop. Orange nodes are similar to pink nodes but without a train station. Blue nodes feature a public transport hodos and bicycle parking.



¹¹³ The default network, route and travel time of an individual using a bicycle sharing service and an on-demand AV.



¹¹⁴ The network, route and travel time of an individual who lives at the destination and uses a bicycle sharing service and an on-demand AV.



¹¹⁵ The network, route and travel time of an individual who lives at the destination and uses a bicycle sharing service and an on-demand AV during an accident.



¹¹⁶ For comparison, the network, route and travel time of an individual travelling by bicycle.

be made for their area of residence, allowing them to enter a vehicle close to their house.¹¹⁴ It is possible to connect a monetary compensation to this privilege in the form of either a subscription or a small fee for every use. Such a compensation can discourage excessive use of AVs.

People with Disabilities

Another exemption can be made for people who are physically or mentally impaired if necessary. These individuals can then be picked up and dropped off anywhere. Such exemptions can be made for a specific period of time, for example until a broken leg is healed, or indefinitely.

During an Accident

If an accident occurs somewhere on the default AV network, (partially) blocking traffic, an alternative network can temporarily be made available for all vehicles until the accident is resolved.¹¹⁵ This exemption is necessary to prevent heavy congestion during accidents.

During Events

When events are held in the centre, an alternative network can become accessible which steers clear of event-related activities. This can contribute to a better flow of traffic and less disruptions of the event.

Moving Services

When people move to or from the centre, it would be extremely inconvenient if they would have to carry all their belongings to their house from the AV network. Hence, an exemption for people who are moving seems reasonable.

Supply of Commerce

Because stores, restaurants and other commercial functions still need a reliable supply of goods, an exemption can be made for them as well. This exemption can be made at a monetary cost and can be restricted to certain times when the volume of pedestrian and bicycle traffic is low. Alternatively, a different logistics system can be implemented (see 4.3.3).

Workers

People who have a job in the city could be allowed to divert from the default AV network. This, however, does stimulate use of AVs and leaving out this exemption can stimulate the use of other modes of transport such as walking, cycling, or public transport. Careful consideration needs to be given to this exemption.

Weather Events

It is possible to temporarily allow all AVs

to divert from the default network during certain weather events. During heavy rain, it is implausible that neighbourhood streets will be bursting with street life and walking becomes much less attractive regardless of the presence of vehicles. At such a time, AVs can be exempted, allowing people to be dropped off at their destination. This makes sure people do not have to walk the last part through the pouring rain.

Credits for Residents

It is possible to provide residents with a limited amount of credits that they can hand out at will. These credits can, for example, be given to visiting friends. This type of example can create a more convenient mobility experience for residents but generates AV traffic in neighbourhoods which, strictly speaking, is unnecessary.

During Peak Traffic

If the default network is not able to deal with the AV traffic, additional streets can be temporarily added to the network to mediate the excess traffic. Here, careful consideration needs to be given because the 'build it and they will come'-principle is applicable. This means that if too much traffic leads to the addition of extra capacity to the network, the availability of this extra capacity will itself attract more traffic because people know that they will never have to wait. As such, giving exemptions for this reason is a bad idea. If it is done nonetheless, a clear maximum percentage of the time in which AV traffic is exempted for this reason should be established, guaranteeing that only the worst peak traffic is mediated in this way.

Specific Vehicle Types

To stimulate the use of specific types of vehicles, these can be given an exemption as well. Examples include vehicles that are very silent or very environmentally friendly.

Monetary Compensation

It is possible, though inadvisable, to allow vehicles to divert from the default network after a payment. This completely defeats the purpose of this entire graduation project and creates more inequality. As such, this is highly inadvisable.

Other Reasons

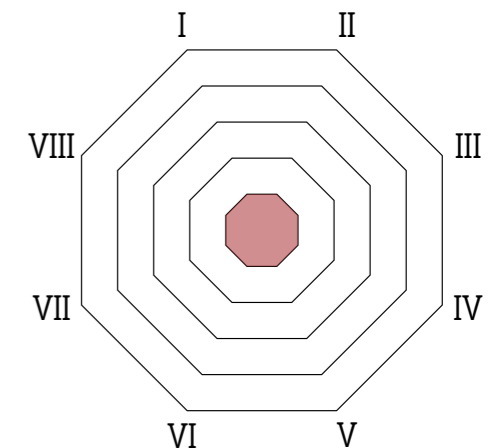
The reasons for exemption listed above by no means form an exhaustive list. Many other reasons are possible and will be discovered after implementation of a dynamic network. Because of the flexible nature of the network and the real-time adaptability of AVs, these can be added by the municipality at any time and will then be active immediately.



This section will discuss, step by step, a suggestion for how Amsterdam's centre can be transformed in response to the ubiquity of automated vehicles which has been assumed for this project. This step-by-step discussion does not reflect a chronological set of interventions. Above, the current situation for a typical part of Amsterdam's centre is shown. It features a canal, a neighbourhood street parallel to the canal, and a radial street which facilitates large traffic flows. On the following thirteen pages, changes to this situation will be shown and discussed. On each page, the illustration showing the result of the change features icons in the bottom left corner which show the instruments that were used to achieve the result. On the bottom right of each page, a diagram shows which pillars of walkability and cyclability (see 2.1) are addressed by the change. The changes are shown in a cumulative way and the changes are relative to the total

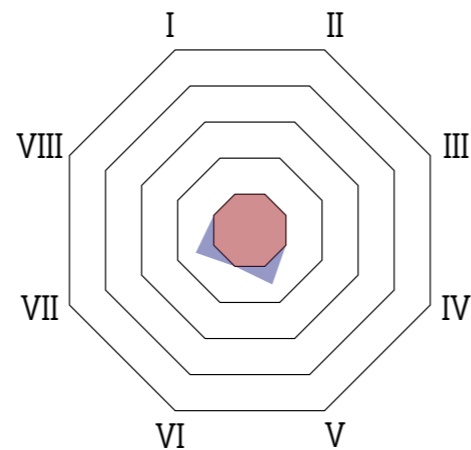
amount of changes made in this project and are not quantified. By definition, the last page shows a diagram which is completely full. The diagrams refer to the pillars by their roman numeral. For ease of use, the pillars will be repeated here.

- I. Mixed Uses
- II. Network Coherence
- III. Legibility
- IV. Protection
- V. Dimensioning
- VI. Presence of Green
- VII. Visual Stimulation
- VIII. Connect Attractors

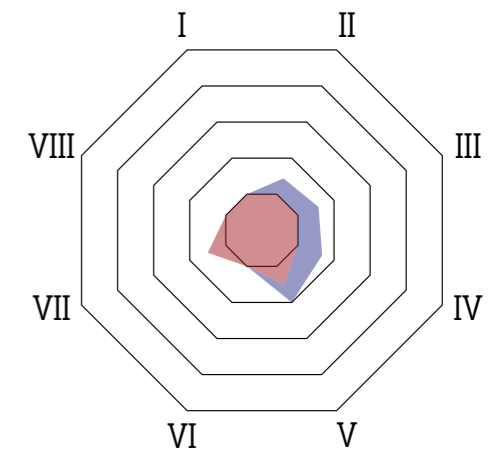




Current forms of public transport at street level can be replaced with new automated forms of public transport. This means trams, buses, and taxicabs in their current form will disappear. This means that all public transport at street level can use the same infrastructure as regular automated vehicles. This allows a more efficient use of street profiles which facilitates optimal dimensioning of infrastructures. Furthermore, visual clutter in the form of tramrails and overhead lines can be removed.

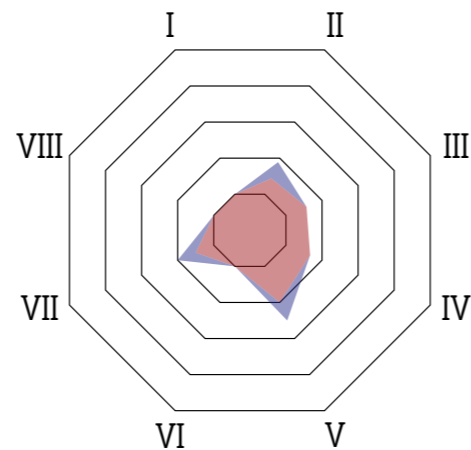


A division can be made between the default AV network, bicycle priority networks, and neighbourhood streets. Here, a clear division is made between priority networks and everything else, which can be transformed into shared space. Above, the radial street becomes an AV priority network, the neighbourhood street features a bicycle priority network, and the canal becomes shared space. This spatial division supports the division between the default AV network and the conditional network (see 5.2.4). The intervention contributes to the maintenance of network coherence, a better legibility of the centre, safety of vulnerable users of public space, and a more efficient dimensioning of streets.

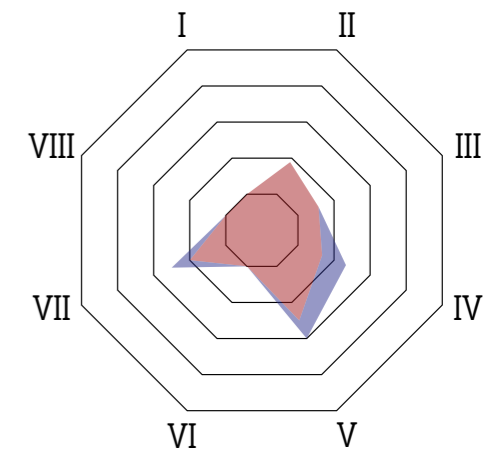


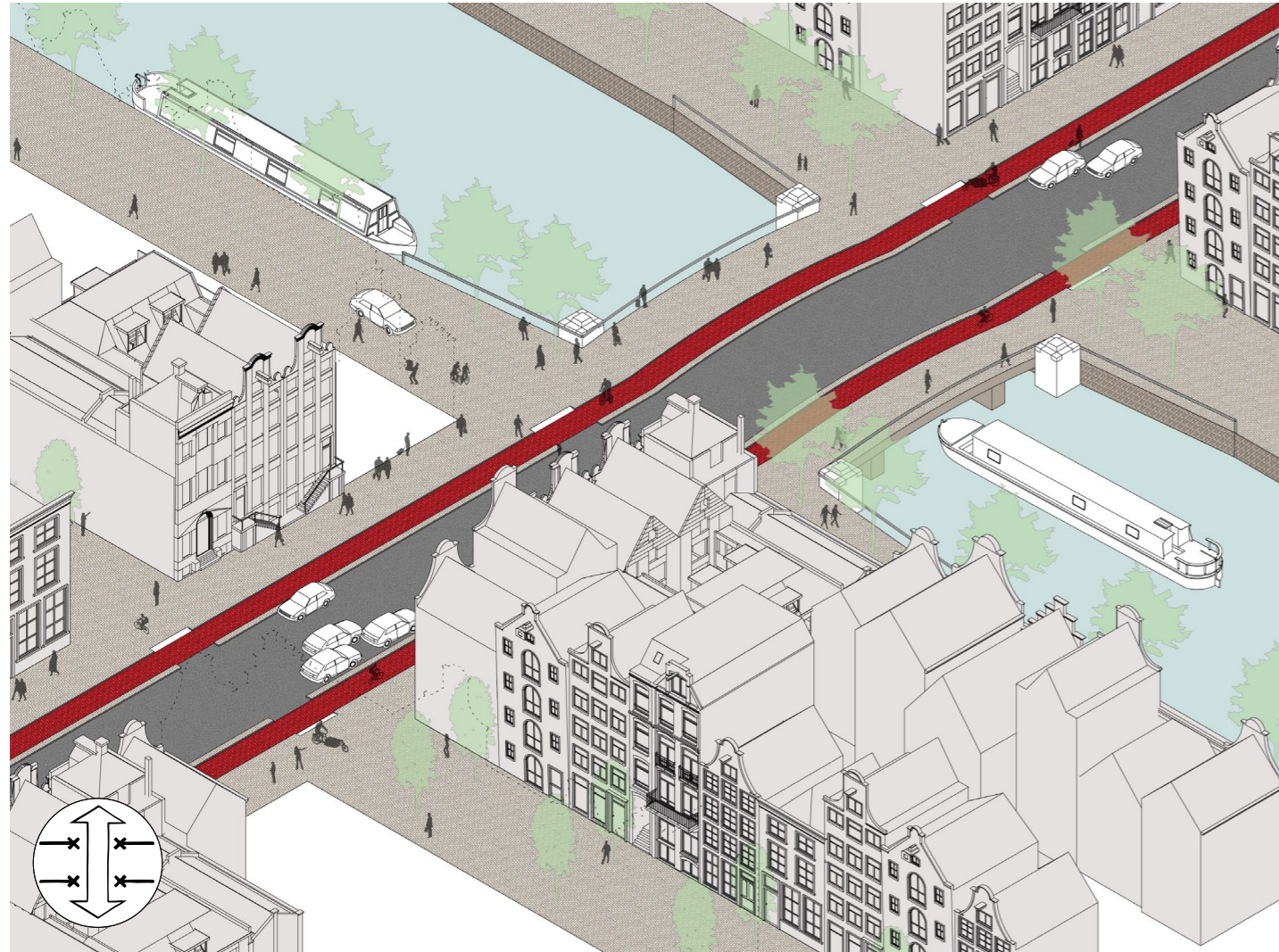


Parking can be moved from the street to garages. Car sharing, more efficient use of space, cloud awareness of parking space, and self-parking contribute to the possibility to remove many parking spaces. The remaining parking spots can be situated in garages. In an optimal scenario, the garages currently present in the centre should have enough capacity (see 4.2.17) but if additional parking is required, subcanal parking can be considered (see 4.2.16).

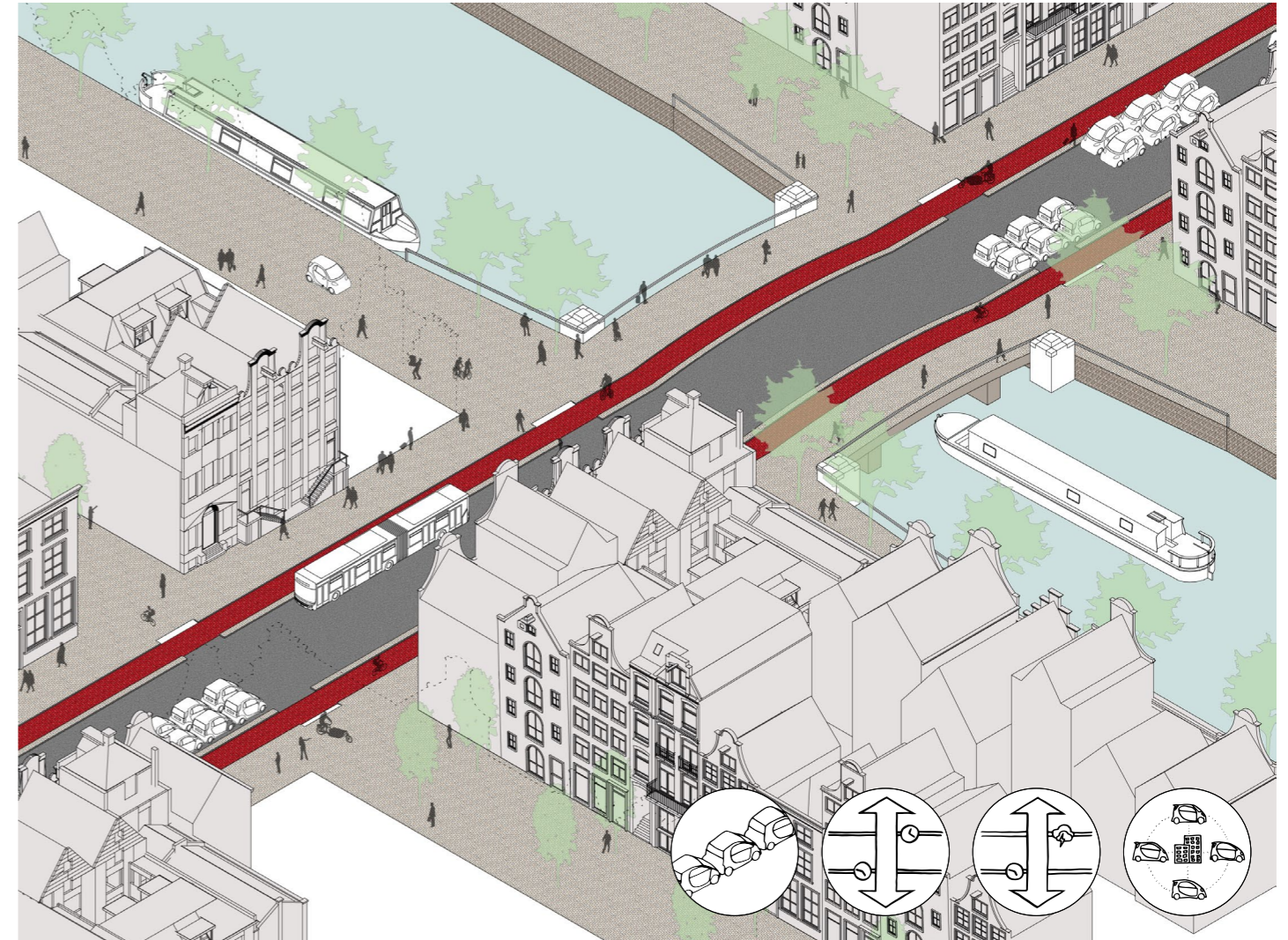
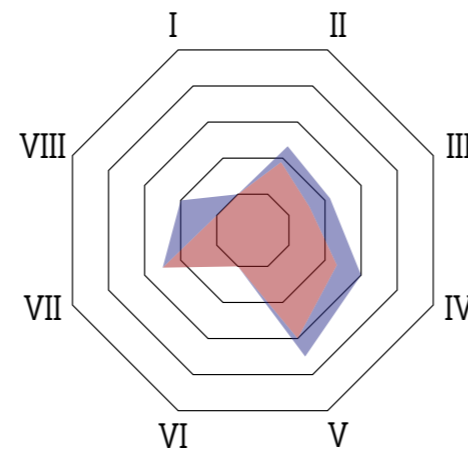


Signage, road markings, traffic lights, and other visual cues can be removed because AVs get their information from the cloud. This intervention is supported by the introduction of the default and conditional AV network. It contributes to the protection of pedestrians and cyclists, proper dimensioning of infrastructure, and visual stimulation. Removing all visual cues poses no problem for AV users but does pose a problem for pedestrians and cyclists, who still rely on their sight for information. To compensate for the removal of signage, an alternative system in the form of digital infrastructure is introduced. This will be discussed five pages from here.

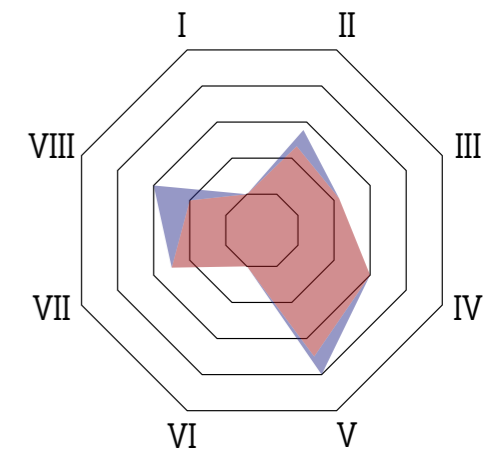


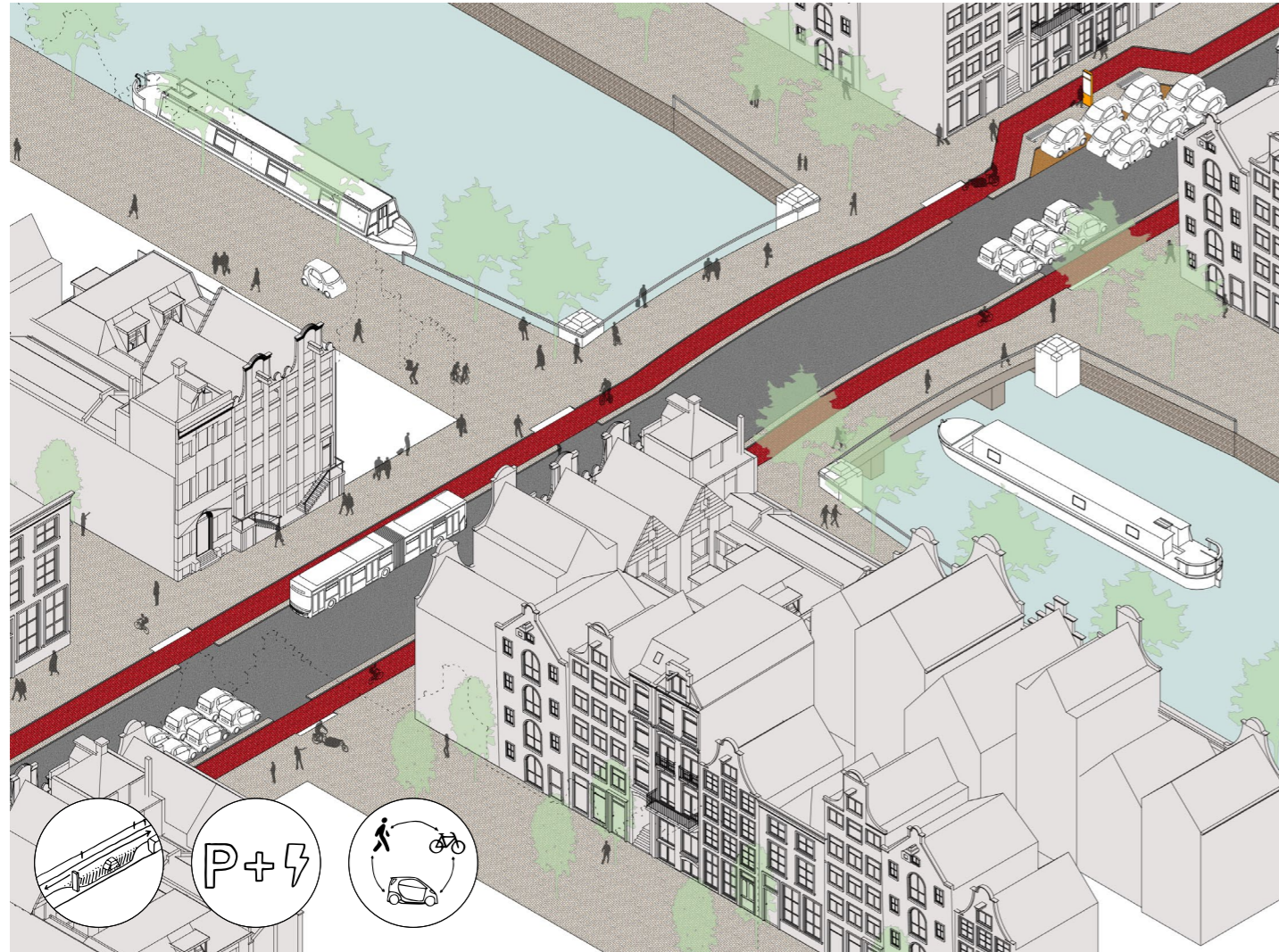


Because regular AVs use the same infrastructure as all forms of public transport on street level, and AVs drive more efficiently, infrastructure for AVs can be more narrow than infrastructure for regular cars. This means that sidewalks and bicycle lanes can be widened. Furthermore, bicycle lanes can be detached from the main road to prevent negative interactions between bicycles and AVs. This decoupling is necessary to guarantee optimal flow of traffic for AV lanes, without which the priority network does not make sense. Narrowing the infrastructure for vehicular traffic and broadening that of pedestrians and cyclists contributes to network coherence for pedestrians and cyclists, legibility of the city structure, protection of pedestrians and cyclists, proper dimensioning, and adequate connecting of attractors.

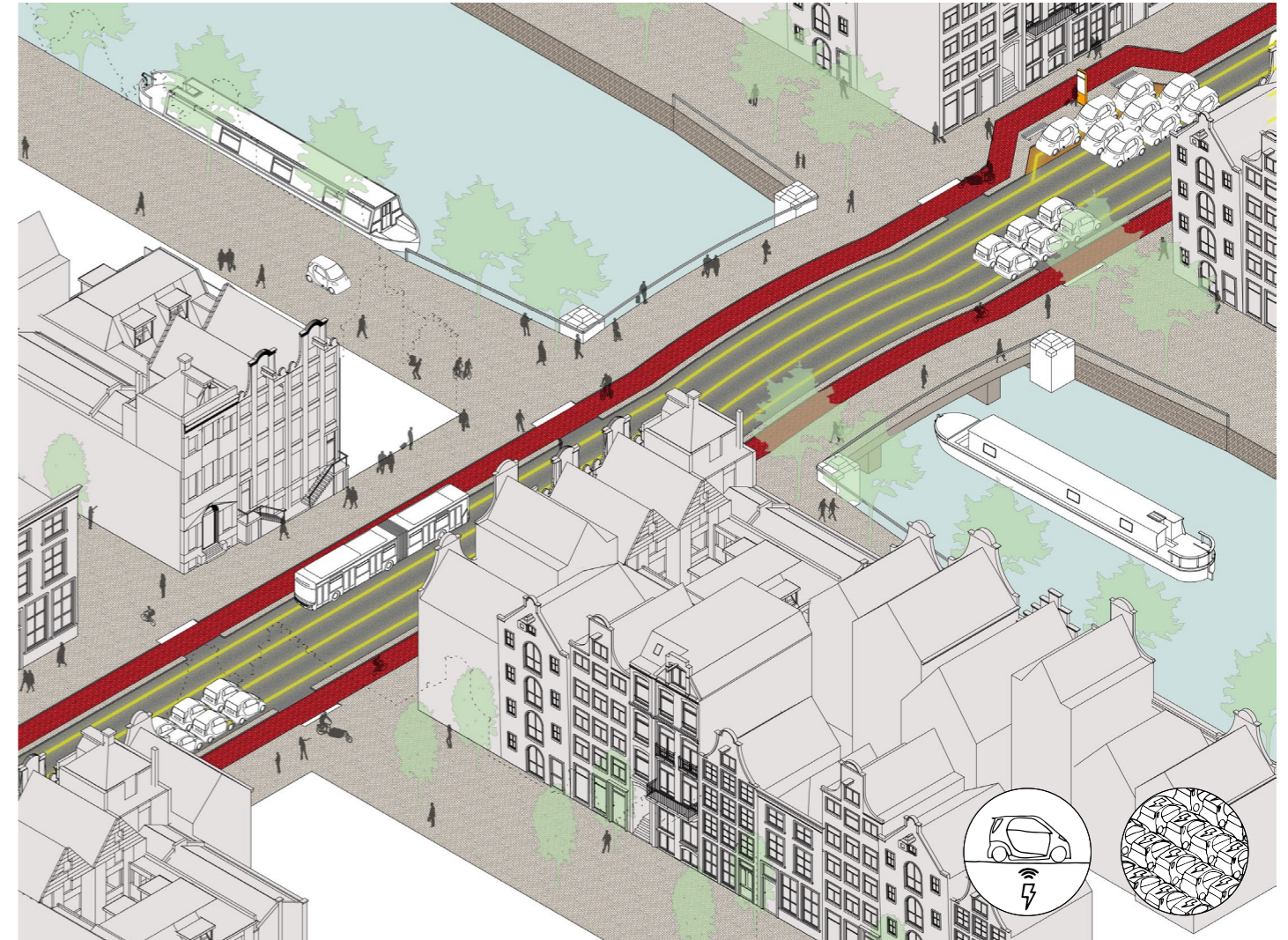
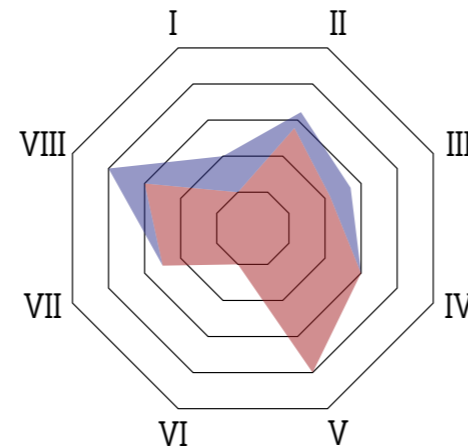


AVs can drive in convoys and high capacity automated vehicles can be added. Alternatively, linkable pods can be introduced which form an extremely efficient convoy (see 4.2.4). Convoy driving and high capacity vehicles lead to more efficient use of energy and large gaps between convoys that can be used for crossing the road. The functioning of convoy driving is supported by the introduction of a centrally owned fleet and conditional access roads. Convoy driving and high capacity vehicles contribute to network coherence of bicycle and pedestrian infrastructure, proper dimensioning of infrastructure, and connecting of attractors.

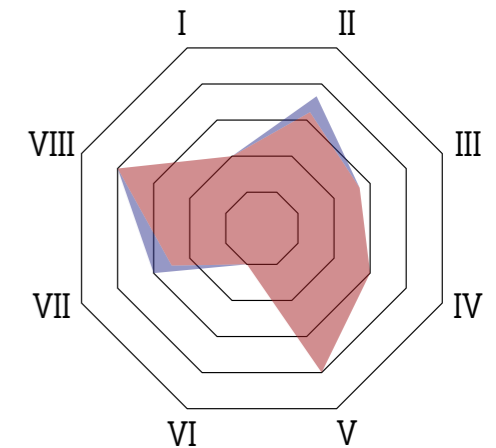


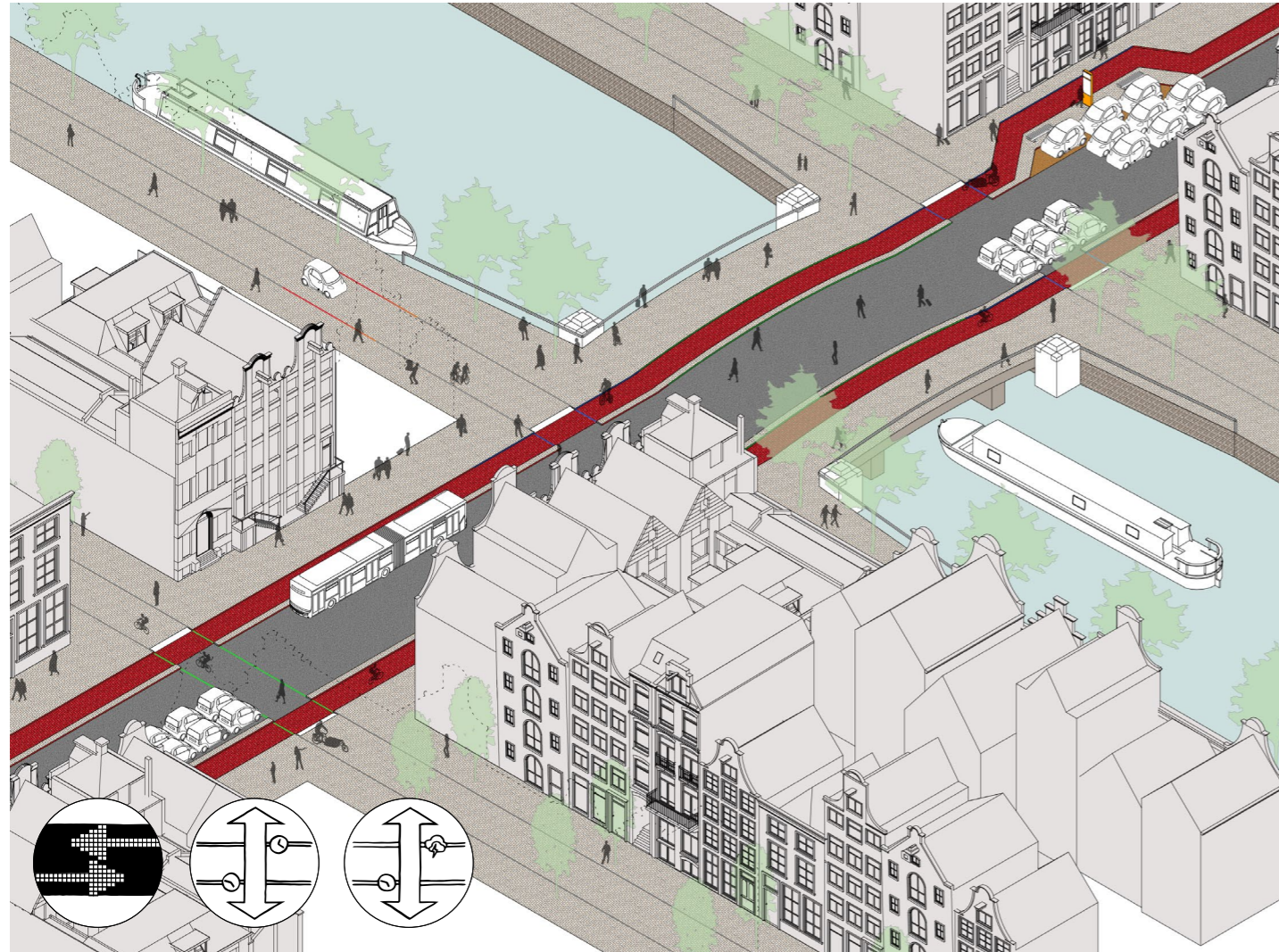


To guarantee both an optimal flow of AV traffic and comfortable embarking and disembarking of AVs, hop-on drop-off-spots are introduced along the AV network (see 4.2.16). These hodosses are outfitted with a recognisable coloured strip of paving and a totem that displays AV arrival times and can be used for summoning of AVs. The network of hodosses is complemented by park and charge hubs that harbour vehicles during off-peak hours (see 4.2.17). The hodosses are part of multimodal nodes which stimulate transfers between different modes of traffic. Introduction of hodosses and multimodal nodes contributes to mixed use neighbourhoods, network coherence, legibility, and connecting of attractors.



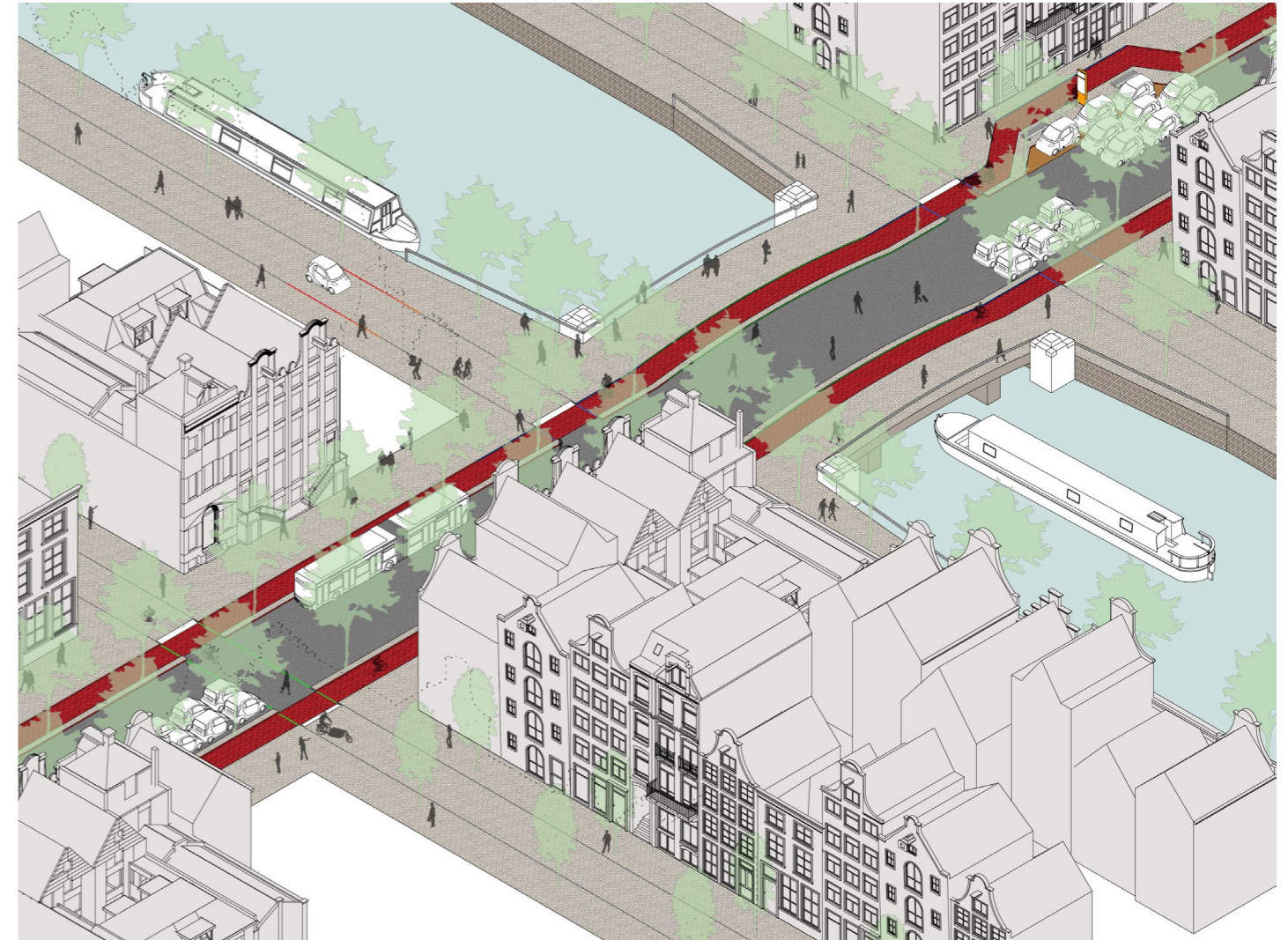
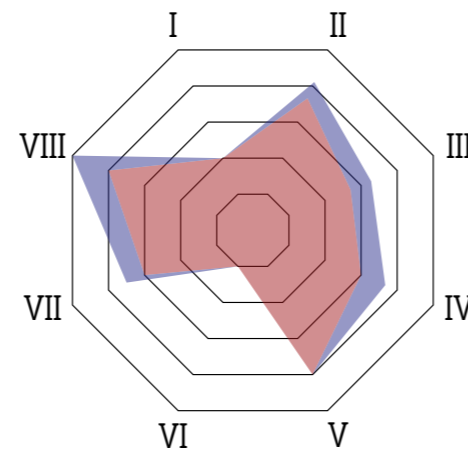
An invisible layer of inductive charging panels is added to the AV priority network (see 4.2.2). This layer charges vehicles while they drive, creating a smoother and more convenient travel experience. It furthermore helps the use of vehicles as a battery for the city. The introduction of an inductive charging layer contributes to network coherence and visual stimulation.



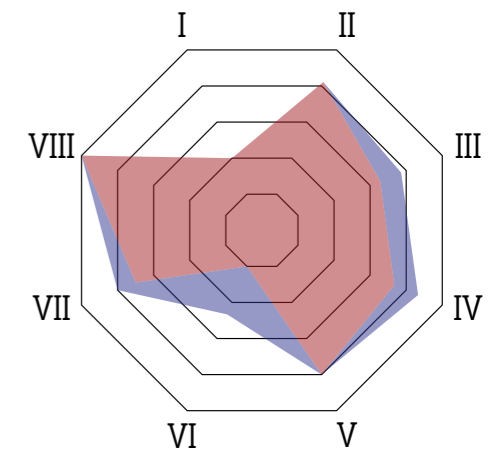


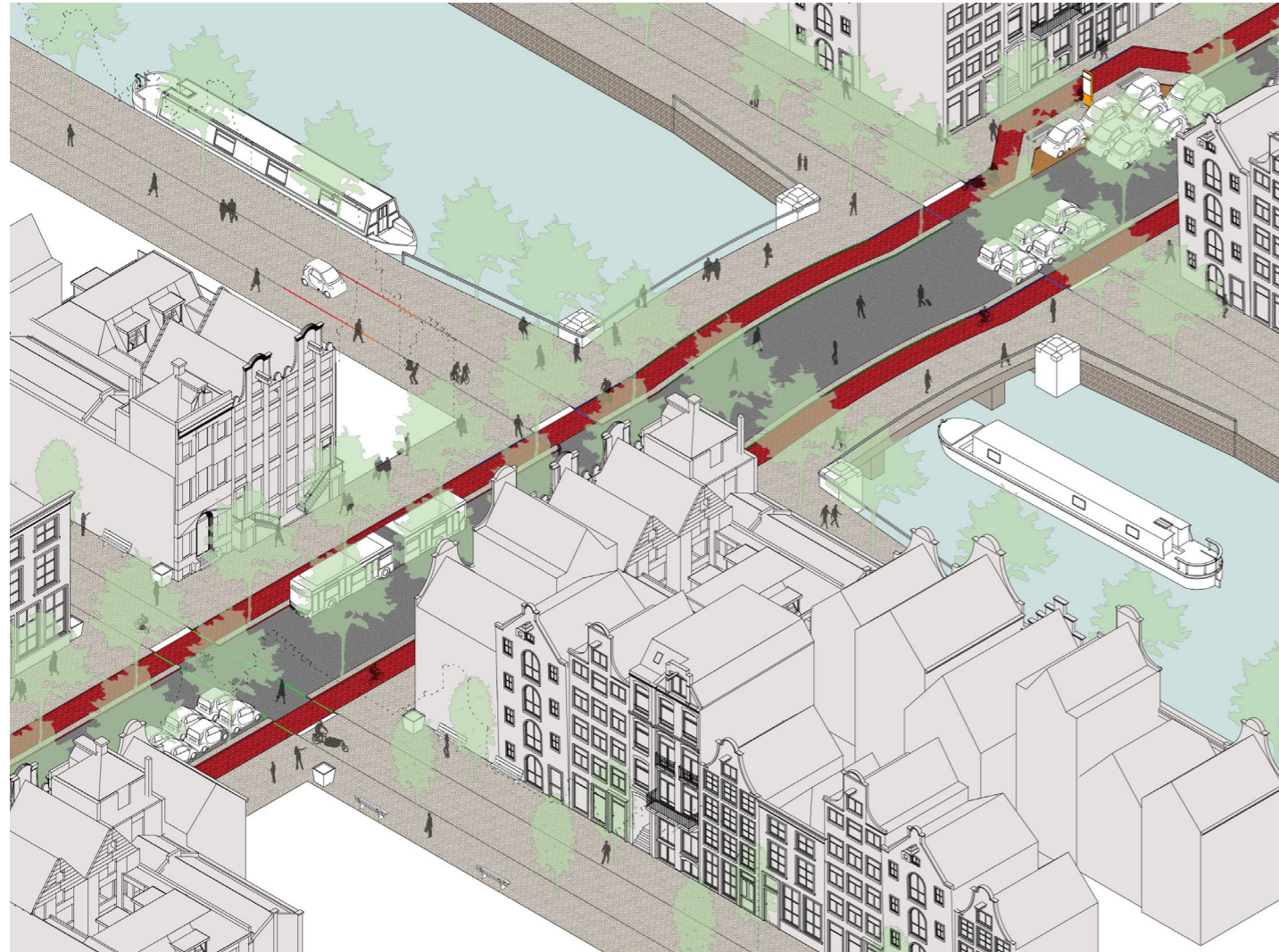
To replace signage, road markings and traffic lights, a digital strip is introduced for transferring information to pedestrians and cyclists (see 4.2.3). Because the strip is present along the entire infrastructure and because it is connected to the cloud. It can display information based on real-time context. Green light can be used to show a crossing possibility for pedestrians, orange light for an approaching crossing possibility, blue light can be used to inform cyclists of the optimal speed they need to adjust to in order to never stop at intersections, and red lights can be used to show the location of (approaching) traffic. Furthermore, red lights can indicate to users of neighbourhood streets that their streets has temporarily been transformed into the main AV network during event or incidents. This system helps pedestrians, cyclists, and people in AVs optimise their travel time and experience. The introduction

of a digital strip along infrastructure contributes to network coherence, legibility, protection of pedestrians and cyclists, visual stimulation, and connecting of attractors.

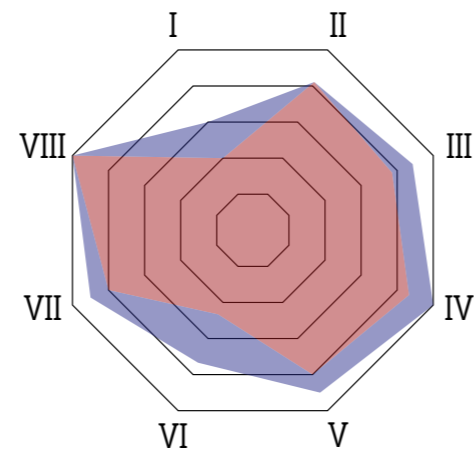


Because the widths of the different lanes in the main street have been changed, trees can be planted along the street. This directly improves the presence of green in the centre. It also contributes to legibility, protection, and visual stimulation.

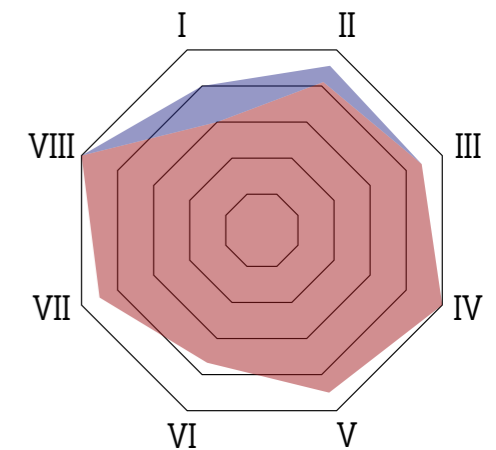


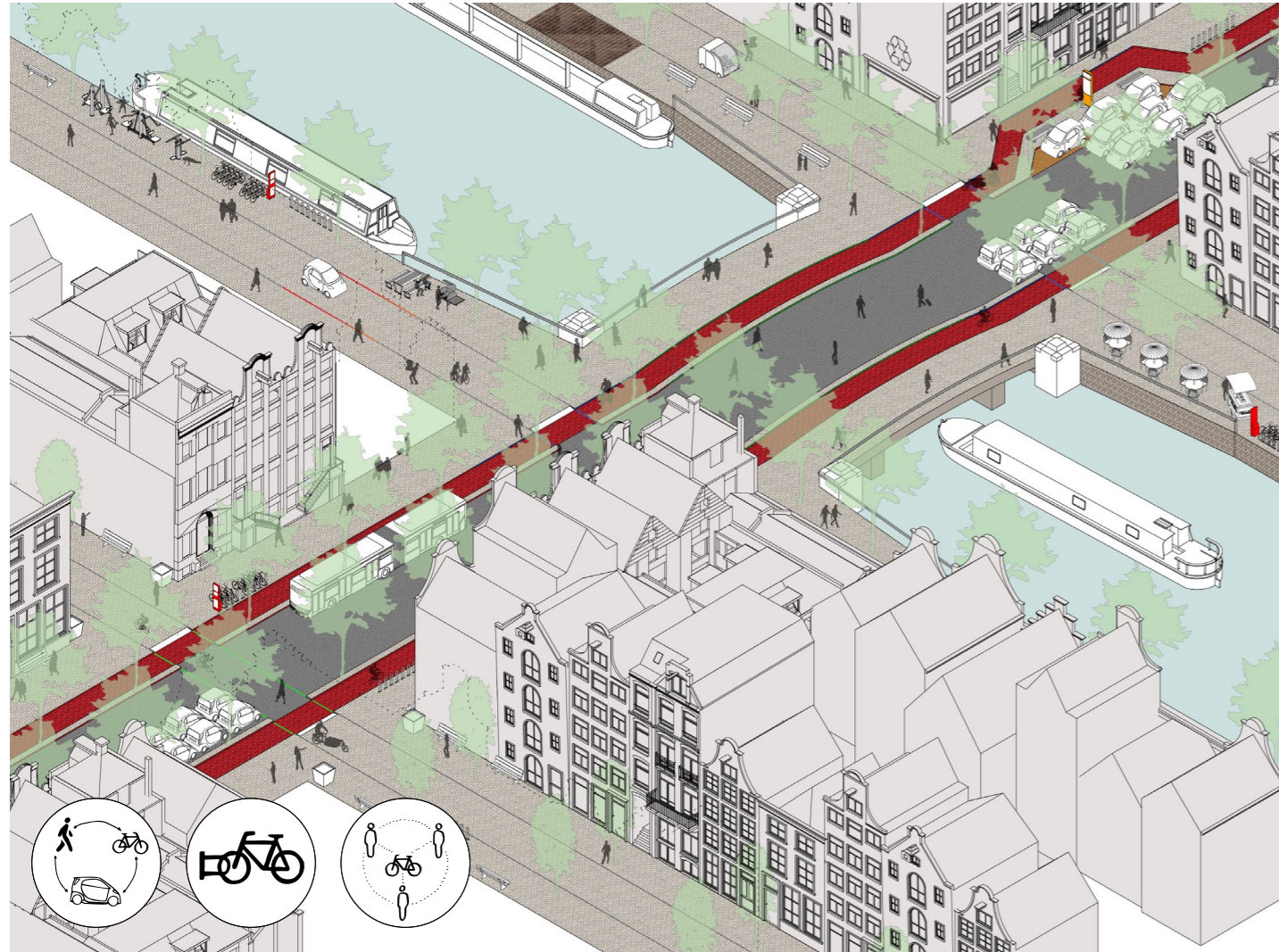


Because street parking has been removed from neighbourhood streets and vehicular traffic is largely absent, more reclusive streets are formed which stimulate space appropriation. This bottom-up process can be catalysed by placement of large obstacles at the corners of neighbourhood streets. These obstacles block passage and create lee at the sides of the street which can then be filled with plants, benches, and other objects by residents. This contributes to mixed uses, legibility, protection of pedestrians and cyclists, dimensioning of street profiles, presence of green, and visual stimulation.

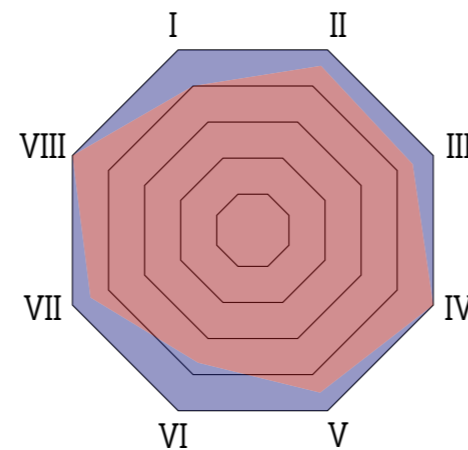


An alternative logistics system can complement the division between the AV priority network and the rest of the centre. Through the introduction of a neighbourhood logistics centre, multi-use vehicles, delivery assistance vehicles, and supply over water by autonomous boats, AVs used for logistics can be restricted to the default AV network while deliveries and supply of stores become more convenient. This intervention contributes to mixed uses and network coherence.





Finally, the space that is unlocked by removing street parking can be transformed into an array of new functions that support walkability, cyclability, and livability in general. Possible new functions include bicycle parking, spaces for a bicycle sharing programme, terraces, public barbecue spots, urban gyms, benches, and many others.⁷⁸ This reallocating of space contributes to mixed uses, network coherence, legibility, dimensioning, presence of green, and visual stimulation.



Pictured above is the street from the perspective of a pedestrian. It shows some of the non-spatial instruments in use: the bicycle sharing programme, the bicycle share smart lock, the GPS transmitter, and the multimodal app. These instruments help create conditions under which the network coherence, the legibility, the presence of green, and the connect attractors pillars can be strengthened more successfully. Also, some of the spatial instruments can be seen in action: the priority lane, digital road surface, convoy driving, and conditional access road.

The logistics app, the car fleet as battery, and the centrally owned fleet instruments have been pictured in none of the images in this section. They are non-spatial instruments that can play an important role in working towards walkability and cyclability however. As such, their presence should be kept in mind when looking at the images.



5.4.1 The Complex Commuter

Esther, 34, is a young woman living in Amsterdam's city centre with her partner and two children. She has a busy social life and she works at the Zuidas. In the past she used to ride her bicycle to work but ever since she had children, she has been going to work by car so she can drop off her kids at school before work.

Esther's transportation challenges

- Has to drop off and pick up her kids from school.
- Has to get to work every weekday morning and back every weekday afternoon.
- Visits friends in many places in the city.
- Needs to get groceries and goods on a daily basis for her family.
- Often struggles to find parking at friends' houses and getting back home means that she or her partner has to be a designated driver.

Future Esther

Esther gets up in the morning and is warned by her transportation app that it is raining outside and asks if she would like to take an AV to work instead of going by bicycle. Her children can go to school independently because the route from her house to school is no longer dominated by cars. Esther decides to take an AV to work and after a short calculation her app tells her that she will be picked up at 8.35 at the nearest hop on drop off spot down the street so that she will arrive comfortably in time at work. Because Esther does not have to bother finding a parking spot, never has to stop for gas, and route information is always up to date, she is quite certain of her arrival time. On her way to work Esther has time to order groceries and a new pair of shoes for her son. After work, it has stopped raining and Esther decides to pick up an electric rental bicycle from the bicycle sharing programme. Her way

home along a new bicycle priority lane is fast and relaxing as there is ample room for all bicycles, slow, fast and everything in between. On her way home she picks up the groceries and shoes she ordered in the morning at the logistics centre at the corner of the street. When Esther gets home, her partner Barbara is playing outside with the children at a small playground that used to be parking space. In cooperation with Amsterdam's municipality, Esther and Barbara have helped come up with a new function for the parking space that had become obsolete. In the evening, after having a few glasses of wine, Esther realises that she forgot to pick up a dress she was supposed to borrow from a friend. In the past, she would not have been able to still drive there, but now, her friend sends the dress with an AV in a special compartment which Esther is able to open with her smartphone, using her personal account.



5.4.2 The Elderly Tourist

Donald, 70, is a tourist from the United States who likes to take a stroll. He would like to explore Amsterdam by bicycle but is afraid he will get hit by a car or an infamous Amsterdamer on a bicycle. Donald would also like to see as many of Amsterdam's touristic attractions as possible but he is afraid that he will run out of energy before getting a chance to visit everything.

Donald's transportation challenges

- Is not familiar with Amsterdam's travel options.
- Is not physically able to travel long distances by foot or by bicycle.
- Does not like to spend a lot of time understanding something complex.
- Wants to move between many different spots using different modalities.

Future Donald

Donald arrives at Amsterdam central station in the morning. Upon arrival he immediately notices a large information desk where he gathers information about Amsterdam's transportation possibilities. He is happy to find that all modalities can be accessed from one application on his phone and he creates a personal account which he links to his smartphone right away. Using this account he immediately rents a bicycle and he sets out to explore the city. Donald ends up cycling mostly through neighbourhood streets, which are free of cars and offer a beautiful sight. After a while he decides that he would like to visit the Anne Frank House but he doesn't know how to get there. Donald returns the bicycle at a small node and summons an AV using the totem at the hop on drop off spot. Within minutes he is picked up and he instructs the car to drive him to his destination. After seeing the Anne Frank House he

decides that he would like to visit the Rijksmuseum. He uses his smartphone application to determine the route and based on the route he decides to walk to the Rijksmuseum. On his way there he is amazed to find that he does not have to wait to cross a road even once. A digital strip along the main roads instructs him where and when he can cross and makes his trip highly comfortable. After visiting the Rijksmuseum, Donald decides to use an AV to get to some other hotspots Amsterdam has to offer. At the end of the day, Donald again rents a bicycle to get to his hotel. He uses one of the bicycle priority lanes and is again amazed by a tremendous digital strip which helps him adjust his speed so that he does not have to wait even once. In the end, Donald had the best day, he had a tremendous day.



5.4.3 The Blind Entrepreneur

Danny, 55, is a blind guy who lives and owns a shop in Amsterdam's Haarlemmerstraat. He usually walks everywhere but his walks have become increasingly unpleasant because of overcrowding on the sidewalk and the road. When visiting friends or family, Because of his visual impairment, Danny depends on cumbersome public transport connections to get around. Danny's shop is supplied daily by friends who own a van.

Danny's transportation challenges

- Often misses transit transfers because of his visual impairment.
- Has trouble getting to local facilities such as the supermarket because of the crowds.
- Relies of his friends for supplying his store.
- Pays too much for supply of his store because van is not at full capacity.

Future Danny

Danny gets up in the morning, has breakfast, and walks to his store. On the way there, he stops at the local logistics centre where he makes an appointment for delivery of his daily supplies. His walk to the store is much more comfortable than it would have been in the past because cars now only drive through the street in exceptional cases. In Danny's case, one car drives through the street during his walk, he is warned of the approaching car by his white cane, which is now outfitted with a sensor responsive to cues given by the infrastructure. Upon arrival at the store, Danny realises he forgot to order coffee. Using a smartphone application with voice control, he expands his order. Later in the day, all his supplies and the coffee are delivered by a postman who is assisted by a self-driving delivery vehicle that automatically follows him and opens when supplies need to be

taken out. After work, Danny decides to visit his mother on the other side of the city. He summons an AV which picks him up at the corner and drops him off right at his mother's house. Normally, this area is inaccessible for AVs but because of Danny's visual impairment, he is exempted from this. Upon entering the AV with his smartphone, the vehicle is automatically granted special access to this neighbourhood. On the way over to his mother, Danny is notified by the vehicle that an accident has happened and that the vehicle is diverting from its normal route, using a temporarily available alternative route which has become accessible after the accident made the main network temporarily unusable. At the end of the day, Danny is taken back home by the AV again. He sits down on a bench in front of his house and enjoys the sounds of passing pedestrians and cyclists before finally heading to bed feeling satisfied.



5.4.4 The Frequent Visitor

Isabel, 24, is a student from Leiden whose boyfriend lives in Amsterdam's city centre. She visits the city often because her boyfriend, many of her friends, and most of her family lives there. She usually walks from the central station to her boyfriend's house, who lives at the end of the Reguliersgracht. She used to have a bicycle but it got removed a few times because it was hard to find a bicycle parking spot so she decided to walk, which she really enjoys. When visiting family or friends, she often uses public transport or she borrows her boyfriend's bicycle.

Isabel's transportation challenges

- Has to get back to her boyfriend from friends' houses late at night.
- Has a small budget.
- Getting to her boyfriend's house on a Friday night is a hassle because of overcrowded infrastructure.

Future Isabel

Isabel arrives at Amsterdam's central station late afternoon. She walks to her boyfriend's house and from there they take a stroll around the centre in search of a place to have dinner. The search doesn't last long, the incredibly walkable centre has incentivised many new restaurants to open their doors. After dinner, Isabel and her boyfriend Adriaan walk around a little more and laughingly enjoy an urban gym that has popped up down the street in place some parking spaces. They then sit down along the canal and enjoy the boats passing by for half an hour before getting on their way. Isabel has a birthday at a friend's house in IJburg. She borrows a bicycle from the bicycle share system and heads to her friend's house. At the end of the night, Isabel decides that she would feel uncomfortable to cycle back to her boyfriend by herself at night and she orders an AV. Because the AV is designed

specifically for transporting one person, it is very affordable, even for her. In the past, she would have paid more for a night bus. Isabel is dropped off close to Adriaan's house and walks the last bit. She is amazed at the amount of trees and plants that now adorn the street, many of which were placed by residents. The following morning, Isabel has to get back home. She borrows a friend's bicycle which is located close to her boyfriend's house, her friend is arriving at the central station later in the day and that is where Isabel needs to go so it creates a mutually beneficial situation. Isabel's friend grants her access through her smartphone and shares her bicycle's location. As such, Isabel is quickly able to find and open the bicycle and get to the central station and back to Leiden.



EPILOGUE

**“Don’t it always seem to go
that you don’t know what you’ve got
till it’s gone.
They paved paradise
and put up a parking lot.”**

Joni Mitchell (1970)

This section answers the research question of the project: “How can Amsterdam improve the walkability and cyclability of its city centre by strategically engaging the transition from cars to automated vehicles?”. The research question is an open question and as such there is no single correct answer. Rather, the answer is multi-layered and aims to answer the question as complete as possible. This is done by discussing the pillars of walkability and cyclability that were established in section 2.1 individually and listing the possibilities opened up by the introduction of automated vehicles that can strengthen these pillars.

The first pillar, *Mixed Uses*, concerns the presence of different urban functions. While Amsterdam’s city centre already features an abundance of functions, automated vehicles do offer the possibility to further improve this. By creating low traffic areas which favour the most lucrative group of travellers¹³: pedestrians. Through the dimensioning of infrastructure, more profitable conditions for shops can be created throughout the centre indirectly. Furthermore, a new system of logistics, complemented by neighbourhood logistics nodes, provides a new physical function to neighbourhoods. The nodes function as an improved post office, pick-up spot, and recycling centre while providing the means for interaction between residents.

The second pillar, *Network Coherence*, was found to be already physically present. The goal of this project was thus merely to maintain this coherence and combat the effect of overcrowding which could render some streets useless as a connection during peak hours. Here, AVs can help by allowing a redistribution of street profiles between modalities. Because streets for AVs are potentially smaller in width, more space can be reserved for pedestrians and cyclists. Also, because AVs do not require a coherent network for wayfinding or other purposes, since they are informed from the cloud, their network can be made incoherent, allowing more space for pedestrians and cyclists at critical spots. Next to this, multimodal travel has been facilitated to improve the coherence not just of the networks, but also of the total travel experience of all users.

The third pillar, *Legibility*, was found to be sufficient but could profit from a more clear division between neighbourhood streets and connecting streets. This division has

been provided. Neighbourhood streets have been transformed into shared space while connecting streets have been transformed into priority lanes which allow an efficient traffic flow through the city for AVs, cyclists, and pedestrians. While the priority networks for pedestrians and cyclists have been organised such that wayfinding is optimised, this was not a criterion for the AV priority network. AVs find their way through external input which does not require physical wayfinding clues or a logical lay-out of the network.

The fourth pillar, *Protection*, has been changed by implementing a combination of shared space and priority networks. Shared space favours pedestrians and potentially becomes even more safe with the arrival of AVs. To optimise the conditions for shared space to function, it has been separated from streets providing the fastest route, the priority networks. In particular, the bicycle priority network aims to attract cyclists who need to get to their destination as fast as possible. By offering this priority network, fast cyclists are mostly diverted from shared space, leaving favourable conditions for pedestrians. AVs make use of exclusively the priority networks, with exceptions that can be changed at any time. By default, only residents and emergency services could enter neighbourhood areas by AV but extra exemptions could be made at any time. Possible exemptions have been listed in section 5.2.3 and include traffic accidents, extreme weather events, and vehicles transporting physically impaired individuals. Sharply setting these conditions can minimise the amount of AV traffic in neighbourhood areas, further optimising the conditions for shared space and thereby the safety.

The fifth pillar, *Dimensioning*, is key in improving walkability and cyclability. It is not only directly important, it also contributes to strengthening some of the other pillars. Because automated vehicles can drive much more efficiently, space is freed up in street profiles which can be used to create space for other modalities. Optimisation has been achieved by replacing trams and buses by high capacity automated vehicles which function similar to regular AVs. This allows them to cooperate and as such, optimise use of infrastructure. Furthermore, and even more importantly, AVs can park themselves at peripheral areas or in efficient garages to free up large amounts of parking space in the centre. This space can sometimes be used

to broaden the infrastructure of other modalities, but can otherwise be used for many different things. This contributes to a better distribution of street space.

The sixth pillar, *Presence of Green*, has been improved by planting trees along connection streets, which is made possible by the efficient space use of automated vehicles. Furthermore, conditions have been created for space appropriation by residents through the transformation of neighbourhood areas into reclusive shared space. Appropriation is often done by placing plants in front of one’s home and as such contributes to a more green environment.

The seventh pillar, *Visual Stimulation*, has been achieved in three major ways. The first is that parking along the canals can be moved or even removed. This allows pedestrians and cyclists to view the canals, one of Amsterdam’s defining qualities. The second is through the transformation of neighbourhoods into low traffic shared space. This will stimulate space appropriation which can create even more diversity in neighbourhood areas. The third is that the transformation of neighbourhoods into shared space and that of parking into urban functions can stimulate street life and street life is considered the most important visual stimulation by many urbanites.

The eighth pillar, *Connect Attractors*, was found to be present in the centre already. The goal here was to maintain these connections, even with growing traffic flows. Automated vehicles contribute here by allowing broader pedestrian and bicycle infrastructure at important connections. Furthermore, connections between attractors have always been optimised for pedestrians and cyclists through placement of priority lanes, sometimes at the expense of AVs. This is possible because AVs do not require a logical route between attractors since they receive their information from the cloud.

In conclusion, AVs are able to address all eight pillars of walkability and cyclability that were established. However, if they are to strengthen the eight pillars, they have to be considered not as a new car technology that needs to be facilitated right away but as a technology that creates possibilities. These possibilities need to be seized through careful and thoughtful planning, through avid testing, and through passionate cooperation.



¹⁷ Typical current situation of a crossing in Amsterdam’s city centre between a connecting radial street and neighbourhood streets, one of which along a canal, and one of which a regular street.



¹⁸ Proposed future situation for a typical crossing in Amsterdam’s city centre between a connecting radial street and neighbourhood streets.

Self-driving cars are currently still surrounded by a shroud of mystery. It is unclear when they will be introduced, what they will be able to do, and how people will use them. If cities anticipate and respond to automated vehicles properly, it is clear that many potential benefits can be reaped. However, forming a proper strategy is complex, and if cities respond inadequately, it is possible that automated vehicles will have a negative influence on cities and city dwellers. The aim of this project has been to show how AVs **can** be used to create a city in which livability, accessibility, and public space are optimised. This has been done by creating a vision of a possible future. As such, it has never been the objective to provide practical recommendations, but rather to inspire. Nonetheless, some expertise on the subject of automated vehicles in the context of Amsterdam's centre has been obtained. This expertise will be employed to make some recommendations on how to anticipate and respond to AVs. Before getting into the actual recommendations I would like to further stress the importance of taking into account pedestrians and cyclists when responding to automated vehicles through spatial interventions. If pedestrians and cyclists are unhappy with their position, their behaviour is currently restricted because ignoring the rules provided by signs and infrastructure is simply unsafe. With the introduction of AVs, this changes. AVs will always stop when a pedestrian or cyclist suddenly crosses, whether or not they are following the rules. Pedestrians and cyclists might certainly take advantage of this inference, and will be more likely to do so if they feel like they are being pushed out of space that they deserve. Hence, giving room to pedestrians and cyclists is not just a courtesy, it is a necessity.

First off, it is important to note that most possibilities that have been shown in this project are made possible by the assumption that **all** regular cars will be replaced by automated vehicles. Interaction between automated vehicles and regular vehicles is suboptimal, and if full automation of vehicles is achieved, an attempt should be made to make a full transition from regular vehicles to fully automated vehicles as fast as possible. Some recommendations aim to achieve this fast transition. All recommendations fit in one of three categories: preparations, immediate responses, and gradual responses. These

categories will be discussed in three separate paragraphs.

6.2.1 Preparations

Some preparations can greatly improve the way the city can deal with the arrival of automated vehicles. These preparations should minimise upfront investments in case full automation is never actually achieved.

Develop Multimodal App

Developing a multimodal app that is able to integrate AVs as soon as they arrive can contribute to the use of AVs in a multimodal chain, discouraging excessive vehicular traffic.

Be Patient with Development

Early forms of automated vehicles are likely to function very differently to later forms. For example, they might actually take up more space than a regular vehicle. Do not adjust infrastructure to these early forms but wait for later forms to arrive, because they offer more advantages and infrastructural developments are a money and time consuming process.

Explore Possible Uses of Unlocked Parking

If less parking space is going to be needed, a significant amount of space will free up. This space must be pro-actively managed to lock in possible benefits. To do this, new possible uses need to be researched in advance. This can be done through cooperative pilot projects or workshops between involved parties such as residents and local businesses.

Develop Parking Removal Strategy

As soon as less parking spaces are going to be needed, it would be beneficial if a strategy were present for transformation. This strategy should consist of a prioritisation of parking spots, e.g. it should be clear which parking spots offer the most advantages if transformed.

Experiment with Shared Space

Creating shared space in neighbourhood areas is a great way to reduce the dominance of vehicular traffic. While automated vehicles can improve the functioning of shared space even further, they are not necessary for shared space to be a success. Experimenting with the introduction of shared space in residential areas can help in the creation of knowledge that can be developed further when AVs are introduced.

Establish Rules for Accessibility

When connected vehicles will be able to adapt to rules in real-time based on their use and user, it will become possible to restrict certain areas for certain uses or people (see 5.2.4). This means traffic can be guided smartly. To do this in an efficient and honest matter, rules need to be established that dictate what constitutes a good enough reason to enter a specific area.

Test Digital Strip Along Road

A digital strip along roads can help transmitting information to road users. The possibility to change this in real-time relies in part on the presence of AVs but the functioning of such a strip can already be tested, for example by placing them along bicycle infrastructure and using them to indicate optimal travel time for a *green wave*.

Research Privacy Issues

Connected vehicles are a great way to gain knowledge on traffic patterns. Also, the personalised nature of AVs allows honest and efficient traffic coordination. On the other side, it poses problems concerning privacy. To take full advantage of personalised and connected vehicles, these problems concerning privacy need to be solved.

6.2.2 Immediate Responses

Limit Vehicle Width

Eventually, AVs are predicted to drive much more precisely. This allows narrowing of roads. However, before all vehicles are able to drive this precisely, people might start using larger vehicles because they still fit on the same road. This would completely ruin the possibility to make roads narrower. To avoid this, a maximum to the allowed vehicle width should be introduced for Amsterdam's centre.

Limit Power of Transportation Companies

Transportation companies like Uber will likely be at the forefront of automated on-demand vehicles. This will make vehicular traffic so accessible and affordable that it will likely grow heavily. To counteract this effect, such transportation companies should be restricted in their powers. Clear arrangements should be made that dictate how automated traffic is allowed to operate. Certain streets could, for example, be made inaccessible to on-demand vehicles.

Incentive Against Unmanned Vehicles

When fully automated vehicles are introduced, cars are able to drive without people in them. This can be used for delivering goods and for making cars park in cheap peripheral areas. This is likely to incentivise more traffic. To counteract this effect, privately owned vehicles should be fined for driving around unmanned.

Stimulate Car Sharing

Car sharing becomes much more attractive with the introduction of automated vehicles. This trend can greatly reduce both car traffic and the amount of parked cars. To stimulate this, subsidies and programmes can be introduced for car sharing.

Announce Ultimatum Regular Car Use

Because regular cars counteract or prevent many possible benefits of automated vehicles, the goal should be to eventually make a complete switch to automated vehicles. To minimise the time of this transition, the intention should be made clear as soon as full automation is introduced. Furthermore, it should be made clear that after a set amount of time, regular vehicles will no longer be allowed to enter the centre.

Stimulate Use of Connected Vehicles

Connected vehicles, as has been mentioned before, offer a range of possibilities for a municipality. They can help guide traffic and create car-free zones where desirable. The use of such vehicles should thus be stimulated.

6.2.3 Gradual Responses

Increase Price of Parking Permits

When on-demand automated vehicles become a viable alternative for privately owned vehicles, private ownership of vehicles should be discouraged. This can be done, for example, by increasing the price of parking permits.

Experiment with Optimal AV Network

If a default network is to be introduced, its layout needs to be established first. This can be done by testing the functioning of a network and tweaking it where difficulties arise.

Reach Out for Other Cities

Development of a coherent infrastructure for automated vehicles can be done more efficiently if cities cooperate. This allows a smoother transition from inner city to intercity travel.

In this section, I will reflect on the process and the results of the project. First, I will discuss what role I envision for the project with regard to the introduction of automated vehicles in cities. From there, I will discuss the sensitivities and pitfalls of the project.

In 1935, 'The Steadyflow Traffic System' was first published. In it, the authors hypothesized that a city where the street system permits vehicles to move around without obstructions would be a city in which pedestrians can move around freely and safely without any fear and danger from vehicular traffic (Malcher, Hubbard, & Hubbard, 1935). The manifesto was heavily influential, especially in many American cities. Cars have been given free rein and this has had its consequences. In cities that adapted to the ideology, pedestrian fatalities did decline (Viola, Roe, & Shin, 2010), but only because people stopped walking as cars annexed increasingly more space. With the introduction of automated vehicles, we find ourselves at a crossroads where we have to choose between facilitating vehicular traffic or facilitating slow moving traffic once again.

This project aims to steer the decision towards slow moving traffic by showing an inspiring possible future. To make people look at automated vehicles differently. To make people think about how automated vehicles can be used to improve the livability of urban areas rather than how urban areas need to be transformed to facilitate automated vehicles. Another objective of the project is to provide a set of tools that municipalities can use if they wish to make use of the possibilities that AVs offer with regard to livability, accessibility, and public space. I have chosen to show the possibilities specifically for the centre of Amsterdam, both because it has been experiencing problems concerning livability, public space, and accessibility at an increasing rate, and because I personally feel connected to and responsible for the heart of this city.

Taking into account these objectives, I will now reflect on the project. Before anything else, I will immediately point out a weakness in the project. While the project specifically aims at inspiring people within the municipality of Amsterdam and at providing them with tools, I did in no way cooperate with the municipality. This decision has been made because I prefer to present them a solid product that is thoroughly

researched. Cooperating with the municipality from an early stage however, would have opened up the possibility for interaction and integration of existing plans and visions. During the project I found out that Amsterdam is in transition more than I could have imagined. Every week, sometimes daily, new relevant developments would pop up in the city or with regard to automated vehicles. Many of these developments could in the end not be integrated into the project. Cooperation with the municipality could have led to a more integrated project.

The first objective of the project is to show an inspiring possible future. To achieve this, an unconventional methodology was created. Scenarios were used for the exploration of possible futures in which automated vehicles operated in different ways. This unconventional methodology yielded an array of instruments that have been combined and applied to show an inspiring and achievable possible future. Reflecting on the result, I am content with the outcome. The exploratory methodology has produced many original ways of dealing with automated vehicles. My main critique here would be that a larger amount of inspirational images could have been created. Images like photorealistic renderings or collages that can be understood by laymen and people from different disciplines can help communicate the presented future better. More of such images would thus have contributed to a more convincing vision for the future.

The second objective is to provide instruments that can be used by the municipality of Amsterdam in particular or as a starting point by other municipalities. Herein lies the most important weakness of the project. Because of the way the project has been structured, the catalogue exclusively contains instruments that were derived from the scenarios that were constructed earlier. During the design phase, additional instruments have been used that were obtained in the literature research phase but these are not present in the catalogue. The most important example of such an instrument is 'autonomous parking'. This weakness follows from the way in which the project has been structured and is thus not necessarily an error but an inconvenient side effect. To solve this, a compressed booklet of the project with just the information relevant for future development will be made, which explicitly includes these currently implicit instruments.

Finally, there is one more important possible pitfall for the project. The decision to create an inspiring vision for the future is both the strength and weakness of the project. An informed decision has been made to embrace the power of design to inspire, but the downside of this will be discussed nonetheless; showing a possible future through images can inspire but has the downside that the images might start to look implausible if just one aspect of the image becomes impossible at any point in the future. This makes the power of the images vulnerable to developments that divert from assumptions that were made while constructing the images.

The reason that I have chosen to work with inspiring imagery is that I believe that we as humans play a role in shaping our own future. This, however, requires us to set goals and act on them. If we are to take advantage of our technological advancements, we need to find out how we can use them for the benefit of mankind, and formulate common goals. I hope this project can contribute to the formulation of these goals and help create a bright future.



RESOURCES

**“If I have seen further it is by
standing on the shoulders of giants.”**

Isaac Newton (1676)

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