The potential role of Dutch urban and transportation planners in the Automated Vehicles transition.

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Preface

This report is the result of a master thesis project in fulfillment of the last course of the Master of Science in Complex System Engineering and Management at the faculty of Technology, Policy and Management of Delft University of Technology, together with a scientific article.

The subject area of this research is the role of urban and transportation planners in the Automated Vehicle transition. This research will evaluate to what extent Dutch planning authorities are considering AV technologies in urban mobility plans at this stage of the Automated Vehicle transition and how they could do this. This is done by conducting first a literature study (chapter 3) and secondly a field research (chapter 5).

I would like to thank everyone that contributed to my research. I would like to thank my friends and family for their patient and support, especially Anduo Kaatee, Laura Matthijssen, Marlies Reekers and Michiel Matthijssen. Secondly, I would like to thank all the respondents of the field research for sharing their knowledge and expertise on this subject. I also want to thank my colleagues at Arcadis, who gave me a lot of helpful advice and positivity. Lastly, I would like to thank the members of my graduation committee for their valuable feedback and motivation during the whole process.

The, Hague, 2018

Opening anecdote

Once upon a time, there was a very happy family, with a father a mother and their three very bright daughters: Diane, Sarah and Jane. The three sisters were inseparable and played together every day. When they got older they turned into a princess, a scientist and an engineer. Diane the princes lived very happily with her prince in a castle and drove around in the most expensive cars. Until they got a horrible car accident, when they were chased by paparazzi. Sarah and Jane were heartbroken. Together they planned to get their beloved sister back. Jane designed a car that could drive itself around, without the control of a human being. This Automated Vehicle was so safe no-one would ever die again by a car accident. In the meantime, Sarah discovered a way to travel through time, to travel back to the time before the accident. The two went back in time and introduced the self-driving car to the society. The car was a great success and the accident did never happen. They lived very long and... Oh, wait… unhappy, because the three were separated from each other. How could this ever happen?

There was one minor detail these geniuses forgot. The transition to the self-driving car went so fast, that it was impossible for urban and transportation planners to keep it into consideration in their plans, which lead to major congestion on all roads. Therefore, it became impossible for these sisters to visit each other. This thesis will explain you why this happened and what we can learn from this story for planning practices in real life.

Executive Summary

Key words – Smart Mobility, multi-actor decision making, automated and autonomous vehicles, spatial planning, urban system, transportation planning, accessibility, mobility, vehicle kilometres travelled, road capacity, case study

1. Introduction (Situation)

This research will focus on the smart mobility concept of automated vehicles (AVs), which consist of the gradual shift from human controlled vehicles to self-driving autonomous vehicles. The following timeline for the deployment of AVs is anticipated by several studies: in 2020-2045 there will be market availability for AVs, in 2030-2050 most/all households will eventually own an AV, which might eventually lead to a regulatory automation level requirement for all new cars (Milakis, Arem, & Wee, 2015) and (Levinson, Boies, Cao, & Fan, 2016). The development of AVs will have an impact on both the spatial planning sector as the transportation sector, because transportation and land-use are interrelated in the urban system. Fitting infrastructure in the urbanization of the system has a huge impact on mobility and accessibility (Jorritsma, Tillema, & Waard, 2016). The space to build is scarce in the Netherlands, and both the urban system (functions) and the mobility system (infrastructure) to connect these functions are competing for this valuable space. With an eye on the goal to concentrate more functions in these metropolitan areas to increase the agglomeration power, the mobility system should not expand anymore in terms of land use. The amount of land that is required for the mobility system depends on the mobility demand (the number of passengers) and the mobility concept (type of vehicle and infrastructure) that is used by these passengers. The required space to build the infrastructure for every mobility concept consists of the size of the roads (the space that is required to move safely) and the size of parking (the space that is required to store the vehicle safely). The introduction of AVs may change future mobility choices and travel patterns on which urban planners base their decisions. Therefore, planners should include this change in use (Childress, Nichols, Charlton, & Coe, 2015).

2. Knowledge gap (Complication)

The timeline and impact of AVs are uncertain. Much is written about the assumed timeline and impact of AVs. However, there is not yet an clear overview of the impact of AVs, that are specifically focused on urban planning issues. Therefore, this research will further explore the potential impact of AVs and the connected necessary land use changes, which are expected to be very uncertain. In the first phase of the research a literature study is performed on the potential impact of AVs on urban planning issues.

The timeline of the development of AVs can be influenced by the actions of vehicle-manufacturers. However, these actors are vague about the topic, due to competition considerations. There are however signs that AVs will be introduced to the market within 10 years. Realizing that the urban and transportation planning sectors are envisioning plans with a time horizon of 2040 and beyond, it seems wise to integrate the impact of AVs already in urban plans. However, it is not clear if spatial and transportation planners consider the development of AVs in their plans. There is not much data from research on the implementation of AV scenarios in planning methods in the Netherlands. In policy document, visions and strategies of the urban planning and transportation sector, is very little written about the expected impact of AVs and related actions. Besides there is no research done to perceptions and related behaviour of other stakeholders in the system, like transportation companies. Therefore, it is interesting to get a better understanding of how all these actors perceive the impact and timeline of AVs. Therefore, in the second phase of the research, a field research was done in order to understand the perceptions of stakeholders in the system on the impact of AVs on urban and transportation planning and the related behaviour and actions of these stakeholders.

The impact of AVs depends on the pathway that the development of this technology will take and the decisions that are made by the stakeholders in the transportation and spatial planning sector. Overall, AVs will have an impact on spatial and transportation planning in: changed mobility demand (private vehicles, shared vehicles, public transport and active modes) and patterns (vehicle kilometres travelled), infrastructure capacity (parking and roads), changed location (for living, working and recreation) preferences (Thomopoulos & Givoni, 2015), (Milakis, Arem, & Wee, Policy and society related implications of automated driving: a review of literature and directions for future research, 2015), (NHTSA, 2013). The main problem that is analysed in this research is the issue of road capacity. This issue can be summarised as the contradiction between road capacity increase due to AV technology without too much growth of AV use and reaching the limits of the capacity if AV vehicles usage will increase to a great extent. Road capacity increase will evolve from narrower following distances between vehicles and more efficient parking possibilities. Reaching the limits of the road capacity will evolve from an increase in vehicle kilometres travelled (VKT), due to empty vehicle travel (in order to pick-up and drop-off users and owners) and an increased car-travel-demand (reduction in the value of time during trips and non-drivers that are enabled to drive) (Thomopoulos & Givoni, 2015). Therefore, the introduction of AVs on public roads, without mitigating actions, might lead to major congestion problems.

Automation will only be an opportunity for the more effective use of road capacity, when it is implemented in the right way and a threat when it is not. A deliberated choice for the type of regulation and implementation of AVs in the urban system is necessary, in order to achieve the efficient management of road capacity. Decisions about the introduction of AVs on public roads are made by both public and private, transportation companies and urban and transportation planners. Therefore, the interactions between these stakeholders are interesting to this research. However, due to competition considerations for market parties and the sentiment of vehicle-use in the political debate the multi-actor decision making process is takes place behind hidden doors. In the last phase of this research stakeholders opinions are confronted with each other in order to get a better understanding about the conflicts and cooperation opportunities between stakeholders in the AV transition.

3. Research Approach

3.1 Research questions

1. What is the expected impact of Automated Vehicles on the urban system?
    - 1.1 What is the expected impact of Automated Vehicles on the urban system according to academics and researchers?
    - 1.2 How do the stakeholders in the urban planning and transportation sector perceive the need to implement new automated vehicle technologies in urban plans?

2. How can transport and spatial planners take the transition to fully Automated Vehicles into account in their long term urban and mobility planning?
    - 2.1 What are proposed spatial planning actions in order to react on the expected impact of Automated Vehicles by academics and researchers?
    - 2.2 What are proposed/realized actions of stakeholders in the urban planning and transportation sector in order to react on the expected impact of Automated Vehicles?
    - 2.3 How do different stakeholders in the urban planning and transportation sector interact, in order to implement transportation technologies in urban development projects at the moment?

The main questions 1 and 2 of this research are based on the 'learning cycle' from Kolb and Fry (1975): by conceptualizing observations from daily practice and reflecting on it, it becomes possible to use the acquired insights into new situations (Kolb & Fry, 1975). These main questions make the connection between planning science and practice. It will summarise the costs and benefits of taking AV technologies into account in urban plans, in early stages of the development of the technologies. The research approach will therefore consist of a combination of a literature study in phase 1 (planning science) and a field research in phase 2 (planning practice).

The first knowledge gap was the uncertainty about the expected impact and timeline of AVs on the urban system. In phase 1, a systematic literature study is conducted in order to gather theoretical insights in the expected impact of AVs (sub-question 1.1) and the related proposed actions (sub-question 1.2). The answers on these sub-questions are useful to design an approach to cope with the uncertainty (timeline and impact) in planning during the transition phase of the introduction of AVs to the urban system of the Netherlands. All the costs and benefits are summarized of taking AV technologies into account in urban plans, in early stages of the development of the technologies.

The second knowledge gap was the uncertainty about the perceptions of stakeholders on the impact of AVs and related behaviour. In phase 2, a field research is conducted in order to compare theoretical insights with insights of practices in real-world-settings. This approach is used, in order to test: What the stakeholders expect from the transition of AVs and to what extent they are aware of the impact of AVs described in literature (sub-question 1.2). In addition it gives insight in how stakeholders perceive these impacts and what actions they are planning to take in reaction to these impacts (sub-question 2.2). The answers on these sub-questions are useful to is to make an overview of the perceptions of stakeholders on the impact of AVs and the actions they propose to steer the AV development in the preferred direction.

The last knowledge gap was the uncertainty about interactions between stakeholders. The field research will also help to understand how different stakeholders in the urban planning and transportation sector interact, in order to implement transportation technologies in urban development projects at the moment (sub-question 2.3). The answer on this question is useful to design an approach to cope with the irreducible uncertainty in intended actions of stakeholders, in order to support urban planners in decision-making about the actions that can be taken in order to successfully implement AVs in the Netherlands.

3.2 Methods and tools

The expected impact of AVs on the urban system and the related possible actions are researched in phase 1, with the help of systematic literature review, in order to assess and make sense of all available literature relevant to the main research question of interest (Kitchenham et al., 2010). The method of forward and backward snowballing is applicated. This is done in order to elite the literature that is most appropriate to the research topic and in order to find additional literature. Four key documents about the main topic ((Fagnant & Kockelman, 2015), (Litman, 2017) and (Milakis, Snelder, Arem, & Homem de Almeida Correia, 2017), (Tillema, Gelauff, van der Waard, Berveling, & Moorman, 2017), are researched. Via the citations and references in these main documents, other documents about the topic are found. These documents are in turn browsed on valuable citations and references etc. Literature that is cited in multiple articles are valued higher than others. With the help of the tool Mendeley the reference table with all the literature is developed. Grey-literature gave very recent insights in the technology and critics on some theories proposed in the literature.

The three methods that are used during the field research are:

1. Interviews

In order to gather the data for sub-question 1.2 and 2.2, the perceptions of stakeholders on the impact and related actions are broadly explored. They are gathered by conducting semi-structured interviews that are based on the theoretical insights gathered during the field research, amongst 24 respondents. The respondents are stakeholders in the spatial planning and transportation sector, because they are considered as the experts on this topic. 20 interviews are conducted and transcribed afterwards. With the help of content analysis, the transcriptions of the interviews are read and observed in a systematic way and assigned headings, in order to find interesting and useful parts of the content to the research (Burnard, 1991). The advantage of this method is that the researcher will not influence the perception of the stakeholder during the research. In addition, the results can be analysed and validated in a very precise and structured way. As a result, a stocktaking is made of the impact of AVs on the build environment and the possible policies, strategies and actions within spatial planning, that will take this impact into account.

2. Questionnaire

In order to explore the results from the interviews in more detail, a questionnaire is conducted. In this way sub-questions 1.2 and 2.2 can be answered in more detail. A selection of insights from these results are further explored by conducting a questionnaire under 15 stakeholders of the same sample of respondents. The questionnaire is used to clarify seemingly antinomy and in order to get a complete understanding of the perceptions of all stakeholders on the same topic. This is necessary, because during the interviews a different/overlaying understanding of concepts/definitions/taxonomy can lead to undesirable misinterpretations of answers. The questionnaire consisted of clearly defined positions and multiple-choice questions. The advantage of this method is that all respondents have to answer the same questions, in order to make a comparation between the perceptions of different individual stakeholders and stakeholder groups.

3. Workshop

Sub-question 2.3 is answered by observations of stakeholders during a workshop. During the workshop stakeholders are triggered to discuss how spatial planning can influence the transition towards fully AVs. The workshop is conducted with 7 participants, in order to find out what future policies, strategies and actions are considered feasible according to stakeholders. The workshop is used in order to broaden the scope of possible actions and to get more immersion in the preferred actions. The stakeholders are triggered to discuss the issue independently from the researcher. In this way the researcher can observe interactions between stakeholders, without the unintended intervention of the conversation (by sub-questions from the researcher to keep the conversation going). The advantage of this is that it will lower the risk of informal manipulation.

4. Results

4.1 Literature review

According to literature most spatial impacts will only appear at automation level 5. When automation level 3/4 is developed, drivers can turn their attention away from the driving tasks at certain moments (for example on highways), which leads: to narrower parking distances between vehicles and increased driving convenience and productivity for drivers. When level 5 of automation is reached this effect will be even stronger, because in that case no human intervention is required at all times.

Parking garages can move to city outskirts. This will lead to a decrease in needed parking space in cities, but an increase in VKT to drop-off and pick-up passengers. However, due to the increase in waiting time for the vehicle (driving from the parking garage on the outskirts to the owner in the city centre), owners might be less inclined prefer an private AV over other mobility concepts. The time schedule of public transport, might for example lead to a shorter waiting time. Shared vehicle services, that are circling around in search for new costumers, might also need a shorter time to get to the user. This might lead to an overall decrease in the use of private vehicles and therefore in a decrease in congestion. When the waiting time for the private AV is not considered as an issue by users, the amount of VKT will increase and the congestion might increase.

In addition, according to literature there will be an increased driving convenience and productivity for drivers, which might lead to an increased willingness to use AVs for trips and increased travel distances. This will increase the overall increase of Vehicle Kilometres Travelled (VKT) and the mobility demand for AVs. This might lead to congestion, assuming the same road capacity. Besides, the preference for functions on certain locations might change, because travel distances become less important due to the reduction in the value of time of AV trips. Therefore, Urban sprawl might appear, which causes more VKT and thus more congestion. Lastly, non-drivers are enabled to drive. This will lead to an increase in mobility demand and VKT. Therefore, congestion might increase.

There might appear a decrease in vehicle-ownership, because it is easier to share a vehicle between users due to EVT door-to-door travel to pick-up and drop-off users. This will lead to a decrease in parking space needed, but an increase in the overall VKT travelled. The constant costs for the use of a shared AV will decrease per person and therefore the mobility demand might increase. Therefore, the overall congestion will increase. Besides there might be an increase in ride-sharing, due to easy door-to-door travel to pick-up and drop-off users. This will lead within cities to more VKT to pick-up and drop-off users, but will lead to a decrease in VKT between cities. However, the decrease in the constant and variable cost per passenger, might lead to an increase in mobility demand. However, the overall effect is expected to be a decrease congestion.

Lastly, there might be a decrease in the mobility demand for walking, public transport and bicycle use. This is caused, by users that switch to the more attractive and sometimes cheaper option of private and shared AVs. This will lead to an increase in VKT per person, because public transport can move more persons per vehicle. Besides it will require more land for mobility, because walking, cycling and public transport requires less land per moved user than AVs. Therefore, the overall congestion level might increase.

Possible actions that can mitigate the negative effect of the increase in congestion caused by AVs are according to literature: 1. Moving parking garages to outskirts, 2. Stimulate car-sharing and ride-sharing, 3. Introduce road-pricing, 4. Construct attractive bicycle and pedestrian lanes, 5. Construct drop-off and pick-up places, 6. Develop mixed functions living areas, 7. Stimulate building offices near public transport nodes.

4.2 Field research

The field research showed that there is disagreement between stakeholders about the time that the AV transition takes. 9 of the 20 respondents think the timeline described in literature is right. While 6 assume that the transition time will take longer and 2 think it will be shorter. 5 respondents would not answer the question, because they thought there was too much uncertainty. 8 of the 20 respondents are dazzled by the promised positive impact that AVs will have on sustainability, safety, sharing rates and road capacity, promoted by the car-manufacturing industry, that they forget to name negative impacts. However, under other respondents there is a shift to a more anxious attitude towards the impact of AVs. 10 of the 20 respondents admit that there exist misperceptions about the positive impact of AVs, like the assumption that the introduction of AVs will automatically lead to lower ownership rates and that it will lead to more sustainability. 3 respondents name the possibility of increased ownership rates and 6 are even worried that the ownership rates increase and 13 that vehicle use might increase and will mitigate positive effects.

Despite these worries, the field research also showed that the introduction of AVs is not included in most strategies and policies. Most stakeholders claim that this is caused by the uncertainty in the timeline of the transition and the new technology itself, which is kept secret by car-manufacturers due to competition contemplations. It might also be caused by a lack of knowledge on the subject, a lack of consensus between the stakeholders, the sentiment of the subject in the political debate and the strong positions of certain stakeholders in the multi-actor decision-making process.

Although, there is a lot of diversity in the visions of the stakeholders on the subject (some stakeholders even have internal contradictions in their opinion), there is also consensus on certain themes and related actions. 5 respondents see that there is a latent question to mobility and the increase of road infrastructure will only have a short-term positive impact on the road capacity. Therefore, there exist two options according to the stakeholders: 1. Do nothing, the increase in congestion will lead to a new balance between vehicle use/ownership and availability of road capacity (6 respondents named this as an option, mostly governmental) or 2. Repulse certain types of mobility concepts (10 respondents) and giving priority to other logistic streams in cities (11 respondents).

The second option can be split-up in two action methods: 1. Discourage private vehicle use and ownership or 2. Stimulate the increase of the number of users per vehicle (10 respondents). Stakeholders that name the first method, named actions like: adjusting parking policies (10 respondents), the introduction of ownership charges (2 respondents) and road pricing (12 respondents). However, there is not a lot of support for road pricing, according to 5 respondents. Stakeholders that name method 2, state that it is also possible to influence the mobility choice of citizen, by improving Public Transport (12 respondents), Shared Vehicle services (9 respondents) and bicycle (6 respondents) infrastructure.

5. Wrapping up

5.1 Discussion

16 of the 24 respondents agree on the expectations from the literature, that vehicle use and ownership will increase. 6 respondents expect that this will lead to road capacity issues. In order to mitigate this negative effect, three actions described by literature are also prominent in the field research.

Half of the respondents agree that that road pricing [action 3, from literature study] would most certainly discourage vehicle use and decrease VKT. However, according to 5 respondents road pricing is also a subject people would not dare to bring up in a conversation. This is a policy that could be implemented on short-term and might therefore be a last expedient, when planners are not taking the impact of AVs on congestion into account. However, it will lead probably to too much resistant of voters.

An option stated in literature is to [action 2, from literature study] stimulate car-sharing and ride-sharing, which leads to less parking and roads necessary. This would be a great way to decrease VKT, respondents agree, but is currently just not that popular, according to 9 respondents. However, with the introduction of AV it could get more popular (14 respondents) and it is definitely something that needs to be stimulated (10 respondents). According to respondents, the popularity depends on: the waiting time for the vehicle (3 respondents), the supply of shared-vehicles in the area (3 respondents), the emotional attachment to vehicle-ownership (4 respondents), the price of the ride (5 respondents), the user-friendliness (3 respondents). Spatial actions that stimulate car-sharing are: reserving space for a sharing system buffer (7 respondents) and create drop-off and pick-up points (5 respondents).

Literature also states that [action 4, from literature study] constructing attractive bicycle and pedestrian lanes would decrease the amount of VKT, by stimulating people to travel by alternative means. This is something 11 respondents agree on, during the field research. Spatial actions are: adjust traffic lights (2 respondents), develop bicycle parking facilities (4 respondents) and E-bike lanes (4 respondents).

Lastly, x participants in the field research recommended that public transport use should be encouraged. Popular actions are: make mobility options easier to compare (6 respondents), speed up public transport (5 respondents), increasing the supply of public transport options (4 respondents), develop parking at public transport stations (4R), make Mobility as a Service (MaaS) more attractive (3 respondents), invest more in public transport (2 respondents), introduce public transport on demand (2 respondents) and adjust public transport concessions (2 respondents).

5.2 Conclusion

First of all, both literature and the field research showed that the timeline of the development of AVs is very uncertain. However, most researchers and stakeholders expect that the development of the technology cannot be prevented and/or prohibited. Therefore, it seems wise that the impact is considered in urban planning but this research reveals that in practice no action is undertaken as yet. It turns out that there is much uncertainty about the impact of AVs on urban planning, and about how to deal with this uncertainty in planning. Both in the desk research as during the field research, there appeared many different opinions and visions on the impact. The impact with consensus is the increased car use. This will lead in all scenarios, to reaching the limits of the current road capacity. Therefore, there is a need for mitigating actions, in order to prevent major congestion.

An action that is described in literature that can be used on short notice, is road pricing. However, the field research showed that there is not support for this action under stakeholders. The actions that are described in the literature, that have support are the following: 1. private car use and ownership can be discouraged by parking policies and 2. The use of public transport, car-sharing/ride-sharing and bicycles can be stimulated, in order to mitigate the expected increase in car-use. This could be done by improving infrastructure for these mobility options, for example.

5.3 Recommendations

Recommendations can be split-up in recommendations in planning practice and planning science.

Planning practice

There are differences in opinions about the way in which actions should be taken. These vary from: do research, develop regulation, facilitate the transition or stimulate the transition. Most stakeholders take a remote position, because they are waiting on more information from other parties (car-manufacturers or governmental regulators). Therefore, it is recommended for the planning practice that the multi-actor decision making process is kick-started by the government as we speak. This can be done on international level (for example European level), in order to create a strong position for public parties against the strong international competition position of market parties. The public parties can develop together with the market parties international AV standards and regulation. In the meantime, it seems wise that planning becomes flexible enough, in order to be adjusted to improved knowledge about the timeline of the technology and the impact of the technology on urban planning. There is a lot of consensus about the use of scenario planning and making planning more flexible under respondents. The planning cycle can be shortened from 15-40 years to 5-10 years (for example public transport concessions).

Planning science

According to most stakeholders (13 from the 24) more research to AVs is necessary in order to make decisions. Recommendation for further research are on validating the effect of proposed actions in this research in practice (with the help of models/simulations and pilot projects) and research the support of citizen for these actions (with the help of social research methods like for example interviews, surveys, serious gaming, etc.). In addition, there should be done more research to the planned actions of AV-manufacturers.

1. Introduction

1.1 Background

The introduction of Smart mobility trends
Recently ICT-solutions are being used in mobility concepts to improve accessibility, this is called smart mobility. There are three transitions, in which transport modes are starting to 1. Drive electric, 2. Be shared via online platforms and 3. Become automated (Flügge, 2017).

1. Electrification
The first trend is electrification, in which there is a shift from gas fuelled vehicles to vehicles that drive electric (Flügge, 2017).

2. Sharing
The second trend makes a connection between mobility and the sharing economy, facilitated by the ICT sector (Jorritsma et al., 2016). Vehicle-sharing companies like Snapp car and MyWheels, developed online platforms in order to make the demand and supply for privately owned vehicles, more insightful and thus easier to match. Another example are ride-sharing companies like Uber and Lyft. They have developed online platforms in order to make the demand for rides (vehicle users, that need to get from A to B) and supply of rides (vehicle owners, that use their private vehicle to serve the vehicle users) more insightful and thus easier to match (Flügge, 2017). In the sharing-economy, goods that are owned privately are used by multiple users during the whole life-span of the good, instead of the usual tradition of buying and selling goods between users over the life-span of the good (Bond, 2015).

3. Automation
The last trend is automation, which consist of the gradual shift from human controlled vehicles to self-driving autonomous vehicles. The level of automation of the Automated Vehicle (AV) will thus develop over time, starting from traditional vehicles that are mainly controlled by humans, to partly automated vehicles that own features like parking assistants and cruise control, towards fully automated and autonomous vehicles that can drive independently. The concept of AVs has a long history. In 1999 Gehrig and Stein, already described it, as a vehicle that is able to navigate itself through its environment without the input of a human driver. In literature AVs are also known as autonomous vehicles, driverless vehicles, self-driving vehicles or robotic vehicles. In chapter 3 is further elaborated on the differences between these concepts, that are mostly based on the level of automation of the vehicle. This research will focus mostly on the transition of the Automated Vehicle (AV).

The stakeholders that can influence the timeline and impact of the Automated Vehicle transition
The timeline of the development of AVs can be influenced by the actions of vehicle-manufacturers. However, these actors are vague about this topic, due to competition considerations. Even though, there is much uncertainty about the timeline of AVs, there are signs that AVs will be introduced in a very near future. The following timeline for the deployment of AVs is anticipated by several studies: in 2020-2045 there will be market availability for AVs, in 2030-2050 most/all households will eventually own an AV, which might eventually lead to a regulatory automation level requirement for all new cars (Milakis et al., 2015), (Levinson et al., 2016) and (Madrigal, 2018).

The impact of AVs can be influenced by the actions of the actors of both the urban planning sector as the transportation planning sector, because transportation and urban planning are interrelated in the urban mobility system.

1. First of all, urban planning is the process in which land use is designed and developed. The land of urban areas is used by the built environment, green, water and infrastructure (partly designed by transportation planners) that is passing into and out of these urban areas. Transportation planning is the process of providing, operating and managing facilities and services to move people and goods to destinations. Therefore, the destinations in urban areas and the infrastructure to access these destinations are competing for the same land. Land that is used for infrastructure cannot be used for other functions.

2. Secondly, urban planning and transportation planning influence each other. Fitting infrastructure (for transportation) in the urban system has a huge impact on mobility and accessibility. The decisions that are made about the localization of homes, work and facilities, influence the transfers that are made with certain transportation modes between these functions and thus influence the localization of infrastructure (Jorritsma et al., 2016). In order to access your home, work or other facilities, mobility is needed to move from one function to the other. AVs are a new transportation mode, which will make more locations accessible (longer travel distances are acceptable, due to the reduction in the value of time) for more users (current non-drivers do not need a chauffeur anymore) for a lower price (the costs for the chauffeur are removed). The decrease in price, the reduction in the value of time and the increase in the number of potential users, might lead to an increase in the demand for mobility. The acceptance of longer travel distances might increase urban sprawl, which in turn leads to more mobility. For these reasons there is a strong connection between the two disciplines of urban and transportation planning in the AV transition. However, the actors in the system have not taken clear positions in the AV transition debate and stated what actions they are going to take.

Uncertainty in the Automated Vehicles transition
During this AV transition phase there are two main problems, that are related to uncertainty. Due to uncertainty about the development of AVs during the transition phase, it is hard for urban and transportation planners to consider AVs in their long-term plans. First, it is uncertain what impact the AVs will have on their environment, because there is no evidence from practice yet. Secondly, it is uncertain how much time it will take to develop fully AVs, because AV-manufacturers are very vague about the topic. Therefore, it is hard to decide when urban planners should expect that AVs will be introduced to the market and how these AVs should be implemented in the urban system.

The potential role of urban and transportation planners in the AV transition
The impact of AVs on land-use depends on the pathway that the development of this technology will take and the decisions that are made by the stakeholders in the transportation and spatial planning sector about the implementation of AVs. There are signs that it is important for urban planners and transportation planners to take AVs already into account in their long-term plans, in order to manage the available space for mobility effectively during the AV transition phase. In order to profit from the potential positive impact and mitigate the potential negative impact of AVs on land use, the expected weaknesses and strengths of the AV technology are described in the next section.

Expected impact of Automated Vehicles
Positive impact (Strengths)
According to some researchers, the implementation of AV technologies might have a positive impact on the transportation system and can make it more efficient, sustainable and accessible (Fagnant & Kockelman, 2014), (Givoni & Banister, 2013). AVs are expected to increase safety and efficiency, because when they are fully automated they might need a shorter following distance that is assumed to be safe (NHTSA, 2013). Due to this increased road capacity, less lanes are needed. Besides, vehicles can drive themselves to lower dense areas and park themselves. Therefore, some lanes are no longer needed for moving or storing vehicles, so the available public parking capacity in

high dense areas will increase. An opportunity to profit from this positive impact is that this public space can be re-allocated. Examples of new purposes are bicycle paths, AV lanes, green or other.

Negative impact (weaknesses)
However, the positive impact might be overshadowed by the negative impact of an increase of private vehicle use. Due to the ability of owning and driving a vehicle of currently non-drivers (children, disabled and elderly) and the reduction in the value of time more and longer vehicle trips might be made (Truong, De Gruyter, Currie, & Delbosc, 2017), this will lead to more Vehicle Kilometres Travelled (VKT). The increase of VKT is an threat of the implementation of AVs, because it might lead to congestion, when assuming the same road capacity.

In addition, the introduction of AVs can lead to urban sprawl. When vehicles are mostly used individually, space becomes more scares in cities, due to the increased road demand. Therefore, more people will choose to live outside dense areas, because of the lower land prices and the reduction in the value of time of a transfer by AV. This can lead to urban sprawl. Urban sprawl leads to also to more VKT on connection between cities and towns.

The role of urban planners solving the issue of congestion, caused by the AV transition.
The problem of congestion, can be solved by increasing the amount of infrastructure, but in that case mobility will require more land.

Another solution is to prevent the increase of VKT, by accelerating the other smart mobility trend of vehicle/ride sharing. The introduction of AVs can accelerate the transition towards shared vehicles, through the possibility of independent door-to-door travel picking up and dropping of users. An increase in car-sharing and ride-sharing might decrease car ownership and the amount of VKT. In this case, less parking spaces and road capacity are required and a different land use could be considered. The land can be used in order to make an optimal use of the sharing system, in which more drop-off points are needed. When vehicles are mostly shared between users, people tend to live in metropolitan areas. The reason for this is that, due to the higher densities, it is easier to develop an efficient sharing system. Therefore, urban sprawl will decrease.

However, the low-costs of trips with shared vehicles (costs are divided by more people), might encourage people to make more use of these vehicles instead of using a bike, public transport, walking or not making the trip at all. This can also lead to increased road demand (Economist, 2018). Therefore, more research is needed to the impact of AVs on the urban system and the role of urban and transportation planners in solving the problem of increased congestion.

Relevance of the research to the problem situation
To conclude, the main problem that will be analysed in this research is the impact of AVs on the road capacity. This issue can be summarised as the contradiction between the possibility of road capacity increase and the possibility of an increase in mobility demand and the amount of Vehicle Kilometres Travelled (VKT), which leads to reaching the limits of the current available road capacity. Road capacity increase will evolve from less car-ownership (stimulated by car-sharing) and shorter following distances. Reaching the limits of the road capacity will evolve from more vehicle kilometres travel due to car-sharing and an increased car-travel-demand (time spend in car is not a waste anymore and people who cannot drive themselves are able to use an AV instead (Thomopoulos & Givoni, 2015).

It is hard to achieve change towards implementation of AVs, regarding such a complex system, with so many stakeholders, which includes both technical and social aspects (Sheller, Urry 2006), (Urry

2004). The automation of vehicles will only be an opportunity for the more effective use of road capacity, when it is implemented in the right way and a threat when it is not.

Threats are that: 1. AVs will not lead to a reduction in the total number of road vehicles, when they are not shared. 2. The sharing of AVs will not lead to a reduction in the total amount of VKT, when the amount of people that prefers shared AVs over public transport and active modes is higher, than the amount of people that prefers shared AVs over private car use. An opportunity of AVs is that they can help to configure the entire transport system, so 1. passengers are discouraged to use personal cars and 2. start using active modes, public and shared transits at predefined transport hubs.

The stakeholders that can influence this, are the transportation and spatial planners of the government, public transport companies, car-sharing companies, AV manufacturers and users. When all these stakeholders are involved in the multi-actor decision making process, they might come to a shared goal and use their combined means to reach this goal. When they are all making decisions individually and strategically for their own profit, they might end up obstructing the process. The negative impacts of AVs on the society and the urban environment might become bigger than the positive impacts, which eventually will lead to the prohibition of the use of AVs. Therefore, it is advised that all the stakeholders, both private and public, in the sectors transportation and spatial planning, are included in the decision-making process of the implementation of AVs in the urban plan.

In order to make decisions about the development of AVs, it is important to understand the potential impact of AVs on the urban system described in literature and the perceptions of stakeholders on this impact. Knowing the future impact and connected perceptions of stakeholders that lead to certain actions, can give the government the opportunity to steer developments in the preferred direction. A huge pitfall of not steering this technology is that the development of AVs will be led by the commercial transportation companies. These companies will focus on the individual financial profit of the company, while not considering the collective interest of the society. In that case AVs can increase congestion and roadway costs (Litman, 2018). Another pitfall is the lock-in effect. Technological lock-in can lead to a situation in which stakeholders have adopt specific features of a technology and are not able or willing to switch to other features, because the technology follows a specific path that is difficult and costly to escape from (Arthur, 1989).

Therefore, this research will uncover what the role of urban planners is in the AV transition. The relevancy of this research to the master program is described in appendix E. In the next section the knowledge gap that prevents urban planners to make decisions about the AV transition is described.

1.2 Complication: Knowledge gap

Uncertainty about the impact and timeline of AVs
There is a lot written about the assumed timeline of AVs. It is expected that AV technologies, may enter the consumer market in ten years or even sooner and will be used by most Dutch households in 2030-2050. However, there are mutual differences about the timeline between articles and there is not one researcher bold enough to state exact dates. At the same time, urban and transportation planners are envisioning plans with a time horizon of 2040 and beyond, without referring much to the impact of AVs. While, in this research it is assumed that the introduction of AVs will lead to the need for adjustments in land use over time. Therefore, it is necessary that AV scenarios are being integrated into the design and planning of the urban system right now. This is not only a difficult job, because the timeline of the development of AVs is uncertain, but also because the impact of AVs is uncertain too. There are different scenarios described about the potential impact of AVs. However, there is not yet a clear overview of the impact of AVs, that is specifically related to land use and urban planning.

The problem statement therefore is to design an approach to cope with the uncertainty (timeline and impact) in planning during the transition phase of the introduction of AVs to the urban system of the Netherlands. Therefore, this research will further explore the potential impact of AVs and the connected necessary land use changes over time, which are expected to be very uncertain. In the first phase of the research a more comprehensive literature study is done to the potential impact of AVs over time on urban planning.

Uncertainty about the perceptions of stakeholders on the impact of AVs and related behaviour
Due to the fact that the impact and timeline of AVs are very uncertain, it might be more useful for planners to predefine goals that can be achieved by the implementation of AVs and find out how these goals can be reached with the help of urban and transportation planning in each scenario. In that way, it becomes possible to steer the development of AVs in the preferred direction. Urban and transportation planners can for example influence the implementation of AVs in the urban system, by the design of infrastructure and the location of work, homes and other facilities. Instead of waiting for the development of the technology and letting the AV-manufacturing market decide what will happen, the urban and transportation planners can steer the impact of AVs on the urban system themselves.

Therefore, it is interesting how urban and transportation planners perceive the impact and timeline of AVs. However, it seems that they have not taken clear positions in this debate, because there are not many documents available in which they state how they perceive the impact (an example is the vision till 2040 of the province of North-Holland, in which nothing is stated about AVs or smart mobility (Geldhof, 2017)). In addition, there is not much knowledge from research on the implementation of AV scenarios in planning methods in the Netherlands (Smartwayz in Brabant is the most advanced on this matter (Smartwayz, 2018)). In policy document and strategies of organizations is the spatial planning and transportation sector, is very little written about the expected impact and related actions (the company 2getthere delivers autonomous vehicle systems for smart cities and discuss some impacts of AVs in their article (Lohmann & Zwaan, 2017)). Therefore, it seems that urban and transportation planners might not incorporate the impact of AVs in their plans at the moment. There is also no research done to perceptions and related behaviour of other stakeholders in the system, like car-manufacturers, transportation companies and consultancy companies. The timeline of the development of AVs can for example be influenced by the actions of vehicle-manufacturers. However, these actors are vague about the timeline of the development AVs, due to competition considerations (Waymo and Uber announced last year that they are starting tests with AVs, but they did not state when fully AVs become available (Bergen, 2017), (Muoio, 2017) and (Lee, 2017)).

The problem statement therefore is to make an overview of the perceptions of stakeholders on the impact of AVs and the actions they propose to steer the AV development in the preferred direction. Therefore, in the second phase of the research, a field research will be done in order to understand the perceptions of stakeholders in the system on the impact of AVs on urban planning and the related behaviour and actions of these stakeholders.

Uncertainty about interactions between stakeholders
It seems that both parties (planners and transportation companies) are waiting for each other to give more information about their expectations, goals and actions. It is not clear for outsiders how the decision-making process about AVs evolves, because most important conversations are behind hidden doors. This research aims to understand AV transport and land use dynamics in the urban system and the complex relationship between them.

The problem statement therefore is to design an approach to cope with the irreducible uncertainty in intended actions of stakeholders, in order to support urban planners in decision-making about the actions that can be taken in order to successfully implement AVs in the Netherlands. Therefore, a better understanding of the interactions between stakeholders in the system is necessary. This makes it possible to analyse what cooperation opportunities exist and what conflict threats can appear. In that way, it becomes possible to translate the goals and means of the stakeholders to concrete steps, that they can take. This will bring a more effective link between planning science and planning practice. In the last phase of the field research, stakeholders are confronted with each other in order to understand interactions between them.

Research area
Studying at a Dutch university, I am most familiar with the Dutch planning approach and transportation system. In the Netherlands AV technologies will probably have a different impact on high- and low-density locations, therefore the province of North-Holland will be an interesting research subject. The province of North-Holland consists of a great amount of different area typologies.

Conclusion
To conclude, in this research it is assumed that the introduction of AVs will lead to the need for adjustments in land use over time and therefore need to be integrated into the design and planning of the urban system. However, it is uncertain what the exact spatial impact is and what the timeline of the development of the AV technology is. There are signs that the transition towards fully automated vehicles might lead to inefficient use of the available infrastructure, while space is already scarce in the Netherlands. Research to the potential use of impact studies in order to solve this problem can help the government in the management of available infrastructure. Still, it is not clear how spatial planners and transportation organizations are perceiving the impact of AVs and if they take this impact into account in their long-term planning. Secondly, it is important to design an approach to cope with the uncertainty in planning during the transition phase of the introduction of AVs to the urban system of the Netherlands. Nevertheless, this is not available yet.

1.3 Research question

The research questions follow from the knowledge gaps. Two main questions will be answered with the help of sub-questions. The questions are answered with help of theoretical insights and insights in daily practices of urban planning.

Research questions

1. What is the expected impact of Automated Vehicles on the urban system?

    1.1 What is the expected impact of Automated Vehicles on the urban system according to academics and researchers?

    1.2 How do the stakeholders in the urban planning and transportation sector perceive the need to implement new automated vehicle technologies in urban plans?

2. How can transport and spatial planners take the transition to fully Automated Vehicles into account in their long term urban and mobility planning?

    2.1 What are proposed spatial planning actions in order to react on the expected impact of Automated Vehicles by academics and researchers?

    2.2 What are proposed/realized actions of stakeholders in the urban planning and transportation sector in order to react on the expected impact of Automated Vehicles?

    2.3 How do different stakeholders in the urban planning and transportation sector interact, in order to implement transportation technologies in urban development projects at the moment?

Connection between knowledge gaps and questions

The first knowledge gap was the uncertainty about the expected impact and timeline of AVs on the urban system. The answers on sub-question 1.1 and 2.1 are useful to design an approach to cope with the uncertainty (timeline and impact) in planning during the transition phase of the introduction of AVs to the urban system of the Netherlands.

The second knowledge gap was the uncertainty about the perceptions of stakeholders on the impact of AVs and related behaviour. The answers on sub-question 1.2 and 2.2 are useful to is to make an overview of the perceptions of stakeholders on the impact of AVs and the actions they propose to steer the AV development in the preferred direction.

The last knowledge gap was the uncertainty about interactions between stakeholders. The answer on sub-question 2.3 is useful to design an approach to cope with the irreducible uncertainty in intended actions of stakeholders, in order to support urban planners in decision-making about the actions that can be taken in order to successfully implement AVs in the Netherlands.

2. Research approach

This section explores and argues which approach seems most appropriate to find an adequate answer to the two main research questions. This will be a qualitative exploratory research, in which both theoretical insights and practical insights are used to give recommendations for real-life planning practices in the Netherlands. It is assumed that the theory about future AV technologies is not brought into practices of the spatial planning and transportation sector yet. According to literature there are signs that, in order to meet future smart mobility travel demands, it seems wise that AV technologies are already to be incorporated in urban plans as we speak. Therefore, this research will evaluate to what extent planners are taking AV technologies in consideration and how they do it, by analysing planning documents and interviewing urban planners and transportation companies. Expected result is, that they mostly do not take it into consideration, because the future of AVs is to uncertain.

This uncertainty might be removed, by a better understanding of the interest of stakeholders in AVs and their related expected actions in the system. Secondly, this approach can help to understand what the perceptions, goals and means of stakeholders are related to the implementation of AVs. This can give a better insight in the future actions of stakeholders and the effect it will have on the implementation of AVs in the urban system. In this way planning practices of planners can be improved. It becomes possible to give recommendations for managing multi-actor decision-making in urban planning projects, to make optimal use of AV technologies in the Netherlands.

The approach will consist of worldwide literature study to the spatial impact of AVs and a field research in the Netherlands to the relation between AVs and urban mobility planning in the area of North-Holland. The choice for North-Holland as research area, will be explained in section 2.2.2. The appropriate research design to answer the research questions will be described below. The sub-headings describe the phases of the research. Together these sub-questions will sum up the two main questions. The entire research process is covered by two main research questions and five sub-questions.

2.1 Research questions

2.1.1 Understanding integration of AV technologies in urban planning projects.

In order to answer the main research questions, it is important to understand the need for the implementation of AV technologies in the Dutch urban plan. For this reason, it is interesting to know what the expected impact of AVs is according to academics and researchers in this field and what actions they propose in order to react on this impact. Therefore, a literature study will be conducted to analyse the relation between the domains spatial planning and transportation, when implementing AV technologies in urban plans. The sub-research questions connected to this analysis are:

1.1. What is the expected impact of Automated Vehicles on the urban system according to academics and researchers?
2.1. What are proposed spatial planning actions in order to react on the expected impact of Automated Vehicles by academics and researchers?

The answer will describe the expected impact of AVs on the system, according to future scenarios described in literature. Secondly, it will consist of a summary of proposed spatial planning actions. The answers to these questions, will form the basis for the field research in the next phase.

2.1.2 Automated Vehicle technologies in urban planning projects in the Netherlands.

In order to understand to possibilities of the implementation of AVs in Dutch urban planning projects, a field research is done in which the practices of stakeholders in the province of North-Holland are analysed. The knowledge gathered during the literature study, can be used to analyse the perceptions and behaviour of stakeholders. The field research is conducted during an internship at Arcadis, because the employees of this organization have a lot of connections in this field. First, the study will conceptualize how the stakeholders perceive the need to implement AV technologies in the urban mobility plan. Secondly, it becomes possible to conceptualize to what extent AV technologies are already incorporated in visions and plans for urban development. This will be done by interviews that are based on the knowledge from the literature study. The sub research questions connected to this analysis are:

> 1.2. How do the stakeholders in the urban planning and transportation sector perceive the need to implement new automated vehicle technologies in urban plans?
> 2.2 What are proposed/realized actions of stakeholders in the urban planning and transportation sector in order to react on the expected impact of Automated Vehicles?

The result of these interviews will be an overview of the perceptions on the impact of AVs. Together with the results of the literature study, the first main research question can be answered. By comparing the results of the literature study and the field research, the expected impact of Automated Vehicles on the urban system can be described.

Secondly, the results of the interview will be an overview of the expected goals that can be achieved with the introduction of AVs and the means of all the stakeholders to act on the expected impact in order to achieve their goals. In order to understand about what impacts and actions there is consensus between the stakeholders, a questionnaire is conducted. In this questionnaire the most striking results of the interviews are repeated in the form of statements or multiple-choice questions. This will give insight in the expected conflicts and cooperation opportunities in the multi-actor decision-making process about the implementation of AVs in the urban system of North-Holland. It will summarize uncertain means that can achieve multiple goals simultaneously and uncertain goals that are appropriate in multiple possible future scenarios. These are called robust goals and means (Bertolini, 2012) or no-regret actions as described by (Tillema et al., 2017). The answers of the stakeholders during the field research are compared to the information gathered during the literature study. In this way the first part of the second main research question might be answered (sub-question 1.2 and 2.2), in order to uncover what actions are proposed.

The last sub-question will be answered by doing a workshop, in which a selected group of stakeholders will discuss, how they would implement AVs in the Netherlands in a way that it will lead to a more efficient, sustainable and accessible urban system.

> 2.3. How do different stakeholders in the urban planning and transportation sector interact, in order to implement transportation technologies in urban development projects at the moment?

In this workshop can be explored in depth how these stakeholders are cooperating and what improvements are necessary in the multi-actor decision making process, in order to integrate AV technologies in urban planning projects. The objective is to improve the urban planning processes within the Netherlands, by exploring how to profit from the cross-sectoral interactions. In this way it becomes possible to answer the last part of the second main question in which recommendations are given to transport and spatial planners on, how to take the transition to fully Automated Vehicles into account in their long term urban and mobility planning.

The result will be an analysis of the risks, benefits and costs of implementing AV technologies in urban plans over time, based on the information gathered during the literature study and field research. The conclusion will consist of no-regret actions, which are actions that stakeholders already can take, without harming possible outcomes.

2.2 Methods and tools

This section describes the selected methods and tools per research question and motivates all decisions about details and research activities. It will explain how the required information/data is gathered and which methods will be used.

First, a literature study is conducted in order to gather theoretical insights in the expected impact of AVs and the related proposed actions. The method that is used is a systematic literature review. The field research consisted of three methods: two survey methods and a workshop. The surveys are longitudinal, because it is attempted to gather several times information on the same subject over a period. The aim is to examine the differences in the collected data and adjust the results to this (Sincero, 2012). First, interviews are conducted from 20th of April to 1st of June, that are based on the results of the literature study. Secondly, a questionnaire is developed based on the results of the interviews, in order to compare interesting views of stakeholders with the views of other stakeholders. The questionnaire is conducted from 15th of June to the 22th of June. Lastly, a workshop is conducted based on the answers on the questionnaire, in order to discuss the negative impact of AVs with the highest risk and the proposed actions to mitigate this impact.

2.2.1 Literature study methods

Sub-question 1.1 and 2.1 are answered by doing a literature research to described scenarios of the introduction of AV technologies. The literature data could help to understand and conceptualize the issue.

The method that is used is a systematic literature review. The method is assessing and making sense of all available literature relevant to the main research questions of interest (Kitchenham et al., 2010). The literature is found with the help of the online database Google Scholar.
Search terms (in the languages Dutch and English) that are used in the data bases in order to find relevant information are: "automated vehicles" and "road capacity" and "mobility" and "accessibility" and "road infrastructure". This gave 67 hits. The search terms: "automated vehicles" and "urban planning" and "accessibility" and "mobility", gave 264 hits. The search terms: "automated vehicles" and "urban planning" and "spatial impact", gave 7 hits. The most important selection criteria are described here. First, the publication year, gave an indication of the usefulness of the article. The introduction of AVs in the urban system is in comparison to other subjects a technology that is relatively new and of which the innovation is moving fast. Therefore, the relevancy of knowledge about this subject is temporary. Secondly, the relevance to the topic is evaluated. The criteria to measure this is gathered from the introduction and conclusion. The literature should be about research to: urban/spatial planning, mobility planning, AV technologies, spatial impacts of AVs and/or related planning actions. The citation numbers and ratings and by what organization it is cited, gave an indication about the trustworthiness of the source.

The method of forward and backward snowballing is applicated, in order to evaluate the relevance to the topic. This is done in order to elite the literature that is most appropriate to the research topic and in order to find additional literature. The search has started with some key documents about the main topic. For the relation between Automated Vehicles and road capacity, the most relevant source was (Fagnant & Kockelman, 2015), because it gives a good overview of all the barriers, opportunities and policy recommendations. Information about the timeline of the introduction of AVs is mainly coming from (Litman, 2017) and (Milakis et al., 2017). The information about scenarios is mainly coming from (Tillema et al., 2017). Via the citations and references in these main document other documents about the topic are found. These documents are in turn browsed on valuable citations and references etc. Literature that is cited in multiple articles are valued higher than others. With the help of the tool Mendeley the reference table with all the literature is developed. Grey-literature gave very recent insights and critics on some theories.

2.2.2 Field research methods

The last three sub-questions are answered conducting a field research and analysing the result with the help of the theoretical insights from the literature review. The main research questions presented in the paper focuses primarily on "how" and thus should make use of one of the following approaches: case studies, experiments, or shared histories (Yin, 1984). However, as an investigator, I will have no access and control over actual behavioural events and I will examine contemporary events. Therefore, a case study approach is best suited. The research method that will be used in this research is comparable to a case study, because the main sources in this research are policy documents, visions, spatial plans and interviews with stakeholders.

The challenges of doing a case study are, first of all, that it is difficult to determine the case that can illustrate the issue and to study the case itself. Secondly, it is challenging to define the boundaries of each case (Eisenhardt, 1989). Lastly, it is challenging to choose between how many cases should be studied to get a good overview without being shallow, because with every case you add to the research it means that the research goes less into depth for each case (Yin, 1984). The dilemma here is that a case study might not provide evidence for cases with slightly other conditions, because a case study is based on one situation in a specific context. A solution to this limitation is to analyze the same issue in a different context, by doing multiple-case studies in the Netherlands (Yin, 1984). In order to get as much into depth as possible in the timeframe of six months it is decided that a single case study is done. The main sources in this case study are policy documents, visions, spatial plans and interviews with stakeholders. One constraints of this last method are that during participant-observation, informal manipulation can occur. The solution to this, as case study investigator, is to work precise and to report justly evidence (Yin, 1984).

The research area that is chosen is the province North-Holland. North-Holland is chosen, because it has a high diversity in area types with high densities and lower densities. This can give a good insight in what impact AVs will have in different contexts and how spatial planning can take this into consideration. Furthermore, in North-Holland is the metropolitan area Amsterdam situated. This is a very interesting area to research, due to the high density of the population and the functions: living, working and recreation. Due to all this inhabitants and functions, there are a lot of movements in the area and mobility and accessibility are very important. The implementation of AVs in this area, can be an example for other metropolitan areas. Arcadis and TNO carried out a research, commissioned by the province of North-Holland and the municipality of Amsterdam, to outline several scenarios of the impact of AVs in the region and the role of the province and the municipality in this matter (Bergveld, Hotic, Snelder, Wilmink, & Arem, 2018). This research will build on the experiences and results from this research.

2.2.2.1 Interview methodology and tools

In order to answer sub-question 1.2, 2.2 and 2.3, semi-structured interviews are conducted among stakeholders. Semi-structured interviews are suitable to gather facts, attitudes and opinions about a specific topic

The interviews are mostly conducted face-to-face, only two of them are phone interviews. 20 interviews are conducted of which most are with one interviewee and three are with two interviewees. The respondent group is represented by a broad group with different fields of experience related to AVs, transportation and spatial planning on different levels. They are divided in three groups: 1. Government, 2. Transportation companies and 3. Consultancy in transportation and urban planning. The first group (the government) makes the decisions about the institutions, processes and technical artefacts of the urban system. This group consists of stakeholders from different governmental levels: Rijkswaterstaat, the provincial deliberation group, the province of North-Holland, the municipality of Amsterdam and transportation region Amsterdam. The second group (the transportation companies) needs to implement their business into this urban transportation system. This group consists of stakeholders from car-sharing/car-rental companies and public transport companies. The last group (consultancy in transportation and spatial planning) has knowledge and experience working with group one and two and gives advice to them. This group consists of employees of the consultancy and engineering company Arcadis. A summary of all the interviewees is presented in table 1 on the next page.

Table 1: ***interviewees by organization type, name and function of interviewees.***

Group	Organization type	Organization name	Sector	Department/Function
1. Government	National government	Rijkswaterstaat	Transportation Planning	Water, traffic and environment
		InterProviciaal Overleg	Transportation and Urban planning	Mobility and land-use
	Regional government	The Province of North-Holland	Urban planning	Traffic-nodes advisor
				Traffic nodes expert
				Environment Vision
	The Province of North-Holland		Transportation planning	Bicycle paths
				Smart Mobility
				Mobility Agenda
				Smart mobility
				Chain mobility & Smart mobility
	Local government	Transportation region Amsterdam	Transportation planning	Project leader & planner of AVs
		Municipality of Amsterdam	Urban planning	Smart Mobility
2. Transportation companies	Car-sharing & Car-renting Company	Anonymous Sixt	Transportation planning	Account Manager Product Manager & Country Manager Benelux Mobility Consulting
	Public Transport	Anonymous		Strategy and innovation
		Transdev		Strategy and development director
		ProRail		Strategy & innovation

				Automated Train Operation
	AV company	2getthere		Chief commercial officer
3.		Arcadis	Urban planning	Landscaper
Consultancy and Engineering				Urban planner
		Arcadis	Transportation planning	Senior consultant policy and mobility
				Senior consultant smart mobility

The interview schedule is developed with the help of the theoretical insights from chapter 3 and can be found in appendix A. There are four subjects that are discussed in every interview: the vision of the respondent on the impact of AVs, the current policies and strategies related to AVs of the company, the potential issues related to the impact of AVs according to the literature and future actions that the respondents propose to solve these issues.

The interview is recorded in order to concentrate on the conversation. Besides notes are taken during the interview, in order to give a brief summary to the respondent at the end of the interview and give them the opportunity to set right misinterpretations.

The interview is then transcribed with the help of the notes and audio record. This is done as soon as possible after conducting the interview. Transcriptions can be naturalised or denaturalised (Bucholtz, 2000). In a naturalised transcription the oral form of the interview is covered in detail. Naturalised transcription can draw the attention to the literalness of the transcript. On the other hand, denaturalised transcription can lead to unintended interpretation. Therefore, there is a balance made between the two. The interviews are transcribed with the help of the free online-transcribe-tool from https://transcribe.wreally.com/, which helps you to replay the recordings on different speeds.

In this research the thematic content analysis is used. According to the method of Burnard (1991), this is done as follows. During each interview notes are made, in order to summarize the most important topics discussed during the interview, to verify it with the interviewee afterwards. The interview is transcribed and structured in categories (Field & Morse 1985). This is done by sorting the statements by relevant themes and omitting redundancies. The list of themes is grouped together under four main categories (Vision, Strategy, Impact & Actions). The sub-themes will be described in chapter 4. Field research. Each transcript is read through, with the list of categories and sub-themes by hand. The four categories and sub-themes are numbered in tables in chapter 4 and in the text of the transcripts. In this way it is easy to look them up, when writing up the research. Each coded section (citation) in a transcript is also saved in a word document, together with citations with the same code from other transcripts. In order to validate the category system the supervisors of the TU Delft and Arcadis are asked to check the category system. Adjustments are made as necessary. Once the category system is validated and all of the citations are together, the writing up process begins. Copies of the complete interviews are kept to hand during the writing up stage as are the original tape recordings (Burnard, 1991). A selection of the various citations under each sub-theme are made, with comments that link the examples together. All of the citations have direct references, when writing up the findings. In the discussion chapter the data examples are linked to the literature.

2.2.2.2 Questionnaire methodology

The questions of the questionnaire are based on the results of the interviews. Sub-themes that were named by many respondents during the interviews are only interesting to ask again in a questionnaire, when there is no common solution named by all respondents. Sub-themes that were named by only a few respondents during the interviews, but are discussed often in literature are also interesting, because these themes are important to researchers but are not on the top of the mind of the stakeholders. These sub-themes are interesting in a questionnaire, because it might uncover conflicting or similar visions about sub-themes that are not very common. Sub-themes that are named by only a few respondents and not named in literature, might be interesting if other respondents agree on it in the questionnaire or workshop. These themes are important, because it might uncover visions that are in planning practice very common, but are not seen by academics in the planning science field.

An example of a difference between planning science and planning practice is the following: according to the interview results, many respondents assume that AVs cause the increase in car-sharing and this will help solving the road capacity problem. However, according to literature car-sharing and car-automation are two different transitions. Therefore, it is important to get an better understanding of the vision of the stakeholders on this sub-theme.

The questionnaire and the answers can be found in appendix C. The questionnaire consists of 16 multiple-choice-questions with an option for their own answer. The questions are divided in five topics: general, car-sharing, public transport, spatial planning and transition phase.

The questionnaire is filled in by 15 respondents via an online form (google-drive-form) and is therefore a self-administered tool (Sincero, 2012). Due to the limited number of respondents, the results cannot be generalized and should be interpreted as a guideline for further research.

The same answer on certain subjects by respondents from the same group reflected a common perspective on the theme. Conflicting answers by respondents from the same group uncovered uncertainty about a theme. Besides conflicting answers between respondent groups uncovered conflicting visions, policies and strategies between them. These topics are most interesting to discuss during the workshop.

2.2.2.3 Workshop methodology

With the help of the results of the interviews and literature review a stocktaking is made of the impact of AVs on the build environment and the possible policies, strategies and actions within spatial planning that will take this impact into account (see the sections results of the literature review and the results of the interviews). In order to validate, which impacts are considered positive or negative and what future policies, strategies and actions are considered feasible according to stakeholders, a workshop is organized.

The workshop is a research method in which a situation can be researched from the third persons perspective. This is different from the surveys, because the conversation (question and answers) can only exist, when the researcher takes part in the conversation and thus influences it. During the workshop the conversation can evolve, without interferents of the researcher and the researcher is therefore able to analyse the conversation from an independent perspective. A workshop is an arrangement in which a group of persons can learn, gather new insights and performs creative problem-solving or innovates in relation to a domain specific issue (Ørngreen & Levinsen, 2017).

During the workshop in this research an interactive presentation was given in which the results of the desk and field research are presented, in order to provide the participants with some prior knowledge about the impact of AVs and the vision of other stakeholders. During the presentation the participants could show how they would react on these impacts. This made it more clear what partnerships would form and what conflicts would arise during a multi-actor decision-making process about the introduction of AVs. In this way it became possible to analyse what the real goals and means of the stakeholders are. This was also a moment in which all the stakeholders could discuss the issue with each other in order to get a better understanding of each other's viewpoints.

The structure of the workshop was as following. First, an introduction to the content of the workshop was given. Secondly, an introduction to the research and research questions was given to the participants and the reason for the workshop was explained. Then the participants got the opportunity to introduce themselves. They were asked to give their name and function and what they expected to get out of this workshop. They were also asked to give their own answer to the research question.

After getting to know each other, the problem statement of the research was explained more detailed. A connection was made between the concerns about the uncertainty of timeline of all stakeholders and the concerns about the impact on the road capacity. In this way it was validated, if the participants also recognize this problem and if they are willing to solve this problem together.

Then participants were given the opportunity to discuss possibilities to solve this problem. Only a limited number of discussion subjects was feasible, because the workshop time was only one hour. In order to use the time in the workshop efficient, a questionnaire was sent to all the participants prior to the workshop. With the help of the answers on the questionnaire, it became possible to sort out what the most interesting topics where to discuss. All the respondents of the interviews are invited to the workshop and eight participants showed up. Some participants were not willing to attend the workshop, because they thought it would not be useful for their organization or it would have a negative effect on their business, due to the high competition and uncertainty in the AV market.

This leads to the three main discussion topics, that will be explained in more detail in the result section (4.3.2). Prior to every discussion on one of these topics, results from the questionnaire are presented to give them a better understanding of the discussion topic. Than a question was asked to all participants. The participants could send their answers live to an online application. All the answers are presented on a withe screen after 1 or 2 minutes. All the answers are repeated by the researcher and the participants got the change to discuss the topic and all the answers for 10 minutes long. Afterwards a summary is given by the researcher.

The workshop took place at 19-06-2018 in the Symphony Tower in Amsterdam. 3 participants from the Province of North Holland were attending. From the municipality of Amsterdam 1 participant was present. From Arcadis 2 participants attended the workshop. From the car-renting/sharing sector 1 participant was present.

2.3 Summary of research approach

The main questions 1 and 2 of this research are based on the 'learning cycle' from Kolb and Fry (1975): by conceptualizing observations from daily practice and reflecting on it, it becomes possible to use the acquired insights into new situations (Kolb & Fry, 1975). These main questions make the connection between planning science and practice. It will summarise the costs and benefits of taking AV technologies into account in urban plans, in early stages of the development of the technologies. The research approach will therefore consist of a combination of a literature study in phase 1 (planning science) and a field research in phase 2 (planning practice). This is presented in the figure 1 below.

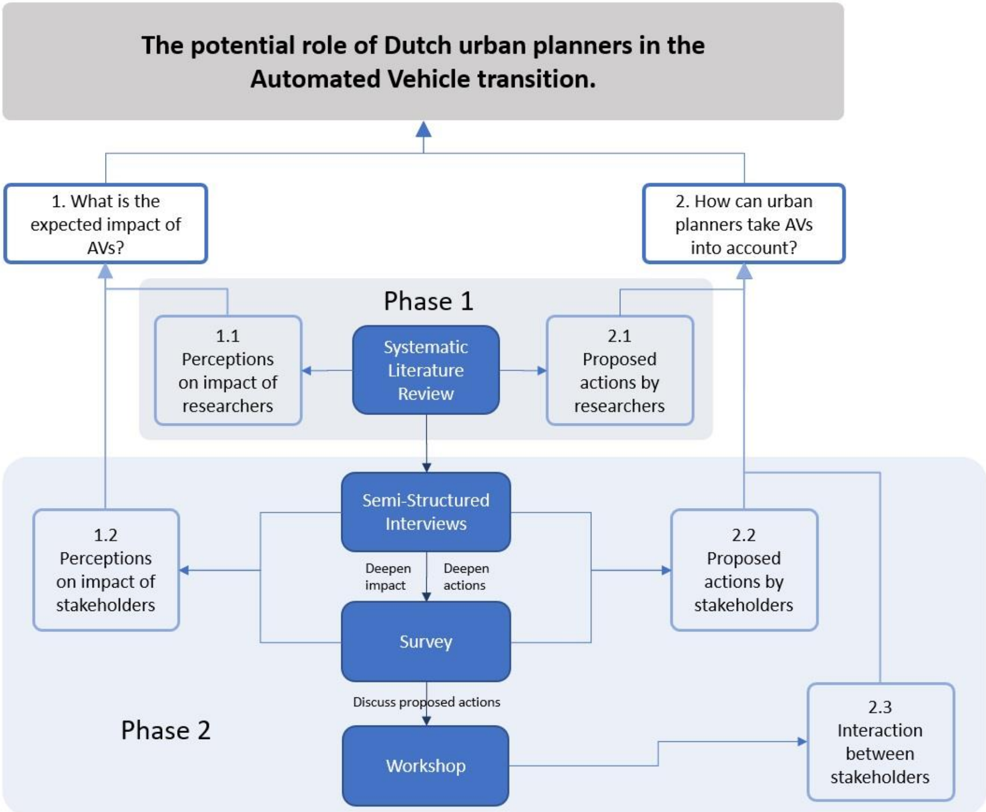


Figure 1, Summary of research approach.

In phase 1, a systematic literature study is conducted in order to gather theoretical insights in the expected impact of AVs (sub-question 1.1) and the related proposed actions (sub-question 1.2). All the costs and benefits are summarized of taking AV technologies into account in urban plans, in early stages of the development of the technologies. The expected impact of AVs on the urban system and the related possible actions are researched with the help of systematic literature review in phase 1.

In phase 2, a field research is conducted in order to compare theoretical insights with insights of practices in real-world-settings. This approach is used, in order to test: What the stakeholders expect from the transition of AVs and to what extent they are aware of the impact of AVs described in literature. In addition, it gives insight in how stakeholders perceive these impacts and what actions they are planning to take in reaction to these impacts. Lastly, it will help to understand how different stakeholders in the urban planning and transportation sector interact, in order to implement transportation technologies in urban development projects at the moment. In this way the second research question can be answered. The three methods that are used during the field research are: 1. Interviews, 2. Questionnaire, 3. Workshop.

3. Literature study

In this chapter, the following research sub-questions will be answered.

> 1.1 What is the expected impact of Automated Vehicles on the urban system according to academics and researchers?
> 2.1 What are proposed spatial planning actions in order to react on the expected impact of Automated Vehicles by academics and researchers?

This chapter will give insights in the impacts of AVs on road capacity from a research perspective (using scientific literature and research reports). In addition, it will describe some solutions, which researchers give, to prevent the increase of the amount of Vehicle Kilometres Travelled (VKT). These insights will form the basis of the field research.

The answer to the first sub-question will derive from the information described in four sections. First, the relation between the most important concepts is described: Automated Vehicles, urban planning and transport planning. Secondly, a description of the current situation in planning practices is given. Thirdly, the vision of academics and researchers on future scenarios of the implementation of AV technologies will be elaborated upon. Lastly, an approach is proposed how to interpret these scenarios and a conclusion is drawn. In the next chapter a stakeholder analysis is done in order to understand their perceptions on the different scenarios.

3.1 The relation between Automated Vehicles, urban and transportation planning.

Land use is a dilemma of urban planning and transportation planning. Modern cities are a residence, for both cars and people. Therefore, the relation between urban and transportation planning is about assigning land to roads and parking for cars and to buildings and public space for people (Economist, 2018).

Currently, Dutch cities are facing a huge sustainability question. In order to comply with the Dutch energy and climate objectives of the Paris agreements, the existing building stock should be energy neutral by the year 2050 (Filippidou, Nieboer, & Visscher, 2017). In order to meet this high demand for more sustainability, buildings need to be renovated or demolished and replaced by new buildings. At the same time the transportation system has to be adjusted in order to become more sustainable. The Clean Mobility Package of 2017 brings additional objectives for the EU Member States. In 2030, the CO_2 emissions from cars have to be 30% less than in 2021 (European-Commission, 2017). Both objectives will have a great impact on the urban systems of the Netherlands.

Figure 2, required land for different mobility concepts (source: momaportal.eu)

Developing urban plans focused on car-use, might increase congestion, discourage the use of public transport and active modes and encourage urban sprawl (Economist, 2018).
- In figure 2, it becomes clear that car infrastructure requires much more land, than other mobility concepts, like public transport and active modes. The land that is available to the mobility system will reach its limits earlier, when most infrastructure is designed for cars. This will lead to congestion.
- Urban sprawl can lead to more Vehicle Kilometres Travelled (VKT). In the US the amount of VKT can be reduced by 25 percent, if the urban density is doubled and employment locations are concentrated within metropolitan regions (TRB, 2009).
- Besides, building cities for cars can discourage low carbon mobility, which is defined as, "mobility that results in substantially lower levels of carbon emissions" (Givoni & Banister, 2013), examples are cycling and walking. Public transport is in some cases also an example, when it is measured per passenger.

All of these impacts are negative in the eyes of urban planners, as is stated in the "structuurvisie" of the ministry of infrastructure and land use (2012). In developed countries worldwide, car ownership numbers are mostly declining (Goodwin, 2012). However, according to Maltha (2016), car ownership rates in the Netherlands have been increasing between 1987 and 2014 and the expectation is that they will keep on increasing until 2050, without considering the rise of car-sharing and AVs (Maltha, Supervisors: van Wee, Kroesen, & Daalen, 2016).

AVs could accelerate both the car-sharing as the car-dependency trend (Economist, 2018). AVs could further increase private and individual car use by navigating autonomously within our cities. When in addition parking and road-use policies stay unchanged, parking and roads continue to require a lot of land (Papa & Ferreira, 2018). When urban planners focus too much on the introduction of AVs and ignore the need for stimulating car-sharing and public transport, it can result in an increase in congestion and reduced accessibility (Papa & Ferreira, 2018). Simultaneous, AVs offer a chance to increase the amount of public and shared cars (Thomopoulos & Givoni, 2015). Whether the AV will lead to a further lock-in of the car-dependent society depends on the decisions of all the stakeholders in the system and not only on the decisions made by the developers of the AV technology (Thomopoulos & Givoni, 2015). Therefore, there exist many possible future scenarios and policy decisions should be made in order to follow the preferred pathway.

3.2 Current spatial planning practices

Spatial planning is the interaction between mobility and urban planning. It includes land use, urban, regional, transport and environmental planning (Van Assche, Beunen, Duineveld & de Jong, 2013). Linking the travel-demand of the future to land use models is achievable now, academics have developed many relevant accessibility instruments (te Brömmelstroet, Curtis, Larsson, & Milakis, 2016). However, travel demand modellers currently lack the research evidence to add future scenarios where AVs are used, because these vehicles are not in use yet (Childress et al., 2015). Therefore, scenario planning could be a solution to this problem.

3.2.1 Scenario planning

In travel-demand forecasting, scenarios are educated guesses of the most likely future. In scenario planning, the term scenario is an envisioned series of future events. This makes it easier for urban planners to decide how effective actions that are taken today, will be in an uncertain future (Zegras, Sussman, & Conklin, 2004). “Scenarios are not seen as a group of quasi-forecasts; instead they are stories that describe different worlds and not different outcomes of the same world” (Wack, 1985). In this research scenario planning will be used in order to make strategic decisions.

In cases of projects where developments take a long time, like large-scale metropolitan transportation projects, the planning timeframe is necessarily long. Underneath such long-term plans are projections and forecasts (Myers & Kitsuse, 2000). This research will evaluate literature about both projections and forecasts of the future spatial impact of AVs in order to develop scenarios that will figure as starting point of the interviews with stakeholders. In the next chapter a literature study is done in order to develop scenarios.

3.3 Vision of academics and researchers

The literature shows, that the impact of AVs is uncertain and depends on the pathway of the development of the technology. The development is dependent on external factors (societal trends) and internal factors (speed of transition towards automation level 5). In the literature the effect of external factors and the expected impact is divided in scenarios and in order to include the effect of internal factors a timeline of the impact is developed.

3.3.1 Timeline

Alain Kornhauser makes a differentiation between the concepts of self-driving and driverless vehicles. This is based on the level of automation. In literature people are using the words, automated/self-driving and autonomous/driverless interchangeably. However, in this literature review we will use the concept of Automated Vehicles (AVs), because during the transition phase the level of automation is most interesting. AVs can be seen as: technological systems that take over the human dynamic driving tasks of monitoring and sensing the environment and navigating through it, by following the instructions of routes and destination from the driver. The higher the level of automation the more the vehicle becomes an autonomous/driverless vehicle. An autonomous vehicle can also take over cooperative tasks of communicating and exchanging information with other vehicles and the infrastructure (Milakis et al., 2015). When you take the literal meaning of autonomous, it will even decide on route and destination independently. There is a lot of uncertainty about the infrastructural needs for all the different levels of AVs.

Currently, it is difficult to predict, how much time it will take before full implementation of AVs (Litman, 2018). That is the reason why developing visions to consider the implications have a lot of uncertainty. Levinson et al. (2016) anticipate the following timeline for the deployment of fully AVs: in 2020 market availability, in 2030 a regulatory requirement for all new cars and in 2040 a prohibition of non-AVs from public roads at most times. According to the scenarios developed by Milakis et all (2016), fully AVs are first expected to be commercially available between 2025 and 2045. After their introduction it is estimated that the number of users will vary between 1% and 11% (mainly partially AVs) in 2030 and between 7% and 61% (mainly fully AVs) in 2050 (Milakis et all, 2016). It is advised that the impact of these AVs is already be integrated in urban plans, because the urban planning sector is envisioning plans with a time horizon of 2040 and beyond. The introduction of AVs may change future transportation choices and travel patterns on which urban planners base their decisions. Therefore, modelers might consider to include this change of use in modelling tools (Childress et al., 2015). The spatial impact of AVs will develop over time according to the level of automation. This is summarized in table 2 on the next page, based on the literature from (Litman, 2017).

Table 2: Timeline of the development of AVs and the expected impact on urban planning

	2018	2020	2025	2030	2040	2050	2060	2070	2080
Event	AVs become legal.								
Impact	Demonstrated functionality & safety.								
Action	Define performance, testing and data collection requirements for automated vehicles on public roads.								
Event		Independent mobility for non-drivers.		Automated vehicle-sharing.	Independent mobility for lower income.				
Impact		Fully AV available for sale.		Moderate price premium. Feasible business model.	Affordable AVs for sale.				
Action		Allows affluent non-drivers to enjoy independent mobility.		May provide demand response services in affluent areas.	Reduced need for conventual PT services in some areas.				
Event		Increase traffic density by vehicle coordination			Reduced parking demand.	Reduced traffic congestion.			
Impact		Road lanes dedicated to vehicles with coordinated platooning capabilities.			Major share of vehicles are fully automated.	Major share of urban peak vehicle travel is fully automated.			
Action		Evaluate impacts and define requirements. Assign lanes.			Reduced parking requirements.	Reduced road supply required.			
Event					Increased safety.		Mandated fully AVs.		
Impact					Major share of vehicle share is fully automated.		Most vehicles are fully automated and benefits are proven.		
Action					Reduced traffic risk, may increase pedestrian and cycling activity.		Allows advanced traffic management.		
Event					Need to plan for mix traffic.				
Impact					Major share of vehicles are fully automated.				
Action					More complex traffic situations, may justify restrictions on human-driven vehicles.				

Source: (Litman, 2017)

3.3.1. Impact of AVs and related proposed actions

The impact of AVs is very uncertain. This section will give an overview of the vision of the researchers and academics on the spatial impact of AVs. In addition, actions that are proposed to make use of these opportunities and safeguard the society from possible threats.

Positive impact
The impact of increased automation on the urban plan is as follows. An increase in automation of AVs will *increase in safety and efficiency*. When AVs are cooperative, they can have a shorter following distance, which *increases the road capacity,* without developing more and broader roads. However, this requires that most or all vehicles on a road operate autonomously. When the technique uses a bigger following distance, due to *increased safety measures*, it can lead to *less capacity on the road*. In addition, the connection, between the highway and the city is an issue. When entering a city and crossing roads, it is more difficult to decrease the following distance. Therefore, the whole chain can be disturbed (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017). When developing new roads, it is important to keep in mind that it might be necessary to transform them to another function in the future. *Road space that is no longer needed for moving or storing cars can be re-allocated* to other purposes such as bike lanes, pedestrian roads, exclusive transit lanes, linear parks or other (Milakis, Snelder, van Arem, van Wee, & Correia, 2016).

Move parking garages to city outskirts
Parking garages could be moved outside the city centre *(see action 1 in summary 3.5)* and AVs could independently park themselves here and pick up users when they are needed again. This can lead to an *increased density in metropolitan areas* as a result of the decreased need for parking solutions in the city centre (Anderson, et al., 2014). In contradiction it can also lead to a *decreased density in metropolitan regions*. Just like the introduction of the automobile led to an increased willingness to live farther out of the city centre, *people will be able to make housing location choices based on their residential preferences* (such as school quality, neighbourhood security, neighbourhood cohesion, etc.) rather than based on urban accessibility (Levinson et al., 2016).

It is not certain to what extent the demand for mobility will increase and what the effect will be on the demand for roads. Extra demand for mobility can be caused by four reasons. First, *the mobility of target groups that are not capable of driving a vehicle themselves (disabled, elderly and children) will be increased be the use of AVs*. In a regular western society this target group represent 10-30% of residents, which might increase over time by agedness. Still many residents of this target group have relatively low travel demands. In addition, they are currently dropped-off and picked-up by family or friends. Therefore, AVs might only increase their total travel demand by some percent (Litman, 2018). Secondly, people are not discouraged by the amount of travel time anymore. *Drivers convenience and productivity is increased*, because they are free to use their time in the vehicle to whatever they want (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017). This can encourage drivers to choose *longer travels to work and reside in more sprawled locations* (Stephens, et al., 2016). Thirdly, *delivery services might also become driverless* (Levinson et al., 2016). which will lead to a decrease in costs and possibly an *increase in the demand of the transportation of goods*. Lastly, mobility demand is strongly dependent to the number of cars that will be shared.

Car-sharing and ride-sharing
The two trends of sharing and automation can reinforce each other. Car-sharing is not very popular at the moment and thus it has little influence on the system yet. However, this can change when AVs are introduced and level 5 of automation is reached. In that case door-to-door traveling will be possible and the costs per passenger per vehicle driven kilometre will decrease, which will lead to a future where ‘mobility as a service’ is the trend (Tillema, Gelauff, Waard, Berveling, & Moorman,

2017). *Car-sharing and ride-sharing can become popular (see action 2 in summary 3.5).* In the Netherlands it is expected, that car-sharing will lead to 30% less car-ownership and 15-20% less Vehicle Kilometres Travelled (VKT) (Nijland, Meerkerk, & Hoen, 2015).

Drop-off and pick-up points
Vehicles that are driverless are able to drop off passengers, redeploy to park or pick up new passengers. This can stimulate an *increase in Empty Vehicle Travel (EVT)*. An increase in car-sharing and ride-sharing would *decrease car ownership*. In this case *less parking space is required* and a different land use could be considered. In order to make optimal use of this sharing system, more drop-off points are needed (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017). Each additional passenger will add *pickup and drop-off delays*. Especially, special need target groups (children, disabled and elderly), but also package deliveries. They need extra space and time to get off. In more low dense areas or dead-end streets, an extra stop also increases the space needed (Litman, 2018). When picking-up/dropping-off or wait for new passengers, it might be cheaper in high density areas for an AV to drive around, instead of paying high parking fees. This is caused by the current parking policies and lack of road-pricing policies of the system. Therefore, *shared AVs are likely to decrease vehicle ownership, but increase Vehicle Kilometres Travelled (VKT)* (Sivak & Schoettle, 2015). Case-study results indicate that in a system of shared AVs, a vehicle can be shared between 10 passengers, but it would incur about 11% more VKT to reach the next passenger (Milakis, Snelder, van Arem, van Wee, & Correia, 2016), (Fagnant & Kockelman, 2014), (Sivak & Schoettle, 2015). According to Trommer, Kolarova, Fraedrich and Kroger (2016), VKT will be increased by 3-9% in 2035 (Trommer, Kolarova, Fraedrich, & Kroger, 2016). The decrease in vehicle-ownership, will mean that less parking space is required and a different land use could be considered. This can for example be assigned to the *drop-off and pick-up lanes that are needed (action 5 in summary 3.5)*, in order to make an optimal use of this sharing system (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017).

Road-pricing
However, the decrease in car-ownership will not always lead to a decrease in roads needed. A switch to shared AVs could decrease vehicle occupancy rates, reducing the number of vehicles needed to move people around and easing congestion. Nevertheless, the low-costs of trips with shared vehicles (costs are divided by more people), might encourage people to make more use of these vehicles instead of using a bike, public transport, walking or not making the trip at all. According to Litman (2018), ride-sharing of AVs will become comparable in price with public transport, because the constant and variable costs of the vehicle are shared over more multiple passengers (Litman, 2018). In this case the problem will be that the demand of roads increases, because traveling becomes cheaper and easier. *Careful pricing of roads and rides can prevent that automated congestion arises (see action 3 of summary 3.5)* (Economist, 2018). On the other hand, the low price of shared AV rides can incline vehicle owners to shift to sharing vehicles. Owned vehicles have high fixed costs regardless of the VKT by the privately-owned vehicle, while the fixed costs of shared vehicles are spread over all the VKT by the shared vehicle. Therefore, the shift from owning to sharing a vehicle can incline users to reduce the VKT, by 25-75% (Lovejoy, Handy, & Boarnet, 2013).

Public transport
Due to the low price of AV ridesharing, some academics are stating that the government should not invest in public transport infrastructure anymore, because in the future *AVs might replace public transport systems*. The main issue in this, is that public transport infrastructure has a long return on investment time and decisions are taken a long time in advance of the development. However, *AV and public transport systems can also be combined and supplement each other*, because the implementation of AV technologies is easier in separated traffic flows. Only when the automation level 5 is reached the systems can compete (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017).

Construct attractive bicycle and pedestrian infrastructure
Bicyclists and pedestrians are hard to detect for AVs and can therefore be a risk for both the users of the AV (congestion, because the vehicle has to stop for uncareful cyclists and pedestrians) and the cyclist and pedestrians themselves (safety) (Sandt & Owens, 2017). Therefore, separated lanes would be better. In addition, in the Netherlands most households are able to use their bicycle or go by foot to most common daily facilities (grocery shops, schools, parks, etc.). Still, cars are used for most trips (Wiersma, Bertolini, & Straatemeier, 2016). This is caused by unattractive, unsafe and insufficient bicycle lanes and parking (Litman, 2018). Therefore, it might be wise to *construct attractive bicycle and pedestrian infrastructure* *(action 4 in summary 3.5).*

Mixed functions living areas and offices around public transport nodes
In order to remove car-dependency, spatial planning can encourage bicyclist and pedestrians. This can be done by compact, *mixed urban development* *(action 6 in summary 3.5)*, which creates residential and working locations, where most common daily facilities can be reached within 5 to 10 minutes by walking or bicycling (Litman, 2017). Car-dependency can also be removed by Transit-Oriented Development. This means that *working and residential locations are located around major transit stations* *(action 7 in summary 3.5)* (Litman, 2017).

3.3.2. Relation between Automated Vehicles and the Sharing economy
In order to create more certainty about the future impact of AVs and the timeline the development of this technology follows, Tillema, Gelauff, van der Waard, Berveling and Moorman (2017), developed four future scenarios' depending on the automation and sharing level of AVs. The two trends of the sharing level and automation level of vehicles are combined to different possible future uses of transportation systems, which will have an impact on the urban mobility system. This means that following different pathways of the level of sharing and automation of vehicles can lead to different outcomes (see figure 3).

These scenarios predict that when we will reach level 5 of full automation following different pathways of the level of sharing vehicles, there exist two possible futures in which a technological lock-in situation has appeared. When we do not reach full automation, also two scenarios of sharing and not sharing vehicles could exist. It is important to understand what effect these four scenarios will have on the urban system and what the perceptions of stakeholders are, in order to make decisions about developments of AVs. The transition of AVs can be influenced by a combination of developments.

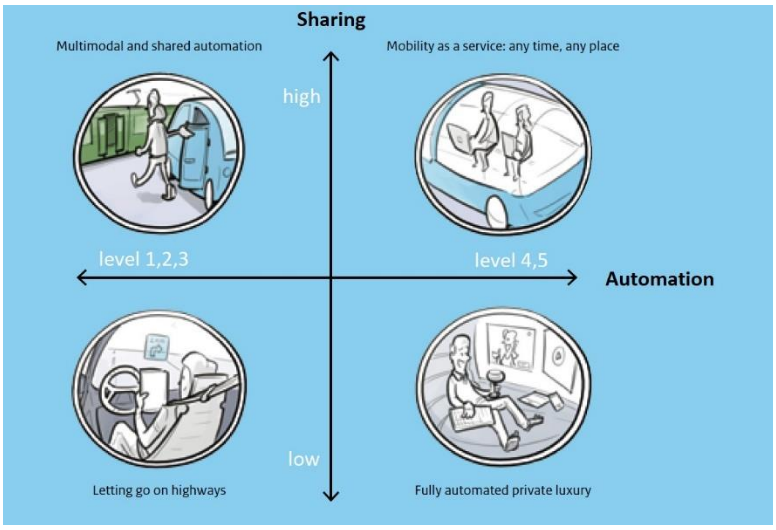


Figure 3, Scenarios of the automation and sharing transition of vehicles (Tillema et al., 2017)

The two trends of the sharing-economy and automation, can lead to different future uses of transportation systems, which will have an impact on road and parking capacity and thus on urban planning. In order to create a better understanding of the impact of the AVs on urban planning, it is important to show what spatial developments are necessary in which scenario. The scenarios of the report described by Tillema et al. (2017), will be used in order show what spatial effects are connected to the level of automation and the level of sharing. The spatial effects of the scenarios will be summarized and categorized per scenario in table 3. The spatial impacts are also described in more detail below.

Table 3: Summary of the spatial impact of the sharing and automation transition.

Spatial effect		level 3/4	level 5
Urban sprawl.	**Shared**	+-	+
Population density in major cities.		+	++
Parking space needed in city centre.		-	--
Parking space needed on outskirts.		+-	+
Drop-off and Pick-up space needed.		+-	++
Lanes needed on high ways.		+	-
Lanes needed in city centres.		+	++
Cycling paths.		+-	-
Public transport (bus and tram).		+-	-
Public transport (train and metro).		+-	+-
Narrower lanes.		+	+
Urban sprawl.	**Not-shared**	+	++
Population density in major cities.		+-	-
Parking space needed in city centre.		-	-
Parking space needed on outskirts.		+-	++
Drop-off and Pick-up space needed.		+-	+
Lanes needed on high ways.		+	++
Lanes needed in city centres.		+	++
Cycling paths.		+-	-
Public transport (bus and tram).		+-	--
Public transport (train and metro).		-	--
Narrower lanes.			+

+

Legend

++	Strong increase
+	Increase
+-	Stays the same
-	Decrease
--	Strong decrease

Level 5

In the scenario, where automation level 5 is reached, AVs will cause some trends.
- Travel-time is not seen as a waste anymore, due to the increased driver convenience and productivity. People prefer to live in healthy, quietly and green areas. There is a change in house, work, recreation location preferences. This might lead to urban sprawl, which makes it necessary to develop more lanes between functions (residence, job, recreation) and to develop, more houses and basic facilities in suburban and rural areas.
- AVs can park themselves more efficient and have a shorter following distance, this might lead to more efficient use of road capacity. Therefore, less parking and road infrastructure is needed. This effect is mostly seen outside the city centre.
- There will be an increased mobility demand, caused by non-drivers. Longer and more travels are made, due to increased driver convenience and productivity. People prefer AVs above the use of public transport, walking and cycling, due to the higher driver productivity. The price of package delivery decreases, which causes more EVT. In addition, empty vehicles are driving around to safe parking fees, return to their owners or new users. This will all lead to an increase in VKT. Therefore, more road capacity and pick-up/drop-off points are needed in inner cities. Especially in inner-city centres with many, short distance travel, public functions and houses and thus final destinations. In low dense areas with less public transportation and sharing possibilities, there is also more road capacity needed.
- The mobility demand does not match the road capacity anymore. Therefore, streams of different transport modes are split up. On some places in the transportation network it becomes necessary to split AV streams from cyclist and pedestrians.

Sharing trend is accelerated

In the scenario, where the sharing trend is accelerated by the introduction of level 5 AVs. AVs will cause some trends.
- The low price and sustainable use of sharing is preferred above the comfort of private vehicles, which cause an increase in ride-sharing and car-sharing. This will lead to a decrease in car ownership. Therefore, less parking spaces are needed, less roads are needed and more drop-off and pick-up points are needed to decrease congestion.
- Due to EVT, empty vehicles driving around to find new users and to safe parking fees. Longer and more often pick-up/drop-off delays. Increased mobility demand caused by low prices of sharing. This

will lead to an increase in VKT. Therefore, more road capacity and pick-up/drop-off points needed in inner cities. Especially in inner-city centres with many public functions and houses and thus final destinations.

- The decreased car-ownership, the more efficient parking ability of AVs and the more intensive use of vehicles, will lead to extremely efficient parking. Therefore, less parking space is needed. Special shared-vehicle parking garages are needed on city outskirts. Less use of parking spots on destinations. More parking spaces needed on distance with drop-off and pick-up space for shared AVs.
- The easy use of sharing transportation system and the healthier and more attractive living environment, might lead to a preference for urban living. The decrease in required land for the mobility system, can make room for houses and facilities in city centres. Due to higher urban densities, more houses and facilities are needed in cities.
- The low-costs of trips with shared vehicles (costs are divided by more people), might encourage people to make more use of AVs instead of using a bike, regular public transport, walking or not making the trip at all. This will lead to a decreased use of Public Transport (PT), bike and walking. Therefore, less public transport infrastructure needed. Especially buses lose clients, trains/metros remain popular. Less bicycle lanes are needed. Less pedestrian roads are needed.

The use of the private vehicle will increase
In the scenario, where ownership rates increase, by the introduction of level 5 AVs.
- The increased mobility demand of non-drivers and attractive luxury use of a car, might lead to more ownership. People appraise AVs as a second moving home. People prefer comfort and privacy above price and environment. Therefore, more lanes are needed, more parking space is needed. less houses/hotels are needed, people live or sleep in their car. This will also lead to a decreased use of PT, bike and walking. Therefore, less public transport infrastructure is needed. Less bicycle lanes are needed. Less pedestrian roads are needed.
- Travel-time is not seen as a waste anymore, due to the increased driver convenience and productivity. People prefer to live in healthy, quiet and green areas (Van Dam, Heins, & Elbersen, 2002). This might lead to a situation in which housing and company preferences are not based on travel-time and accessibility anymore. -This might lead to urban sprawl. More lanes are needed between functions (residence, job, recreation). Especially companies and recreation facilities are moving out of the city centre. More houses and basic facilities needed in suburban and rural areas and less in city-centres. In cities can exist multiple subcentres.
- The more efficient parking ability and more intensive use of vehicles, will lead to efficient parking. Therefore, less parking space needed on destinations. Parking garages are needed for valet parking and parking on distance. Pick-up and drop-off spaces needed.

Level 3 and 4
In the scenario, where only automation level 3 to 4 is reached, AVs will have less impact.
- People prefer the comfort and privacy of a private AV, above price and environment. Small decrease in use of conventional PT and shift to Private AVs and AV taxi's (PT on demand). Small shift from walking and cycling to use of AVs. This will lead to a decreased use of PT, bike and walking. However, almost no spatial impacts are expected.
- When it will take a long time before level 5 AVs will be developed, it can be considered to split up transportation streams in order to create more safety. Therefore, some urban routes need to be designed for AVs and these roads should not cross roads of cyclists and pedestrians.
- The increase of parking on distance or final destination and a small increase in valet parking, will lead to efficient parking. Therefore, more parking garages are needed at the outskirts of cities. Parking space can become smaller.

Sharing becomes more popular
In the scenario, where the sharing trend is accelerated by the introduction of level 5 AVs. AVs will cause some trends.
- Some people are more inclined to move from rural areas and small cities in order to live in bigger cities to use the sharing concepts. This might lead to a change in living preferences. Therefore, more houses and functions necessary in big cities.
- Sharing concepts are not as popular as in the scenario with level 5 of automation, because door-to-door travel is not possible yet. Therefore, there will still be a slightly increase in car-ownership. Therefore, More lanes and parking lots are needed.

The use of the private vehicle will increase
In the scenario, where ownership rates increase, by the introduction of level 5 AVs. AVs will cause different trends.
- Living preferences are less based on accessibility and travel time. More urban sprawl can be noticed. This will lead to a change in living preferences. Therefore, more houses and facilities are needed in lower density areas.
- More private vehicles are driving around. AVs are not shared between owners. Rides are not shared between AV-taxi-costumers. Therefore, more lanes are needed and more parking space is needed.

3.4 Summary of literature study

To conclude total congestion impact will depend on how AV technologies affect travel and urban development patterns. Three indicators can show if there will be an increase or decrease in congestion, namely Vehicle Kilometres Travelled (VKT), mobility demand and road capacity.

VKT is defined as: the number of kilometres that is travelled by a vehicle.
Mobility demand is defined as: the demand for a certain type of mobility, expressed in the number of trips that is made by a vehicle.
Road capacity is defined in the dictionary as: The maximum traffic flow obtainable on a given roadway using all available lanes, in this research expressed in vehicles per hour.

3.4.1 Expected impact of AVs on urban planning

In order to structure the impact of AVs on the VKT, mobility demand and road capacity, both within cities as on highways, a table is made (see table 4). The spatial impacts are also described in more detail below.

The trend of sharing vehicles between owners (vehicle-sharing) and users (ride-sharing) is considered as the most important external factor (Tillema et al., 2017). However, beside the development of the sharing economy, there exist many more trends that have an impact on the future impact of AVs. Changes in demographics (aging population and working from home), consumer preferences (increased urban living, increased support for a healthy lifestyle), economics (rising fuel prices, economic downturns and grows), mobility options (improved walking, cycling and public transport, telework and delivery services), intelligent transport systems (improved user information and navigation, electronic pricing, improved information traffic), urban planning (priority for certain functions and mobility use), will also have a big impact on the ways people travel by the use of AVs and how urban mobility planning is organised (Litman, 2018).

In this research all external factors are combined (summarized in table 4 on the next page). Most spatial impacts will only appear at automation level 5. When automation level 3/4 is developed, drivers can turn their attention away from the driving tasks at certain moments (for example on highways).
- Due to valet parking (in which the AV parks itself without a driver that needs space to get out the vehicle), parking distances between vehicles can decrease. This will lead to an increase in parking capacity (Timpner, Friedrichs, van Balen, & Wolf, 2015).
- In addition, there will be an increased driving convenience and productivity for drivers, which might lead to an increased willingness to use AVs for trips and increased travel distances (Trommer et al., 2016). This will increase the mobility demand for AVs and the overall VKT by AVs, and therefore with constant road capacity may increase congestion. Besides the preference for functions on certain locations might change. Urban sprawl might appear, because for example the acceptable travel distance between work and home might increase. When level 5 of automation is reached this effect will be even stronger.

When automation level 5 is reached, no human intervention is required at all times. The next impacts are expected in literature.
- The following distances between vehicles, can become shorter. However, the increase of the throughput of highway facilities, as well as the improvement of the stability of the traffic stream, are dependent on the percentage of automated vehicles and the speed harmonization (Mahmassani, 2016). However, there are also safety reasons why the AV might keep a larger-than-usual following distance (Maurer, Gerdes, Lenz, & Winner, 2016), which increases congestion.

- Parking garages can move to city outskirts (Maurer et al., 2016). This will lead to a decrease in needed parking space in cities, but an increase in VKT by AVs to drop-off and pick-up passengers. However, due to the increase in waiting time people might be less inclined to use an AV instead of other mobility concepts. This might lead to an overall decrease in VKT by AVs, and therefore with constant road capacity may decrease congestion. When the waiting time is not considered as an issue by users the amount of VKT will increase and therefore with constant road capacity may increase congestion.
- In addition, non-drivers are enabled to drive (Litman, 2018). This will lead to an increase in mobility demand and VKT by AVs. Therefore, assuming the same road capacity congestion may increase.
- There might appear a decrease in vehicle-ownership, because it is easier to share a vehicle between users, due to EVT door-to-door travel to pick-up and drop-off users. This will lead to a decrease in parking space needed, but an increase in the overall VKT travelled (Truong et al., 2017). The constant costs for the use of a shared AV will decrease per person and therefore the mobility demand for shared AVs might increase. Therefore, assuming the same road capacity, congestion may increase.
- Besides there might be an increase in ride-sharing, due to easy door-to-door travel to pick-up and drop-off users. This will lead within cities to more VKT to pick-up and drop-off users, but will lead to a decrease in VKT between cities. However, the decrease in the constant and variable cost per passenger, might lead to an increase in mobility demand for shared AVs. The overall effect is expected to increase congestion, assuming a constant road capacity.
- Lastly, there might be a decrease in the mobility demand for walking, public transport and bicycle use. This is caused by users that switch to the more attractive and sometimes cheaper option of private and shared AVs. This will lead to an increase in VKT per person, because public transport can move more persons per vehicle. Besides, it will require more land for mobility, because walking, cycling and public transport requires less land per moved user than AVs. Therefore, the overall road capacity will decrease.

Table 4: Impact of AVs on urban planning, the increase/decrease in mobility demand, VKT, road capacity and congestion, on highways and in cities

Impact of AVs	**Spatial impact**	**Level**		**Impact on mobility choices and travel patterns**										**Relevant source**
	On Lanes On Parking	3 4	5	Mobility demand			VKT			Road capacity			Congestion	
				Total	Cities	High ways	Total	Cities	High ways	Total	Cities	High ways	Total	
Decrease in following distance.	D Lanes		+							I		I	D	(Mahmassani, 2016)
Decrease in distances between parked vehicles.	D Parking	+	++							I	I		I	(Timpner et al., 2015)
Moving parking garages to outskirts, leads to increased Empty Vehicle Travel.	D Parking I Lanes		+				D	I	D	D	D	I	D or I	(Maurer et al., 2016)
Increased drivers' convenience and productivity.	I Lanes	+	++	I	D	I	I	D	I				I	(Trommer et al., 2016)
Enable non-drivers to drive.	I Lanes		+	I	I	I	I	I	I				I	(Stephens et al., 2016)
Increased EVT, due to increased demand for transporting goods.	I Lanes		+	I	I	I	I	I	I				I	No literature found. Assumed by researcher.
Sharing AVs, leads to decreased vehicle-ownership and to EVT.	D Parking I Lanes		+	I	I	I	I	I	I				I	(Truong et al., 2017)
Increase ride-sharing.	D Parking D Lanes	+	++	D	D	D	D	I	D				D	(Childress et al., 2015)
Decreased use of Public Transport, bike and walking	I Lanes	+	++				I	I	I	D	D	D	I	(Litman, 2018)

Legend: Decrease = D, Increase = I, No effect = blank space, Relation = +, Strong Relation = ++

3.4.2 Proposed actions for the effective integration of AVs in the urban plan.

To sum up, many impacts in urban areas might lead to an increased mobility demand and amount of VKT, when road capacity stays the same, this will lead to an increase in congestion. Therefore, it is a logical step to steer the development of AVs or to adjust roads, in order to prevent future major congestions. Below is a summary of actions that are proposed in literature:

1. Moving parking garages to outskirts

Less attractive to use car for short distances. Less space needed for parking and access roads in inner-cities. Use shuttles, public transport, bicycles and pedestrian roads to bring people to their final destination in the city-centre

2. Stimulate car-sharing and ride-sharing

Less parking and roads necessary. Les congestion. In order to keep stimulating using public transport, walking and cycling, introduce road pricing to keep the balance in mobility demand per travel mode. Make walking and cycling more attractive by giving them priority is cities.

3. Introduce road-pricing

In this way using vehicles will be discouraged.

4. Construct attractive bicycle and pedestrian infrastructure

In this way cycling and walking is encouraged.

5. Construct drop-off and pick-up places

In order to prevent congestion and to stimulate that people get on and off a vehicle at the same place to become more efficient and reduce the amount of VKT.

6. Develop mixed functions living areas

In order to stimulate walking and cycling. All necessary daily functions need to be on walking distance. Weekly trips need to be on cycling distance.

7. Stimulate building offices near public transport nodes

In order to stimulate people to go to work by public transport.

4. Field research

It is unknown if the impact of AVs is perceived positive or negative by different stakeholders in practice (urban planners, consultants). This chapter will give an overview of the expectations of the stakeholders on the spatial impact of AVs. In addition, actions that are proposed to make use of these opportunities and safeguard the society from possible threats are described. In this chapter the results of the field research are presented. The field research consisted of three methods. First semi-structured interviews are conducted, that are based on the literature review. These interviews are giving a broad overview of all the different perceptions that exist among stakeholders. The results of these interviews are analysed with the help of content analysis, in order to find debatable and/or controversial viewpoints. Secondly, a questionnaire is developed based on the results of the interviews. The questionnaire will go deeper into detail about the viewpoint of the stakeholders, in order to find conflicts and opportunities of cooperation. Lastly, a workshop is conducted based on the answers on the questionnaire. The workshop will focus on the interaction between stakeholders, when they are discussing impacts and proposing actions.

This chapter is build-up of three sections. First, the general vision on AVs of the stakeholders is described. Secondly, the current strategy of dealing with AVs of the stakeholders is described. Lastly, the proposed actions on possible AV scenarios by stakeholders is described. Every section consists of first the interview results, which give a general impression of the perceptions of the stakeholders. Secondly, some viewpoints are highlighted and researched in more detail with the help of the questionnaire. The results of the interviews and questionnaire are compared and summarized and the results are adjusted. Lastly, the proposed actions from the interview are discussed during the workshop and additional proposed actions are gathered. The summary of the actual discussion is represented in the last section.

The next section describes the category system that is used to represent the results of the interviews in tables (tables 5 to 9). The viewpoints of the respondents (the results) are summarized, coded and represented in these tables. On the horizontal axe of the table, the respondents are categorized in seven groups:

1. Rijkswaterstaat (RWS)
    - Transportation planning
        - Water, Traffic and Environment (WTE)
2. Interprovinciaal Overleg (IPO)
    - Transportation planning
        - Mobility
3. Province North-Holland (Province of North-Holland)
    - Transportation planning
        - Chain mobility (CM)
        - Mobility agenda (MA)
        - Smart mobility (SM)
        - Bicycle paths (BP)
    - Urban planning
        - Environment Vision (EV)
        - Traffic nodes (TN)
4. Municipality of Amsterdam (Ams)
    - Urban planner
        - Smart mobility (SM)
    - Transportation planner
        - AV planner (AP)
5. Arcadis (Arcadis)
    - Transportation planner
        - Policy and mobility (PM)
        - Smart mobility (SM)
    - Urban planner
        - Landscape Architect (LA)
        - Smart Cities (SC)
6. Public transport companies (PT)
        - Train (T)
        - Bus (B)
        - AV (AV)
        - Anonymous (-)
7. Car-sharing/renting companies (Sharing)
        - Car-renting (CR)
        - Anonymous (-)

Group 1, 2, 3 and 4 are from the government. Group 6 is the consultancy company. Group 6 and 7 are transportation companies.

On the vertical axe of the tables, the viewpoints on certain subjects of the respondents are categorized in categories and themes.

Categories:

- Vision (code: V)
- Strategy (code: S)
- Impacts (code: I) and Actions (code: A)

Themes:

Vision (code: V):
- Timeline
- Strengths
- Weaknesses
- Threats
- Opportunities

Strategy (code: S):
- Documents
- Research
- Goals
- Policy Windows
- Strategies
- Pitfalls

Impacts (code: I) and Actions (code: A):
- land-use mobility system
- Mobility choice
- Spatial planning

The sub-themes are numbered. A more elaborated explanation of all the categories, themes and sub-themes is described in section B of the appendix. When the viewpoint/subject came up during the interview with the respondents an "x" is placed in the table. When the respondent during the questionnaire agrees on the viewpoint a "Y" is placed in the table and when the respondent disagrees on the viewpoint a "N" is placed in the table. This is a verification of the perceptions of the stakeholders during the interviews. When the respondent is uncertain about the subject a "?" is placed. When the topic is not discussed during the interview, the space in the table is left empty. The same viewpoint on certain subjects by respondents from the same group reflects the main perspective on this theme. Conflicting viewpoints by respondents from the same group can uncover uncertainty about a theme.

The results of the questionnaire are presented in line graphics (figures 4 to 14 and all the figures in Appendix C). On the horizontal axe the number of persons that gave a certain answer is showed. The colours of the results show from which organization the respondent is. Below the horizontal axe the legend of these colours is presented. On the vertical axe the answers are showed. The results are also showed in circle diagrams. The colours of the diagram show the percentage of respondents that gave the certain answer. Underneath the legend of the answers is presented. All the results are presented in Appendix C. The most striking results are presented in this chapter.

The most important insights of the workshop are described throughout this chapter. In addition, an English summary is made of the discussion (which can be found in Appendix D).

The most striking results of the interviews, questionnaire and workshop are combined in tables (tables 5 to 9). These tables use the same code-system as the tables of the interviews.

4.1 Vision of stakeholders

The interview was structured in order to first find out, what positive and negative impacts stakeholders foresee. Therefore, the first category of the content analysis is "vision" (see table 5b in appendix B). The first question in most interviews related to this category was, "What is your vision on the future impact of AVs?"

A more detailed description of all the sub-themes, that are named in this section can be found in appendix B "Vision". A summary of the results can be found in table 5b in Appendix B "Vision". A more detailed described for the understanding of the tables can be found in the previous section (the introduction to the results of the field research, 4. Field research).

The sub-themes are strengths and weaknesses of AVs and challenges and opportunities of AVs. This is based on the SWOT-analysis method. This shows how stakeholders perceive the impact of AVs and what they consider positive or negative. The SWOT-analysis consists of strengths, weaknesses, opportunities and threats. The strengths of AVs are the characteristics of the technology that give an advantage over other mobility concepts. These can also be perceived as positive impacts of the AV transition. The weaknesses of AVs are the characteristics of the technology that place it at a disadvantage relative to other mobility concepts. These can also be perceived as negative impacts of the AV transition. Threats are elements in the environment that could cause trouble for the integration of AVs in the urban plan during the transition phase. These are challenges to the right implementation of AVs in the urban plan and need extra attention of planners. Opportunities are elements in the environment that can be exploited to the advantage of the AV transition, in order to integrate the technology in the urban plan. This are not necessarily positive impacts, but these aspects bring an opportunity to the introduction of AVs.

In general, it is expected that it is impossible to prevent the transition towards AVs. At the same time, many stakeholders find it hard to make a forecast of the timeline of the transition towards fully AVs. In addition, the forecast they do made are conflicting between respondents.

Strengths

The expected strengths of AVs are an increase in traffic safety (6 of the 20 respondents, from this point forward revering to the amount of respondents will be abbreviated with #R), an increase in road capacity (5/20R), a decrease in parking norms (11/20R), an increase of accessibility for less mobile citizen and therefore an increase in social inclusion (4/20R), a decrease in the costs of mobility (5/20R) and an reduction in the value of time (3/20R). The most striking results for the strengths are the following. The government expects a lot from the increase in traffic safety and social inclusion, while in the private sector these subjects are less dominant. The public transport companies expect more from the reduction in the value of time, the decrease in costs and the increase in road capacity. Respondents from all sectors are interested in the decrease in parking norms.

Weaknesses

The expected weaknesses of AVs are: an increase in private car ownership and use (10/20R, 1R is uncertain), which in return might lead to a decrease in public transport (4/20R) and bicycle use (4/20R). Private car use requires more land, than the use of public transport and bicycles and therefore the land-use of the mobility system will increase (4/20R). This can be solved by a payment system. However, the negative side-effect of this might be that social exclusion will arise, because the poor have less meant to travel. It is interesting that the decrease in public transport use is only expected by one stakeholder from a public transport company. The weakness of AVs that is named by most respondents is the increase in car ownership and/or use. Many names also that there is a relation with the transition towards sharing vehicles, but that this trend is not accelerated yet. The respondents of Arcadis are more focused on the weaknesses, than the strengths of AVs. While all the other respondents focus more on the strengths.

Threats
The threats to the introduction of AVs are first of all complex traffic situations and high speeds (10/20R). Another is the decrease in living quality, which evolves from congestion of AVs in city centres (named by two transportation planners of the government). Due the expected increase in the target group for cars, a decrease in car-ownership is preferred. However, the sharing transition (from ownership to use) is not there yet. It is also possible that the transition towards shared vehicles strands (9/20R, only transportation planners). During and even after the transition phase, there might be two mobility systems that exist next to each other (the current mobility system and the AV mobility system). The current infrastructure is not accessible for current AV concepts and might be for possible future AV concepts (6/20R). This will require a lot of land.

Another threat are misconceptions about the impact of AVs (V4.5). Under respondents there exist misconceptions about the relation between AVs and Electric Vehicles (EVs). It became clear that AVs are still sometimes confused with EVs. Therefore, AVs are wrongly connected to the positive impacts of improved air quality (2/20R) and the reduction of noise (2/20R). Four respondents from the government claim in the interviews that the transition to AVs, will also lead to an improved air quality (2/20R) and a decrease in noise (2/20R). However, these positive impacts will only appear with the introduction of EVs. Some of these respondents corrected themselves eventually during the interview, by recognizing that these are two separated transitions. Some respondents state that there are misperceptions about the expected positive impacts of AVs. An example is that the automation transition is automatically connected to the sharing transition and decreased ownership, while there are also scenarios possible in which AVs are mostly used privately (4 transportation planners are worried about this misperception).

Opportunities
Opportunities that come with the introduction of AVs are the development of an integral mobility system. Three respondents of the government and one of public transport, think the whole mobility system can be transformed and different modalities can be integrated with each other by the introduction of AVs and a new mobility system will arise. According to an urban planner of the province of North-Holland: “It can be an opportunity for a new way of organizing logistic streams through the city.” Five respondents of the government expect that the use of MaaS concepts is accelerated. Seven respondents think a more efficient public transport system, while only one of them is actually from a public transport company. The acceleration of the transition towards shared vehicles is expected by 14 of the 20 respondents. Two respondents think it becomes necessary to use a different type of AV, in for example automation level or size, per context. The reason for this is that the diversity in traffic complexity and speeds on different roads is too difficult to handle for only one type of AV. This can be connected to the threat that is named by most respondents, that AVs have difficulties with handling complex traffic situations and high speeds. It is also connected to safety and the level of automation of vehicles that will develop over time during the transition phase.

Interpretation
Although, some impacts are not named by all respondents, this does not mean that they are not important to them or that they do not have a vision on them. The impacts from the vision table are the subjects that come first to mind at the respondents during the interview and are therefore a first indication of the perception of the different stakeholders. The questionnaire that is described in the Results section 5.1.3. is developed in order to compare the vision of the different stakeholders. The

subjects that are found during the interview are repeated and connections are made between the subjects in order to force the respondents to decide what impact is most important and what actions are needed.

Not all results are important to answer the research question. This research is focused on the spatial impact of AVs, therefore the subjects that are related to spatial planning are researched in more detail.

4.1.1 Timeline

During the interview many stakeholders found it hard to make a forecast of the timeline of the transition towards fully AVs (See V1.2). However, this is important for the urban planning sector in order to know when the urban system needs to be ready for the introduction of AVs. Therefore, the first proposition in the questionnaire is: "*1. Timeline: Between 2025 and 2030 the first AVs will appear on the roads. From 2050 more than half of the households will own a AV.*" This is answered differently by the three respondent groups (see figure 4). The Government is more negative and uncertain about the development of AVs over time than the transportation companies and Arcadis.

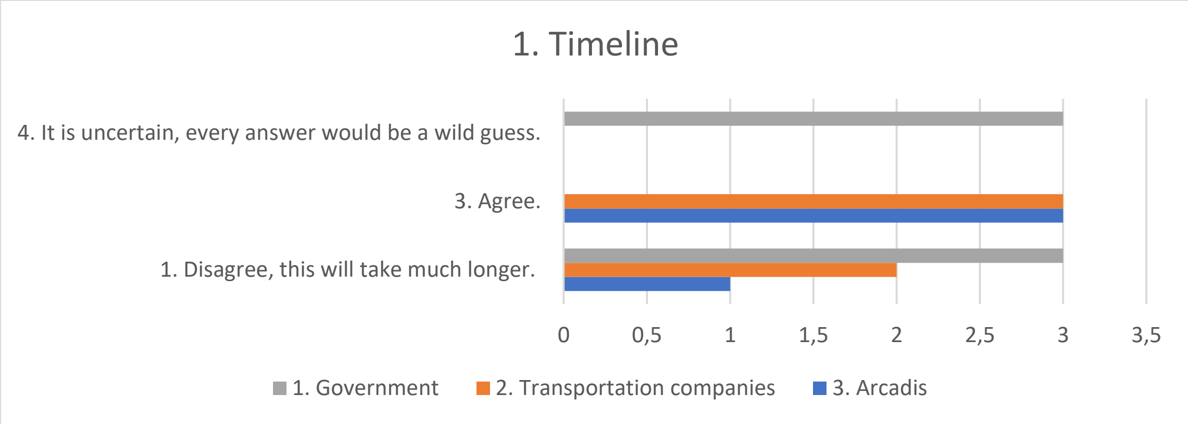


Figure 4, Expected timeline of the development of AVs based on results of the questionnaire.

Table 5b is completed with the results of the questionnaire, for the sub-theme with code V1.2 (see table 5a on page 63). Two respondents from the government changed their viewpoint from agreeing to the statement to expecting that the transition will take longer. To sum up 8/20 respondents think the expectations about the AV transition speeds in literature are right. 6/20 think it will take less time and 3/20 think it will take more time.

4.1.2 Impact on parking capacity

During the interviews the positive impact of AVs that was named by most respondents (11/20 respondents), is the expected decrease in needed parking capacity within city centres. Therefore, parking norms might decrease (V2.2). In the questionnaire in question 6 this perception is checked again (see figure 24 in appendix C). The question was: *"Due to the introduction of AVs, it becomes possible to make cities car-free and cars can be parked outside the city. Is this desirable?"* 11/14 respondents agree and 3/14 disagree that AVs influence parking. Together the results of the interview and the questionnaire show, that 15/20 respondents agree and 3/20 disagree that AVs might lead to a decrease in parking norms in city centres and 2 respondents did not mention this subject. 10/20 respondents think, that car-free city centres are desirable. 12/20 respondents think, that parking outside city centres is desirable (see table 5a on page 63).

4.1.3 Impact on road capacity

The results of the interviews are conflicting in the impact on car-use and car-ownership. Many respondents name the possibility on an increase in car ownership and car use as a weakness of AVs (V3.1), but they also name the acceleration of the sharing trend as an opportunity for AVs (V5.4). The increase in car ownership and the increase in car-sharing are conflicting statements. However, when more immersion is created, it might be possible to understand this seemingly conflict. Therefore, the third question in the questionnaire was: *"3. Impact on car-use and car-ownership: The introduction of the AV will lead to more car-use (vehicle kilometres travelled) and/or car-ownership* *(number of vehicles), without the intervention of the government."* This question is answered by most respondents with "Only car-use" and secondly by the answer "I agree on both" (see figure 5). This shows that however the time of the introduction of AVs might be uncertain, there is more certainty among stakeholders about the negative impact. Respondents expect that the impact of an increase in car-ownership and use is more likely, than a decrease. It is interesting to discover, if all stakeholders perceive this as a problem or not. This will be answered by question 2 of the questionnaire (see figure 5 below).

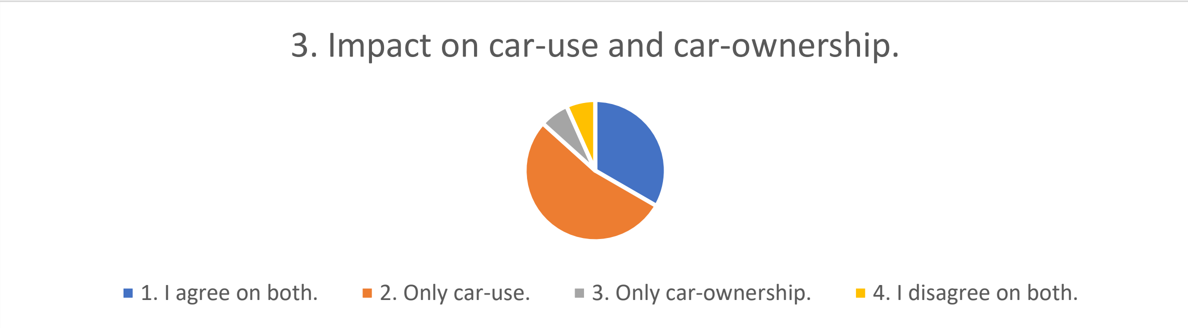


Figure 5, Impact on of AVs on car-use and car-ownership, based on the findings of the questionnaire.

More than half of the respondents think that only car-use will increase. More than a quarter of the respondents think that both will increase. One respondent thinks only car-ownership will increase and one disagrees on both. Table 5b is completed with the results of the questionnaire on the sub-theme with code V3.1 (see table 5a on page 63). 6/20 respondents are worried that ownership rates will increase. 13/20 respondents are worried that vehicle use might increase. 3/20 respondents only name the possibility of the increase of vehicle ownership and/or use, but are not sure about it yet. 1 respondent from the car-sharing sector thinks, there will be no increase in vehicle ownership or use.

The results from the interview on the expected impact of the increase in car ownership and use on the road capacity are conflicting. Many respondents say that AVs can lead to an increase in road capacity (due to shorter following distances, see V2.5). While they also state it can lead to an increase in ownership rates and vehicle use (V3.1), which has as side-effect: extra pressure on the road capacity. One respondent even said that both scenarios are possible: an increase in road capacity or an increase in required land for the mobility system. Some respondents admit that there exist misperceptions about the positive impact of AVs, like the assumption that the introduction of AVs will automatically lead to lower ownership rates and that it will lead to more sustainability (V4.5).

The vision of stakeholders on the connection between these expected impacts is researched, with the help of the questionnaire. The second question in the questionnaire is: *"2. Road capacity: Although the road capacity can increase due to a steadier speed and a narrower standard distance between two AVs, it is possible that the road capacity will find its limits, due to the increased car-use and -ownership rates. What would be the total effect on the road capacity?"* The answers on this question show, that there are concerns about the increased use of car-ownership and -use, that are related to land-use and spatial planning (see figure 6).

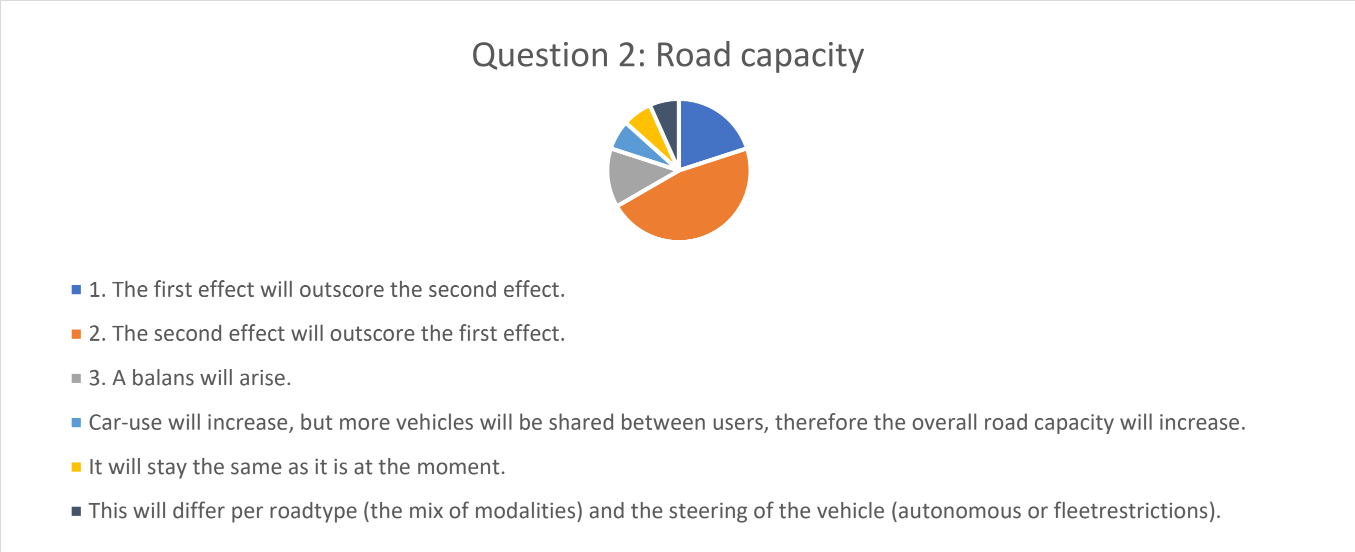


Figure 6, The impact of AVs on the available road capacity, based on the questionnaire results.

Most respondents think that the road capacity will decrease, due to an increase in car ownership and -use.

Table 5b is completed with the results of the questionnaire for the sub-themes with code V2.5 (positive impact 1. Decrease in following distances) and V3.1 (negative impact 2. increase in vehicle use/ownership) and V3.4 (the total effect on the land use of the mobility system) see table 5a on page 63. It is interesting that from the government and Arcadis most respondents think that the total effect of AVs (the shorter following distances and the increase in vehicle use/ownership), is negative for the availability of road capacity. They assume that the second impact (increase in vehicle use/ownership) will outscore the first impact (shorter following distances). The stakeholders from the transportation companies think it is the other way around. According to an transportation planner of the province of North-Holland, it will depend on more factors, like the road type and automation type, and thus is hard to predict.

4.1.4 Relation between Automated Vehicles, Electrical Vehicles and Shared vehicles.

Some respondents from the transportation companies recognize that there exists a misconception, that AVs will automatically lead to an acceleration of the sharing trend and thus to a decrease in vehicle ownership (V4.5). However, these are two separated transitions, which are only interrelated.

Due to the expected increase in vehicle use and ownership, there might however be a need for an increase in car-sharing and this can be accelerated by the introduction of AVs, due to easy and comfortable door-to-door travel (V5.4). Though, many respondents state that car-sharing is not popular yet (V4.3).

Therefore, the fourth question of the questionnaire was: *"4: Sharing transition vs. AV transition: Although the AV will make car-sharing easier, the transition towards sharing will not take place without intervention of the government. At the moment it is important that the government will invest in sharing and not in the introduction of AVs."* According to the answers most respondents think that both transitions need the same attention. However, a quarter of the respondents think that car-sharing needs more attention. One respondent thinks it is the task of transportation companies to influence this, because it is unclear to him/her how the government can influence this (see figure 7). Table 5b is completed and adjusted with the results from the questionnaire (see table

5a on page 63). There is a new sub-theme created with code-number V6.2: The sharing transition is more important than the AV transition.

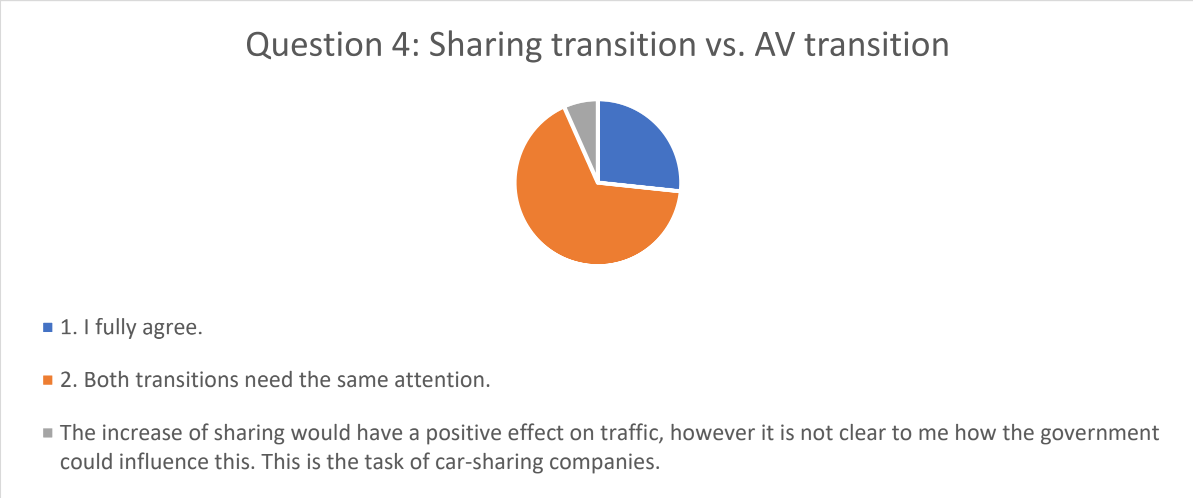


Figure 7, Preferred strategy focused on the sharing transition of the automation transition.

It might not be clear to all respondents that car-sharing can be stimulated by spatial planning solutions. Therefore, it is interesting to discuss this during the workshop. This is described in section 4.3.2.1. Stimulate car-sharing.

Table 5a: Overview of most striking visions on the impact of AVs, based on the interview and questionnaire results

Groups		Government										Consultancy				Transportation companies					
Organization		RWS	IPO	Province of North Holland						Amsterdam		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	T/UP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Vision	V																				
Timeline																					
The AV transition speed in literature is right Faster = + and Slower = -	1.2			N-	N- Y	Y	N+	? Y	N+	?	N-	Y	Y	N-	Y	N-	Y		Y	Y	N-
Impact on parking norms																					
Parking norms in cities might decrease: - car-free city centers are desirable. - parking outside city centers is desirable.	2.2	x x x	x x	Y x	N		x	Y Y Y	Y Y Y	N	Y Y Y	Y Y Y	Y Y	Y Y Y	N	Y Y Y	Y Y		Y Y Y	Y Y Y	x
Impact on available road capacity																					
Road capacity might increase, due to decrease in following in distance between AVs.	2.5	x	x					x				Y				x	Y	x		Y	Y
Increase in car ownership/use. Ownership = + and use = -	3.1	Y	Y	Y-	Y-		Y+-	Y-	Y	Y+-	Y-	Y-	Y+-	Y-	Y+-	Y-	Y+		Y-	Y+-	N
Land-use of mobility system might increase. Balans or dependent on more factors = ?	3.4			?	Y		Y	?		?	Y	N	Y	?	Y	Y	N			N	N
The sharing transition and AV transition																					
Car-sharing is not popular yet.	4.3	x	x	x	x				x		x			x	x	x					
Misperceptions about AVs AV leads automatically to sharing	4.5	N														N	N			N	
Transition towards sharing might accelerate.	5.4	x	x	x	x		x	x	x		x			x	x	x	x			x	x
Sharing is more important than AV transition. ? = they have the same priority	6.2			?	?			?	?	Y	Y	?	Y	Y	?	?	?		?	Y	?

4.2 Strategy of stakeholders

The next sub-questions during the interview are more connected to the strategy of organizations, because they are about the envisioned strategy and the need for guiding/steering the transition. Therefore, the answers are assigned to the category "Strategy" (see table 6 a/b/c). The open-ended question connected to this theme is: "How is the introduction of AVs represented in the strategy/policy of the organization?" The sub-themes are documents: policies/strategies, research, goals, policy window, guiding/steering principles and pitfalls.

Many respondents state that there are not many documents that consist of a policy or strategy related to AVs. The only documents that say something about AVs that are named by more than one respondent are: "Omgevingsvisie" (Dutch spatial planning instrument, describes the general vision on the mobility and urban system of the Netherlands), "Relatie Toekomstbeeld OV 2020-2040 (Dutch spatial planning instrument, describes the vision on the public transport mobility system), "Koers Smart Mobility" (Regional transportation planning instrument, describes the vision on smart mobility technologies on the public road). The results are summarized in table 6b in Appendix B, Strategy, with code number S1. In addition, there are some other documents that are named that can be found in appendix D, strategy.

Many respondents state that they have not include it in their strategy yet, because they are still in the exploratory phase. Research that is carried out during this phase are pilot projects in real-life-settings (examples are: self-driving public transport buses, self-driving four-passenger cars, park shuttles, etc.), research to methods in order to make infrastructure digitally available and Scenario planning (which involve impact studies on AVs). The results are summarized in table 6b in Appendix D, Strategy, with code number S2.

The main goals of the stakeholders are: good accessibility and mobility (13/20R), increased safety (7/20R), increased liveability (5/20R), increased sustainability (4/20R), increased health (3/20R) and a stronger competition position (7/20R). The results can be found in table 6a on page 66, under code number S3. These goals can be reached by finding out what actions are needed to mitigate the negative impact and accelerate the positive impact of AVs, which is researched further in the next section 5.2.3: Impact and Actions. Striking is that accessibility and mobility is valued mostly by the government and public transport companies. However, it is also valued by a Landscape Architect of Arcadis, but this was more focussed on a decrease in land-use of the mobility system. To become frontrunner in knowledge about AVs, is important to the commercially orientated companies. The international competition position of the Netherlands in AV knowledge, is important to the government and public transport companies. In the goal of safety, the respondents from the government are prominent (6/7R).

Table 6a: Current goals and proposed strategies of stakeholders, based on the interview result

Groups		Government										Consultancy				Transport companies					
Organization	S	RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Goals: decide what is most important	3		x		x												x				
Accessibility (economic and basis) & mobility	3.1	x	x	x	x	x		x	x	x	x	x				x	x		x		
Safety.	3.2	x	x			x	x	x		x									x		
Livability / quality of life / Attractiveness	3.3		x							x					x	x					x
Sustainability.	3.4		x						x						x		x				
Health (Air-quality and exercise)	3.5						x			x					x						
Competition position	3.6							x		x				x	x		x		x	x	
Principles: Give direction to the development.	5																				
Stimulate	5.1			x	x	x		x		x					x	x	?	?	?		
- Invest in AV technologies and infrastructure.	5.1.1									Y	N						Y	N	?		
- Give opportunities to pilot projects.	5.1.2			Y	Y	Y		Y		Y					Y	Y		Y	Y		
Facilitate	5.2		x	x		x				x	x						x	x	x	x	
- Remove barriers in regulation.	5.2.1									Y							Y	Y	Y		
- Facilitate cooperation between parties (lobby)	5.2.2		Y	Y		Y				Y	Y								Y		
- Make transportation concessions more flexible.	5.2.3										Y							Y		Y	
- Make policies and documents more flexible.	5.2.5					Y		Y		Y											
Regulate (**not too much**)	5.3			**x**	**x**	x	x	x	x	x	x				x	**x**	x	x	x	x	x
- Make regulation for AVs.	5.3.1					Y				Y	Y				Y	Y				Y	
- Regulate mobility services: Shared (S) / bicycle (B)	5.3.2		S		S	S	B		S		SB				S	S				S	S
- Standardization of policies in **EU**/national level.	5.3.3		Y	Y		**Y**		Y									**Y**			Y	Y
Prohibit	5.4					N				N	N				N	N				N	
Research	5.5	x	x	x	x	x	x	x		x	x			x			x	x			x
- Do research and share data/knowledge	5.5.1		Y		Y		Y				Y									Y	Y
- Get information from market-parties about AVs.	5.5.2	Y	Y		Y	Y				Y											

Not all goals or actions are wanted by the society. According to the respondents there are three trends, which might lead to an opportunity to get a certain policy related to AVs on the political agenda. These Policy Windows are: the realization in high dense areas, that there is scares space in the Netherlands, which can be used for other functions than mobility. More information/knowledge from the technique of AVs from car manufacturers and more information/knowledge about the regulation for AVs from the RDW, can give an incentive to take decisions about spatial planning related to AVs. Some governmental organizations are moving from a vehicle ownership-based policy to a vehicle use based policy, which can lead to a decrease in the required land for the mobility system, because they want to discourage people to choose to physically own and store a car. These results have code number S4 and are summarized in table 6b in appendix B, Strategy.

There are several options for the government to give direction to the development of AVs: stimulate the development (7/20R), facilitate the development (7/20R), regulation (18/20R of which 3R think it is foolish to develop too much regulation), prohibition (6/20R think that it is undesirable to prohibit AVs), do research (12/20R). The results can be found in table 6a on page 66, under code number S5.

Stimulating is an initiative manner of steering the development. This can be done by investing in the technology and initiating to test the technology in pilot projects. When other parties should invest and initiate the pilot projects, it is a pro-active way.
Facilitating is a pro-active way of giving direction to the development. This can be done by removing barriers in the regulation. It can also be done by making urban and transportation planning more flexible to the developments over time. Lastly, they can make the documents and policies they use more flexible in order to give other stakeholders more opportunities.
Regulating the development is also a pro-active manner, when the regulation is designed at the start of the transition phase and adjusted over time when necessary. Designing regulation (like road pricing) after the AV transition has taken place, is a reactive steering method. Standardize policies, strategies and regulation, upfront the transition phase, is a pro-active steering method.
Prohibiting the access of AVs on public roads, is a reactive steering method.
Letting others initiate pilot projects and waiting for them to share their knowledge, is a reactive method.
Researching and sharing own data and knowledge with other parties, in order to stimulate corporation and creating awareness under citizen about the topic, is pro-active.

From table 6a, it becomes clear that most respondents from the government are preferring a pro-active (5/10R) or reactive (4/10R) steering method. 1 respondent of the government chooses an initiative steering method. When we look at the transportation and consultancy companies they mostly expect a pro-active (5/8R) steering method from the government, 2 respondents expect a reactive steering method and 1 an initiative steering method.

In figure 8, the results on question 9 of the questionnaire are presented. The question was: "*Although, the costs of Automated public transport and the (shared) automated taxi will decrease in the future, at the moment is AV mobility not feasible economically for public transport and car-sharing companies. Therefore, the government should also invest in these services, in order to stop the domination of the private AV sector."*

The investment of the government in automated public transport, would be an initiative steering method. 2 respondents from the transportation companies fully agree. 2 respondents of the government give options, how they could invest in automated public transport. 6 respondents disagree, that the AV business model is not feasible for public transport yet. 2 respondents of the government agree that the public AV business model is not feasible yet, but consider this not as their responsibility. 3 respondents (2 Arcadis and 1 transportation company), think that a cooperation within the EU, should prevent the market domination of the private car sector in AV technologies. The results from this question show again, that the transportation and consultancy companies expect, that the government becomes more pro-active and initiative in the AV transition.

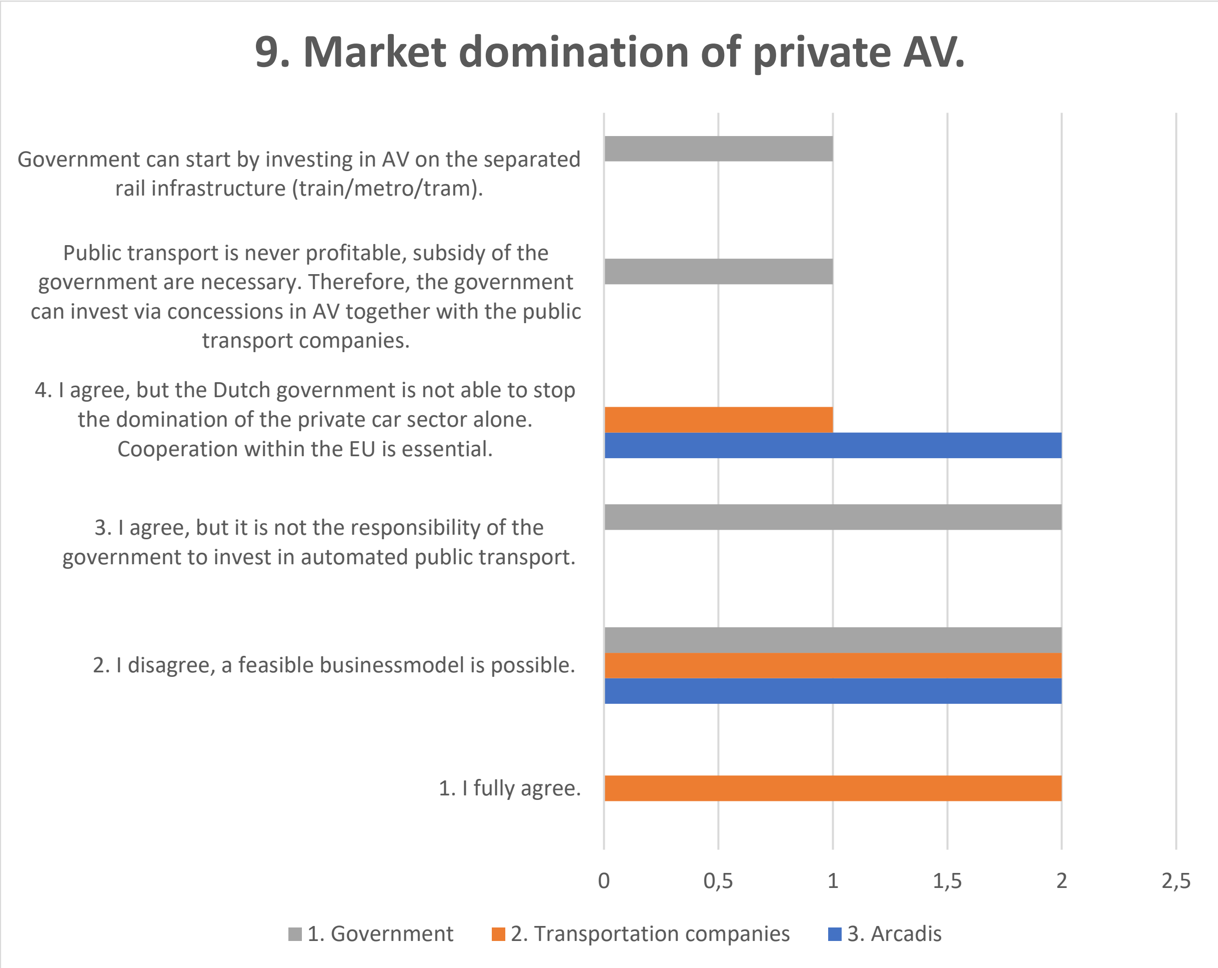


Figure 8, The necessity to prevent market domination of private AVs, based on questionnaire results.

There are some Pitfalls and points of consideration, while developing strategies and policies for AVs. The most important are the following. The time horizon of visions and plans is long, which makes it difficult/dangerous to give a detailed vision and makes them shallow (6/20R). The maintenance of roads, can already take the introduction of AVs into consideration without a lot of investment (5/20R). Investments in large infrastructure projects are of high risk, due to the high level of uncertainty (3/20R). The AV business model, might not be feasible yet (3/20R think the AV business model is feasible and 3/20R do not). Especially for PT companies it is hard to invest in this technology at the moment, because currently the cost is much higher than the profits. These results have code number S6 and are summarized in table 6b in appendix B, Strategy.

4.3 Perceived impact and proposed actions by stakeholders

The last two open-ended questions during the interview are connected to the "Impact" of AVs on spatial and transportation planning and the related "Actions". The open-ended questions connected to these themes are: "What is your vision on the following possible impacts of AVs?" and "What decisions and actions can be taken about the introduction of AVs, at the moment?" The sub-themes are the decrease/increase of required land for mobility, influencing the mobility choice, urban sprawl and spatial planning actions. These categories indicate what actions can be taken in order to respond on specific impacts of AVs on urban and transportation planning.

4.3.1 Impact on land-use of mobility system

The most important spatial impact of AVs is the possible increase or decrease in required land for mobility. The results of this sub-theme are presented in Table 7a, b and c in appendix B, Impact and Actions.

4.3.1.1. The decrease of required land for mobility

The decrease of required land for mobility, is caused by changes in parking infrastructure (6/20R) and road infrastructure (5/20R). 6 respondents state that AVs might lead to an increase in car-sharing. This might lead to lower ownership rates and thus less parking demand. 9 respondents state that AVs might be able to park themselves, which might lead to clustered parking (7/20R) and more efficient ways of parking, which leads to a decrease in the required space for parking (4/20R). The positive impact of clustered parking is less parked cars in city centres and thus an improved living quality (2/20R), the drawback are more EVT, because vehicles move from destination to parking and back (2/20R). Therefore, the usefulness of the clustered parking system will depend on the waiting time for the vehicle (2/20R). The road infrastructure can increase due to: a steady speed and a shorter following distance between vehicles (5/20R agree, 1R disagrees), less unforeseen moments, might lead to less congestion (3/20R), AVs might lead to an increase in ride-sharing and this might lead to a decrease in vehicle kilometres travelled (VKT). However, this all depends on the type (level of automation) and the size of the vehicle in relation to the number of users of the vehicle (5/20R). This increase in capacity or the space that will come available can be used for more green and water storage that is needed to react on climate change (4/20R) and concentration of houses and facilities that is needed in cities due to urbanization (4/20R).

4.3.1.2. Increase of required land for mobility

In another scenario there can be an increase of required land for mobility (see table 7b). The results of this sub-theme are presented in table 20 on the next page. This can be caused by an increase in vehicle ownership rates, the number of vehicles per person (9/20R and 3 are uncertain) and an increase in car use, the number of vehicle kilometres travelled per person (14/20R and 4 are uncertain). The number of respondents that expect an increase in vehicle ownership rates and vehicle use, are based on both the questionnaire as the interview results.

The increase in ownership can be caused by the broadening the target group, which might lead to a situation in which people that use public transport or share a vehicle switch to using private vehicles (5/20R). This is caused by elderly, children and disabled, that can use a private AV (2/20R) and a decrease in AV prices over time, so that more people can buy an AV (3/20R). The increase in ownership can also be caused, by an reduction in the value of time (6/20R). This might lead to a situation in which people that use public transport switch to using private vehicles (3/20R) and/or people are willing to travel longer distances (1/20R).

The increase in car use can be caused by AVs that are accommodating easy and comfortable use of shared vehicles from door to door (10/20R) This might lead to a situation in which people that walk, cycle or take public transport switch to using shared cars (8/20R). It can also lead to more VKT to pick-up and drop-off every person, this is called Empty Vehicle Travel, EVT (4/20R). Lastly, it can lead to a decrease in the price of using a shared vehicle, because there is no driver and more people share the costs (4/20R). This in return can lead to unnecessary car mobility, because the negative incentive of high prices is removed (3/20R). The increase in car use can also be caused by, an reduction in the value of time (5/20R). This might lead to a situation in which people that use public transport switch to using shared cars (1/20R). It might also lead to a situation in which people are willing to travel longer distances (3/20R agree on this and 2/20R disagree).

Multiple mobility systems during the transition can also cause an increase in required land for mobility. AVs need their own lane, because of difficulties with complex traffic situations, this lane requires a lot of land (5/20R).

Actions that can prevent the increase of required land for the mobility system are the following (see table 7c).

There is a latent question to mobility (5/20R). Therefore, the increase of road infrastructure will not have a positive and long-term effect on the road capacity (6R agree on this and one respondent does not). When the road infrastructure is not increased or changed, new congestion can lead to a new balance in road capacity (6/20R).

Another option is to stimulate an increase in the number of users per vehicle (10/20R). This can be done by adjusting parking policies (for example: increase prices for public parking or decrease parking norms in zoning plans) (10/20R). This can also be done by an increase in ownership charges (for example: increase taxes for parking permits for a second car or vehicle excise duty) (2/20R). Lastly, the size of a vehicle can be adjusted to the usual number of users and making the vehicle excise duty also dependent on size (2/20R).

Another action is to stimulate a decrease in the amount of vehicle use by road pricing (12/20R). This can be done by discouraging travelling during rush hours, by a rush-hour-charge (5/20R). This can be done by an increase in charges on carbon-intensive-vehicles and vehicle noise, while subsidizing low-carbon-vehicles (5R). This can be done by assigning toll roads (3/20R) on national (2/20R) or regional level, with a difference in costs for dense and low dense areas (1/20R). However, this strategy is not politically accepted yet, road pricing is a forbidden word in the political debate (5/20R). They currently only agree on charging on the weight and the pollution level of vehicles. Another action is to give priority to some logistic streams in cities (11/20R). This can be done by designing the mobility system in a way, that there is a differentiation in certain types of logistic streams per transport node (2/20R) or repulse certain types of mobility concepts (for examples: conventional car, carbon-intensive vehicles, buses, etc.) (10/20R).

4.3.2. Relation between interview, questionnaire and workshop results.

From the interviews it became clear that the road capacity problem could be solved by making more efficient use of the available space in the Netherlands. This can be achieved by discouraging vehicle use and ownership (as we saw in the previous table 20), but it can also be achieved by stimulating the use of mobility concepts that require less land, than the private car. The most interesting to research in more detail by a questionnaire and to discuss during the workshop, is the spatial impact of the introduction of AVs on public transport and car-sharing, because they are space efficient mobility concepts that can also be automated. In the next sections the results from the interviews on influencing the mobility choice of citizen are described in more detail. Thereafter, the results of the questionnaire and workshop on these topics are described.

During the workshop the possibilities to stimulate the use of these space efficient mobility concept are discussed (car-sharing and public transport). The focus was on spatial planning actions that take the rise of AVs into account. Together they searched for the no-regret actions in spatial planning, that are mediating, compensating or preventing the negative impact of AVs and facilitating and stimulating the positive impact of AVs. Together they came up with actions that already can be taken during this transition phase towards fully AVs. The transition phase can also lead to inefficient use of space, because multiple mobility concepts will exist next to each other in this phase. Therefore, this topic is also researched in more detail during the questionnaire and workshop.

Together the topics of the workshop were: car-sharing, public transport and the transition phase. Prior to every discussion on one of these topics, results from the questionnaire are presented to give them a better understanding of the discussion topic. Than a question was asked to all participants. The three questions are: *"What spatial adjustments could stimulate car-sharing?"*, *"What spatial adjustments could bundle traffic streams towards large transportation nodes (like train stations)?"* and *"What spatial adjustments are possible during the transition phase?"*

4.3.3. Speeding-up transition towards fully Automated Vehicles.

Another option, in order to prevent the increase of required land for the mobility system, is speeding up the transition towards the introduction of AVs on the public road. When the shift from traditional vehicles to fully AVs can take place in a shorter amount of time, there is no need for two types of infrastructure for both mobility systems at the same time (the current system and the AV system).

The AV transition can be accelerated, by adjusting the infrastructure (2/20R think this is sensible, 6/20R name it as an option, but are not sure yet). This can be done by adjusting road alignment/markering (for example: use other types of painting or place sensors) (4/20R), introduce flexible road profile design, that gives access to multiple modalities (2/20R). This can be done by adjusting bus and tram lanes in a way that they become accessible for AVs in the future (3/20R). This can be done by redesigning crossings and junctions in a way that there are less crossing streams of different modalities (2/20R). This can be done by designing infrastructure in a way that there is a better separation between pedestrian/bicycle/car paths, in order to increase safety (4/20R). This can be done by research to infrastructure necessities for AVs (2/20R). It is judicious to research the relation between the level of complexity of roads and the automation level of AVs (Operational Design Domain). Some moderated environments can figure as test-area for different levels of AVs. Lastly, it can be done by developing separated lanes that are specified to AVs, in order to increase safety (7/20R). However, considerations are: the high costs of the investment in this infrastructure and the land that is needed for this infrastructure (3/20R). This can be solved by a feasible business case for some private parties that are interested to invest in infrastructure for AVs (2/20R). The results of this sub-theme are presented in Table 8 in appendix B, Impact and Actions.

Question 15 and 16 from the questionnaire are related to the AV transition phase. *"15. Transition phase and adjustments to the infrastructure:*
Is it necessary to come up with spatial solutions for the transition phase from automation level 1 to 5. (adjustments in infrastructure) or is it possible to use different types of AVs per context?", shows that many respondents think it is important to adjust the infrastructure for the transition phase of AVs (see figure 9). However most think flexible adjustments are reasonable. It is interesting to discuss during the workshop, what kind of adjustments they propose.

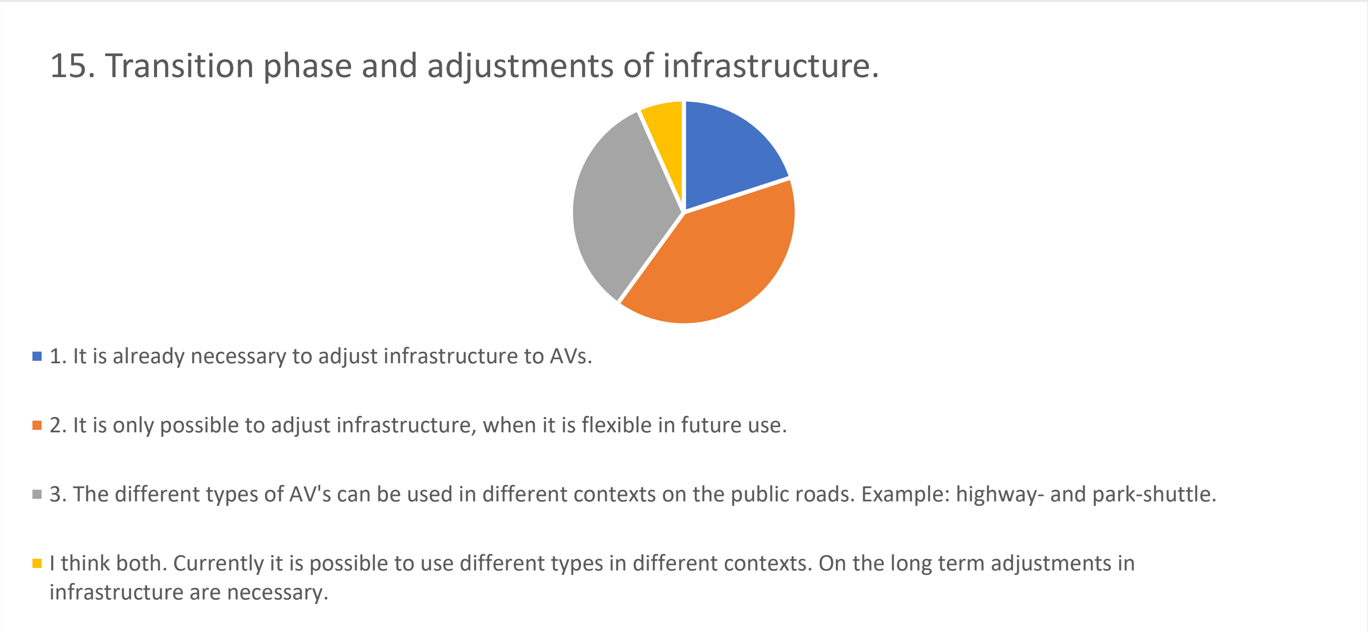


Figure 9, Proposed actions for speeding-up the AV transition by adjustments of infrastructure, according to respondents of the questionnaire.

Question 16 gave some examples of spatial adjustments for the introduction of AVs. *"16. Speed up transition process by spatial planning: Is it necessary to come up with spatial solutions, in order to speed up the introduction of AVs? How can this be done with the use of spatial planning? Multiple answers are possible."* The already given answers give a good overview, because there are no real new answers (see figure 10). Some of these answers can also be used during the transition phase. During the workshop it would be interesting to discuss, what the no-regret adjustments are according to the participants.

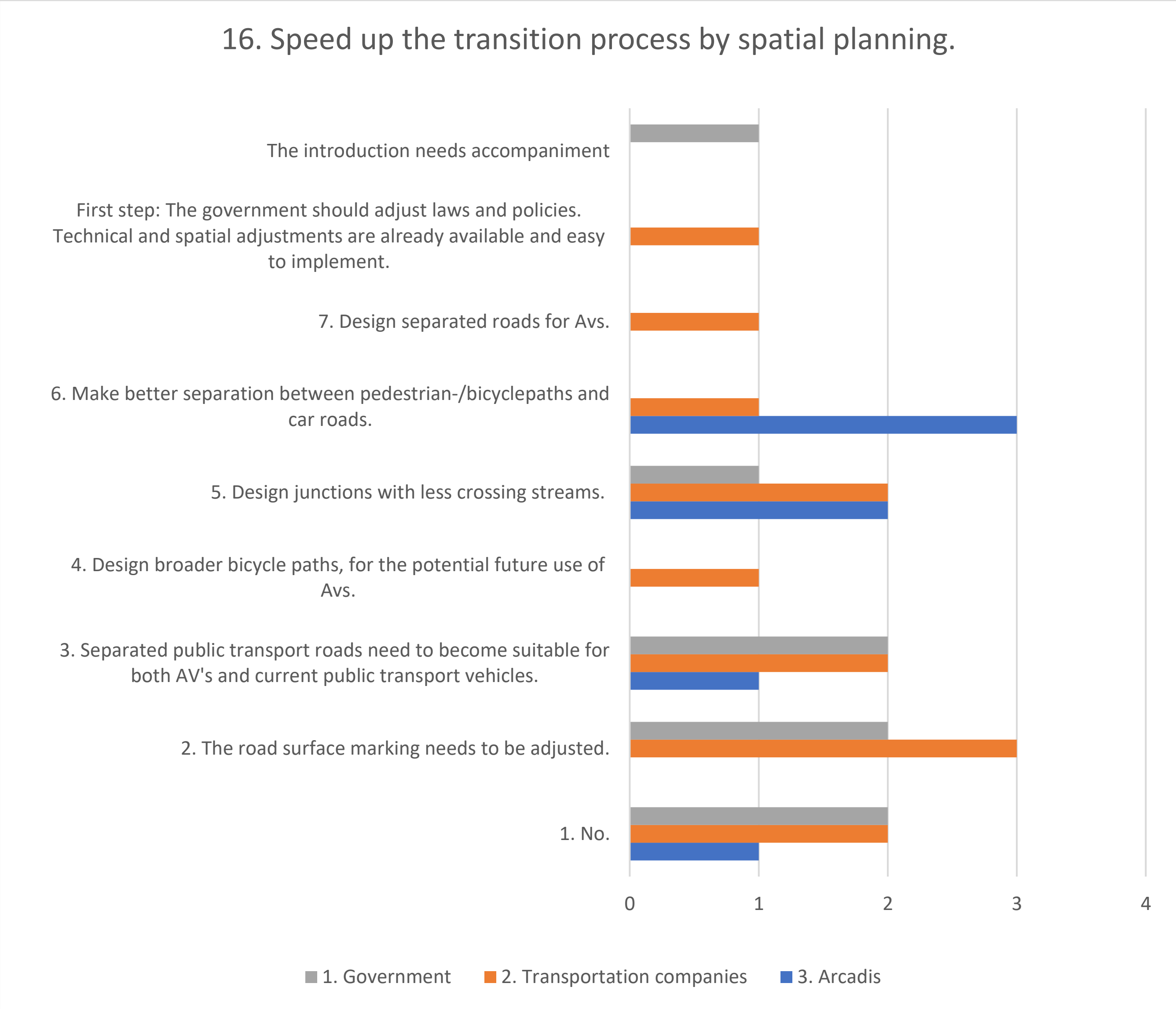


Figure 10, Proposed actions in order to speed up the transition process by spatial planning, according to respondents of the questionnaire.

The results of the questionnaire are added to the table Actions/Impacts of the interviews (see table 9 on next page).

Table 9: Proposed actions to speed-up the transition process by adjusting infrastructure, based on interview, questionnaire, workshop.

Groups		Government										Consultancy				Transport companies						Work shop
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing		
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP		
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-	
Speed up transition by adjusting infrastructure.	2.4.6	?	?	N	Y	?	?	Y		Y	N	N	Y	?	Y		N		N	?	Y	
1. Road alignment/markering.			x		x	x				x				x		x	x				x	1/7
2. Flexible road profiles for multiple modalities.			x								x						x					1/7
3. Make bus and tram lanes accessible for AVs.					x			x			x				x		x				x	
4. Redesign crossings, less crossing streams.						x		x				 x			x	x	x					1/7
5. Separation of pedestrian, bicycle and car path				x		x			x			x		x	x	x	x					
6. Specified and separated lanes: - Cost a lot of money & space. - Is there a business model for private parties?		x x		x	x x x	x x	 x		x							x	x			x		 1/7
9. Research to infrastructure necessities for AVs. - Research to road complexity (ODD). - Pilots in moderated environments.		x x															x x					 2/7
10. parking combined with mobility offer.																						1/7
11. parking/stops: more K&R's and P&R's																						2/7

During the workshop the participants first saw the results from question 15 and 16 of the questionnaire. The next question was: “What are the No-regret actions related to the transition phase towards fully AVs?” Together they thought of spatial actions, that can already be taken. These actions have a low level of risks in costs and/or uncertainty. After repeating the answers, the discussion was started. Below are the most interesting conversations summarized and categorized. In appendix D, you can find the full summary of the workshop discussion. The answers that are given via the online-application are also summarized and categorized below, with the help of the codes used in the content analysis of the interview results. The number after each sub-theme in table 9, on the previous page indicates how many participants named this answer.

There are some sub-themes that are named during the interviews that are also discussed during the workshop.
A.2.4.6.1: Adjusting road alignment/markering.
There is 1 participant during the workshop that named the adjustment in road-surface marking and beaconing.

A.2.4.6.2: Design flexible road profiles that can be used by multiple modalities.
There is 1 participant during the workshop that named the introduction of the shared-space 2.0. Instead of designing vehicles for the existing infrastructure, it might also be possible to re-design this basic structure/grid for the preferred type of new vehicle (what profile fits what mobility concept?). It might be an option to design according to the speed of the vehicle.

A.2.4.6.4: Redesign crossings, in order to have less crossing streams of different modalities.
1 participant names this during the workshop: Redevelop infrastructure, in order to create easy to overlook crossings.

A.2.4.6.6: It will cost a lot of money and space, in order to develop specified and separated lanes for AVs.
1 participant names this during the workshop: The costs for the development of infrastructure per modality are too high. The costs (land and money) for the development of infrastructure per modality are too high. Infrastructure from other/outdated modalities should be replaced, when it is decided that the transition needs to be accelerated. Operation and maintenance of AVs in the existing infrastructure is also possible. With smaller adjustments over time it might also be possible to make the infrastructure accessible for the new technology. This is a relevant discussion, because some modalities are already banned from city centres (private cars, next is public transport), because there are too many mobility concepts at the moment.

A2.4.6.9: There is a need for research to infrastructure necessities for AVs. For example research to road complexity (ODD) of different types of highways.
2 participants names something similar. 1 named that it would be useful to design a framework for highway design for AVs. Another said it would be useful to do 3D modelling for current road infrastructure, in order to adjust them for AVs.

There are two new answers that are not heard before during the interviews.
A.2.4.6.10: Parking norms and permits in combination with the mobility-offer.
A.2.4.6.11: The development of parking/stops, like the development of Park & Rides and Kiss & Rides.

4.3.4 Impact on mobility choice

Other actions that are possible that are researched in more detail during the questionnaire and workshop, are related to influencing the mobility choice of citizen. The proposed actions related to influencing the mobility choice of citizen are summarized in table 9 a, b and c in appendix B, Impact and Actions.

Car-sharing
Car-sharing might increase due to the introduction of AVs. This depends on the: Waiting time for vehicle (# distance (km) between user and vehicle divided by speed (km/h) of vehicle). The supply of shared-vehicles in the area (# number of vehicles in the area). The emotional attachment to vehicle-ownership (status and freedom). The price of the ride (# price (€) per distance (km)), will be lower because there is no driver needed and more persons can share.

Therefore, are actions that can stimulate the increase of car-sharing, creating sufficient drop-off and pick-up points in order to reduce congestion of stopping vehicles on the public road (3/20R) and reserving space for a sharing system buffer, in order to fulfil in/increase the demand to shared-vehicles in the area (4/20R). However, do consider a maximum number of different shared-vehicles services in an area, to for come over supply (2/20R).

Public Transport
Public transport use, might decrease due to the introduction of AVs. This depends on the: competition between the type of public transport and type of AV, which depends on the average travel distance of the AV (10/20R), the location of the public transport facility (5/20R) and the automation level of PT modalities (7/20R).

Actions that can stimulate the increase of PT use are an increase in the number and supply of PT mobility options (4/20R), making MaaS concepts more attractive (3/20R), making mobility options easier to compare by showing the differences in costs & travel time, in order to make a deliberated choice (5/20R), investing more in PT infrastructure in order to accelerate a reversed trend: a switch from private vehicle use to PT use (2/20R), develop parking at PT stations in order to switch from modalities (4/20R), Let PT modalities pick-up and drop-off users on demand (2/20R).

Bicycles
Bicycle use, might decrease due to the introduction of AVs. This depends on the: parking accessibility and safety of bicycles in residential areas and at public facilities and stations, the schedules and appointments of bicycle users (mainly: scholars), the development of electrical bicycles (E-bikes) and automated-bikes, the travel distance, bikes are used for travel distances of 5-10 km and E-bikes for travel distances of 5-15 km, and the societal considerations of the importance of health and exercise during travels.

Actions that can stimulate the increase of bicycle use are: stimulating the development and use of E-bikes, in order to create competition on more travel distances, by developing broader bicycle highways/fast-lanes, in order to create competition in travel time, decrease congestion and increase safety (4/20R), adjusting traffic lights by adding sensors, in order to give priority to bicycles, in order to create competition in travel time (3/20R), developing bicycle tunnels, in order to create competition in travel time (1/20R) and developing parking lots at transportation hubs and bicycle renting locations, in order to give people the opportunity to switch from car to bicycle (4/20R).

Question 8 from the questionnaire is related to influencing this mobility choice. *"Spatial incentives to stop trend towards increased use of private car: The use of public transport and the bicycle will decrease, due to the increase in the use of private cars, due to the introduction of AVs. What spatial solutions could stop this trend? Multiple answers are possible."*

This question gives an overview of all the possible incentives to decrease the private AV use that are stated by the respondents during the interviews. Only one respondent gives a new answer. It is interesting to see, that all respondents of the government want to give more priority to bicycles, while Arcadis and transportation companies do not think this is of major importance (see figure 11). During the workshop it is interesting to discuss the argumentation behind all these answers.

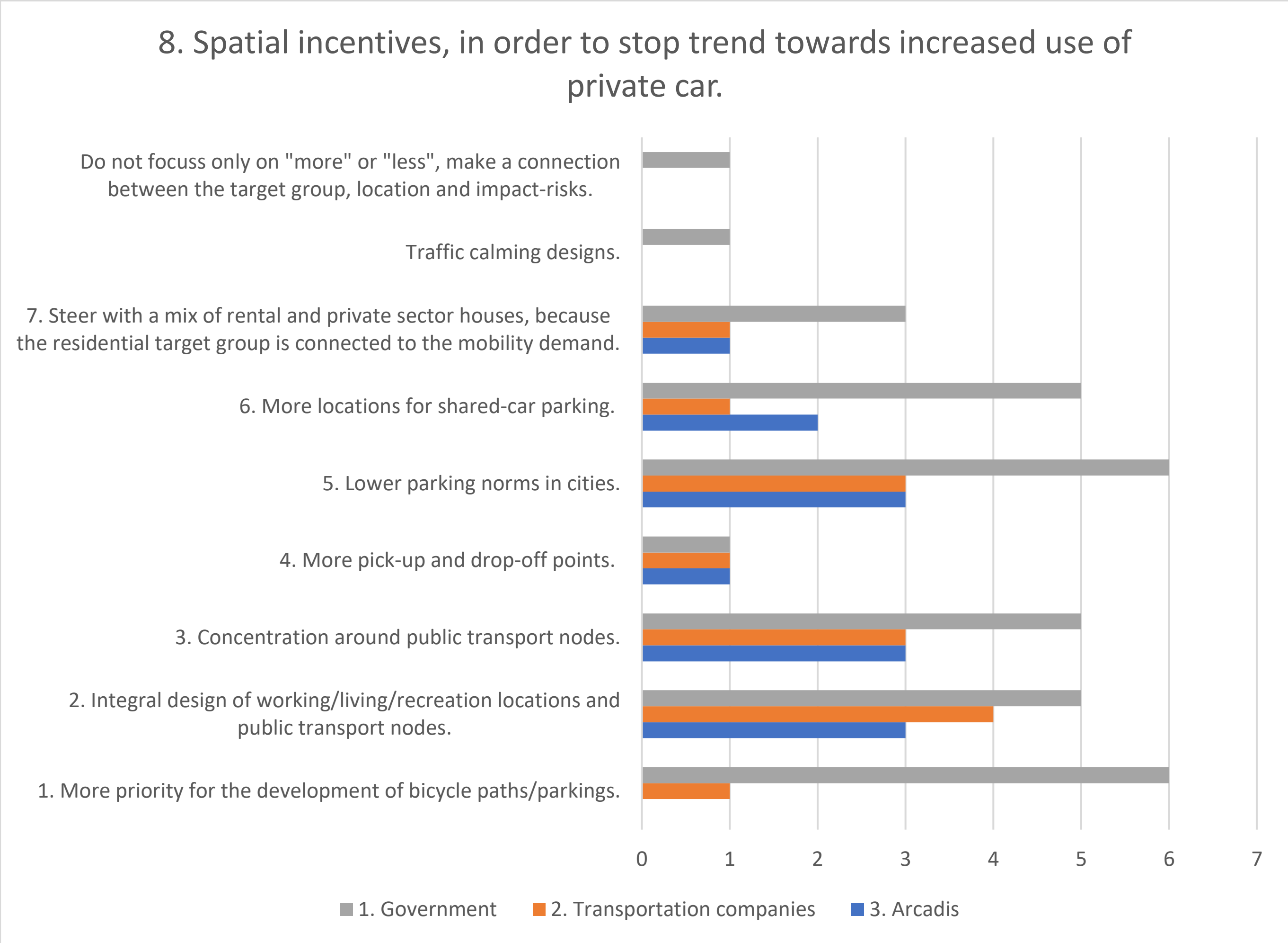


Figure 11, Most popular incentives to decrease the private AV use, based on questionnaire.

4.3.2.2. Stimulate bicycle-use

Figure 11 shows that there is support for more priority to the development of bicycle paths and parking. This is something 5 of the 20 respondents agree on, during the interviews. In the questionnaire an additional number of 7 of the 14 respondents named it (of which 6 are from the government). Therefore, in total 11 of the 20 respondents (5/20R of interview and 7/14R of questionnaire) find it a good solution to stimulate bicycle use. These new insights from the questionnaire are also added to table 9c, in appendix B, impact and actions. It is striking that all these respondents are from the government or public transport organizations.

4.3.2.1. Stimulate car-sharing

The action of creating more pick-up and drop-off points. This is something 2 of the 20 respondents agree on, during the interviews. In the questionnaire an additional number of 2 of the 14 respondents named it (1 respondent named it both in the questionnaire as in the interview). Therefore, in total 5 of the 20 respondents find it a good solution.

During the workshop the participants first saw the results from question 2, 3 and 4 of the questionnaires about car ownership and car-sharing. The next question was: "What spatial adjustments are possible to stimulate car-sharing?" The answers that are given via the online-application are summarized and categorized below. The category is chosen by the researcher. The number after a sentence indicates how many participants named this answer.

A.3.1.2.1: Reserve space for a sharing system buffer (7/20R), by for example develop parking for shared-vehicles.
During the workshop two participants named these car-sharing locations.
During the interviews 2 respondents say that you have to reduce the number of different Shared Vehicle services.
However, during the workshop however 2 participants say that it was important to have sufficient online peer-to-peer car-sharing platforms.
A.3.1.2.2: Create drop-off and pick-up points (3/20R).
During the workshop 1 participant named this.
A.2.4.2.1: Increase the number of users per vehicle, by adjusting parking policies (10/20).
During the workshop participants named the solution of increasing parking tariffs (3 participants), decrease parking norms (2 participants, 1 focused on parking at public transport stations), decrease number of public parking locations (1 participant).
A.2.4.2.2: Increase the number of users per vehicle, by increasing ownership charges (2/20R).
During the workshop participants named the adjustment of parking permits (2 participants).

New actions that are named during the workshop are:
Stimulate car-sharing companies, by creating a cooperation with the government.
Stimulated car-sharing, by spatial planning. This can be done by: developing transportation nodes on strategic locations, adjust the design of neighbourhoods (2 participants) develop traffic calming designs and regulate the accessibility of the area.

Most interesting is that multiple answers are not related to spatial planning alone. Secondly, answers are chosen that are discouraging private-car use by parking and traffic calming designs. Some participants thought of actions that would have an indirect effect, like community living and strategic nodes. After repeating the answers. The discussion was started. Below are the most interesting conversations summarized and categorized.

During the discussion in the workshop, some additional requirements for actions are argued for. Car-sharing companies have difficulties with getting a parking permit for shared-cars. Parking permits for shared-cars need to be more flexible in use in the whole Randstad, in order to get a feasible business model. In that way shared-cars can be a part of the chain-mobility, for example combined with train-travel.

The transition towards car-sharing, will also have an impact on delivery services. When users of shared-cars cannot park in front of their door, neighbourhoods can be clocked by delivery service vehicles, that deliver products. A central pick-up point could be a solution.

It is possible to give negative incentives to discourage private car ownership, but it is important to give sufficient mobility alternatives. However, most locations have already plenty mobility alternatives, but users still prefer the private car.

Therefore, it is considered to focus on a change of behaviour in order to accelerate the transition to car-sharing. The need for this change in behaviour can be argued for by politicians, when they connect it to sustainability goals, like the transition to less energy and land consumption.

It is hard to fulfil the mobility-demand by shared cars during rush-hours, because most opposite mobility streams are not equipollent in size to each other over time. Therefore, the first step in the transition is, to measure the number of cars that is needed per location over time and replace the private-cars that are not needed by shared-cars. These are mostly second cars and the ownership can be discouraged by deleting second-car-parking permits.

Most of these conversations, are also heard during the interviews. However, the topic about delivery services was not covered in the interviews. All these new insights from the workshop and questionnaire are combined with the interview results and showed in table 9d, in appendix B, impact and actions.

4.3.2.2. Stimulate use of public transport

In the questionnaire question 10, 11 and 12 are related to giving priority to some logistic streams (A.2.4.5). However, it is not clear from the interviews how this will be achieved by spatial planning.

Two urban planners of the Province of North-Holland, proposed that this can be achieved by a differentiation in nodes and logistic streams. They expect for example that the train mobility demand will decrease at small train stations in low dense areas, because this will be replaced by demand guided road AVs. This will lead to different logistic streams.

Question 10 of the questionnaire is related to this: "Bundling public transport streams. *In low-dense areas it becomes possible to fulfil the mobility demand by demand-guided AVs. They can figure as optimal feeders for thick public transport streams. Therefore, public transport streams can be bundled more effective."*

Most respondents from Arcadis and the Transport companies agree on this, while the respondents from the government are more divided in their opinion (see figure 12). The answers on question 10 show a great difference in the visions between respondent's groups. Most transportation companies, agree on the statement, but think it is too uncertain to steer this. Most respondents from Arcadis, agree on this statement and think it can be steered. The respondents from the government are divided in their vision (see figure 12). The great diversity in visions and the fact that two respondents did not understand the question, make this topic interesting to discuss during the workshop.

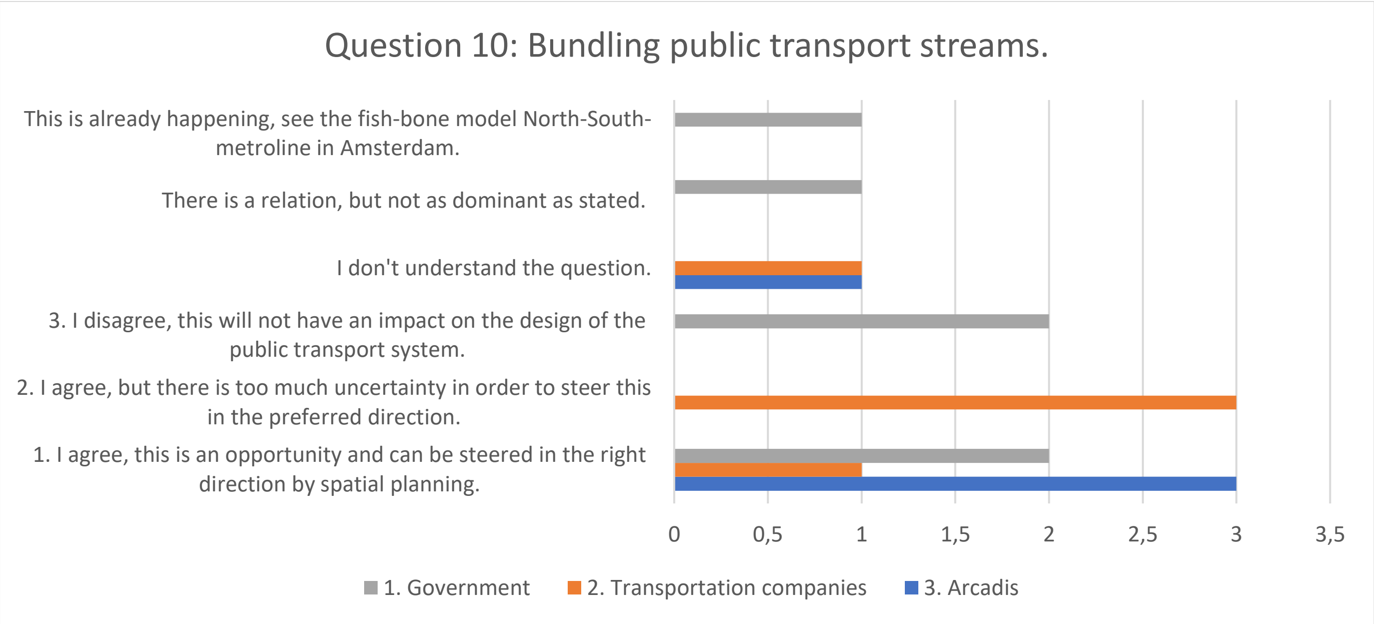


Figure 12, Support for the action of bundling public transport streams, based on questionnaire results

According to respondents during the interviews, at certain stations in low dense areas the mobility demand will decrease, while it will stay the same in the Randstad. Therefore, the space around these stations will be used differently. Question 11 of the questionnaire is related to A.2.4.5., because it will lead to a differentiation in the modality that is used to access a train station. It is also related to A.2.4.2 as an example of a parking policy, that will influence car use, that is proposed urban planners of the province of North-Holland. It is also related to the proposed actions to stimulate the use of public transport (A.3.2.2.5 develop parking at stations) and car-sharing (A.3.1.2.1 reserve space for a sharing system buffer). Lastly, it is related to the regeneration of locations and the acceptance to move parking to low dense areas (city outskirts).

The answers on question 11: *"Train stations and car-parking: In a future with AVs it might be, that some stations will be used less. The stations where it is assumed that the number of users will decrease in the future, can be assigned a new function. An example is car-parking. In low-dense areas it becomes possible to fulfil the mobility demand by demand-guided AVs. They can figure as optimal feeders for thick public transport streams. Therefore, public transport streams can be bundled more effective,"* show a great difference in the visions between respondents groups (see figure 13). Most respondents of the government think that AVs wo not have to park close to stations. Arcadis names a lot of different solutions. The transportation companies do not all agree on the statement and possible solutions. The great diversity in visions make this topic interesting to discuss during the workshop.

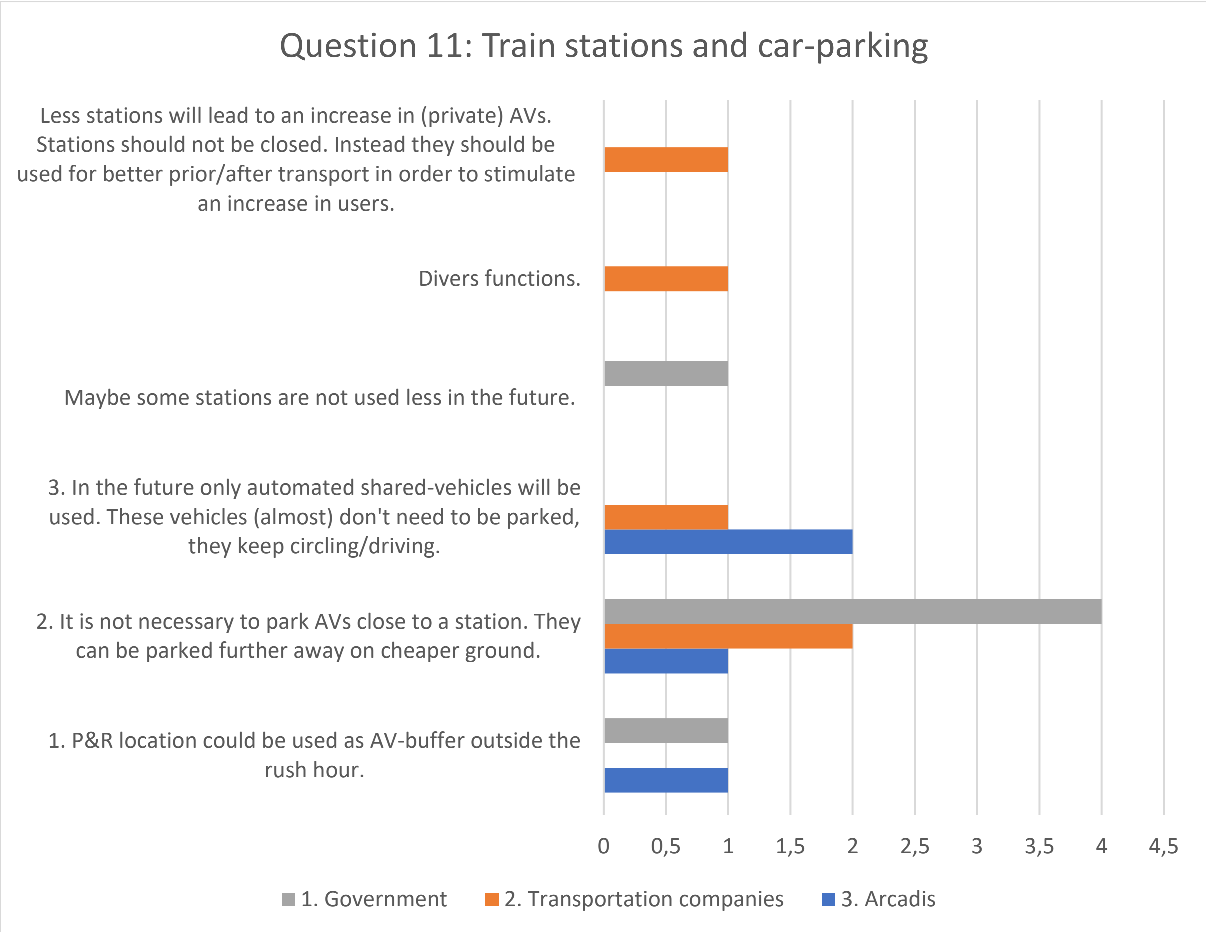


Figure 13, Support for the proposed action to adjust parking at train stations, according to respondents of the interview and questionnaire.

The answers on question 12: "*In a future with AVs, it becomes possible to assign different functions to all stations in the public transport system. An example is that some stations become more accessible by bus and bicycle and others for AVs. What spatial adjustments are necessary?*" show that transportation companies believe in the adjustment of infrastructure in order to make a differentiation in the use of stations. While respondents from Arcadis and the government also think that it is possible to steer this with parking norms. It is interesting to discuss the topic public transport use in connection to adjustments in infrastructure and parking norms.

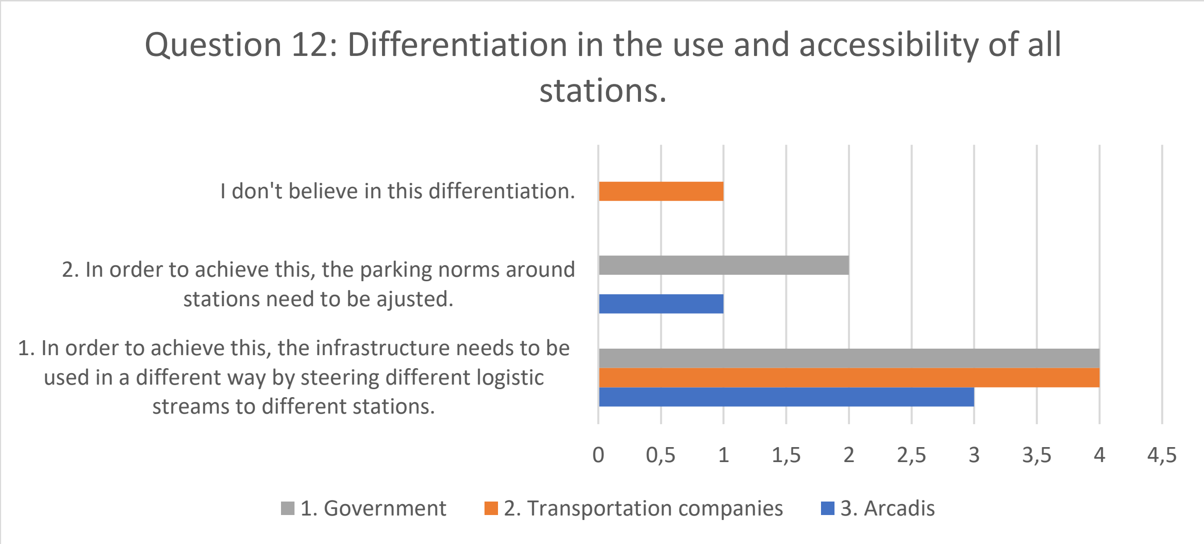


Figure 14, Support for the action to stimulate a different use of and accessibility to all stations.

During the workshop the participants first saw the results from question 10, 11 and 12 of the questionnaire. The next question was: "Which spatial adjustments are possible to organize and bundle traffic streams towards public transport nodes?" This question was hard to connect to the results that were showed from the questionnaire for most participants. Therefore, the researcher proposed that the participants could interpret this question more creative. For example: "What spatial adjustments are necessary in order to use the public transport system in a smarter way, when you also have the option AV?"

The answers that are given via the online-application are summarized and categorized below. The category is chosen by the researcher. The number after a sentence indicates how many participants named this answer. After repeating the answers, the discussion was started in order to get a better understanding of the answers. Below are the most interesting conversations summarized and categorized, according to the codes of the content analysis used for the interview results. In Appendix D, is a summary of the whole discussion.

A.2.4.4.1. Design the mobility system in a way, that there is a differentiation in certain types of logistic streams per transport node.
Answers from the workshop that are comparable are the following. Make better use of Public transport infrastructure, by regulating the accessibility to infrastructure or steer mobility streams on availability of capacity on roads, rails and stations. Make a more selective use of stations, by offering different modalities at stations.
A.3.2.2.1. Increase the number and supply of PT mobility options. The answer from the workshop that is comparable is: offer different modalities at stations.
A.3.2.2.5. Develop parking at PT stations. The answer from the workshop that is comparable is: create regional or sub-urban PT-hubs with P&R's.
A.3.2.2.6 Do not stop at every station, stop on demand. The answers from the workshop that are comparable are: use less stations and disband stops.

There are also three entirely new categories.
A.3.2.2.7. Speed-up public transport modes. The answers from the workshop that are connected to this category are:
- Decrease the need to live in the Randstad, by speeding-up PT.
- Make intercity hubs more attractive.
- Create fast urban PT-connections.
- Develop High speed rail.
- Develop the Hyperloop.

A.3.2.8. Adjust spatial planning. The workshop that are connected to this category are:
- concentrate functions, in order to lower the mobility demand to access these functions (2 participants).
- Stimulate walking and cycling in city centres
- Create traffic-calming city centres and fast urban PT-connections.

A.3.2.9. Adjust PT concessions. The workshop results that are connected to this category are:
- Make public transport connections easier, in order to give users less time loss and more certainty about time of arrival.
- Decrease the need for target group transport (costs).
- Replace public and private transport.

During the discussion, the topic of special needs target group transport was brought up again. Using AVs for public transport is difficult for these people, but can be very useful for elderly and students. This might help to prevent that these non-drivers will buy a private AV. Spatial actions that are necessary are developing easy to access pick-up and drop-off places. MaaS concepts can become very successful in high dense areas, but actions to prevent congestion when there will be an increase in use are necessary. The size of cars is an interesting topic, because the size of cars is also discussed during the interviews in relation to actions to stop the increase in land required for mobility.
A.2.4.2.3. Adjust the size of a vehicle to the usual number of users. Make the vehicle excise duty also dependent on size. AVs can be developed in any size, when car-manufacturers are incentivized by the government to do so. This can be done with for example: standardization, regulations or financial incentives.

All these new insights from the workshop and questionnaire are combined with the interview results and showed in table 9e, in appendix B, impact and actions.

4.3.5 Impact on land-use of urban system

Spatial planning can influence the use and impact of AVs on the mobility system. However, the other way around AVs can also influence spatial planning. AVs can cause a tendency to urban sprawl, instead of urbanization (according to 2/20R this is a negative impact and 2/20R it is a positive impact, according to 10/20R AVs can influence this and according to 6/20R AVs do not influence this).

Some respondents expect that, urban sprawl can be caused by AVs, because the travel distance between work and home might increase (8/20R). This is caused by several impacts of AVs. Working during the travel becomes possible, because of automated driving tasks (6/20R agree, 1/20R disagrees). There is a law of nature of acceptable travel time of an hour (Brever law), which might increase due to reduction in the value of time (3/20R agree and 2/20R disagree). There is no necessity to move from modality to modality (chain-travel), which makes the travel more comfortable (2/20R). People can live in an AV (3/20R).

Some expect that the travel distance between work and home will not increase, because there are more criteria than only travel time and a reduction in the value of time, on which people base their working or housing location (6/20R). This has several reasons. People in our society are obligated to schedules and appointments with others (4/20R). In addition, driving will still be unattractive, because the number of tasks that can be done during the travel are still marginal (1/20R). There is a trend towards flex working and working from home, which will make it unnecessary to base housing or working choices on mobility in general (4/20R). The limit of the road capacity will lead to so much congestion that people do not want to travel longer distances (1/20R). The living environment is far more important for housing choices than the travel distance to work (7/20R).

Aspects that influence someone's housing choice are: the amount of mobility options in the area (5/20R), the amount of facilities and functions on walking and cycling distance (6/20R), the amount of employment in the region (1/20R), the household composition that is searching and the housing target group (4/20R), the amount of m2 of the house and the plot (2/20R).

Housing and working locations might be regenerated when AVs are introduced, because some functions can move to low dense areas. Parking can be moved to outskirts of cities, because they can park themselves (6/20R agree and 3/20R disagree). Working locations can move, because they are more dependent on mobility options than agglomeration power (3/20R disagree). The respondents name examples like the high-tech campus in Silicone Valley or in the Netherlands the high-tech Campus of Eindhoven, that are attracting companies and are both located in dense areas. The public transport stations can be moved to city outskirts, because the last mile can be travelled by shared AVs (3/20R agree). Moving these functions from city centres, makes room for other functions that can regenerate the city. In addition, working locations, stations and parking-hubs in low-dense areas, can become more attractive when small businesses (like cafe's, restaurants and shops) are developed, that can attract residents and make the area livelier.

The combination of urban sprawl and private vehicle charges can lead to segregation in residential areas and mobility options (2/20R agree, 1/20R disagrees and 2/20R are uncertain).

A counter effect of the combination of the sharing and automation transitions, can be that people move from low-dense areas to high-dense areas in order to make use of the sharing-system (2/20R disagree).

Spatial planning actions that can influence the introduction of AVs are the following. Introducing flexible spatial planning, to keep options open and prevent the loss of investments (6/20R). An example is: develop only above ground parking facilities, that are flexible enough to transform to a different future function, in an AV scenario where parking moves to outskirts.

Concentration of functions: create proximity and accessibility of functions in order to decrease mobility (7/20R.) Examples are the following. Put restrictions on developments in certain areas, in order to concentrate developments in other areas. Decrease travel distance by spatial planning (like increasing the number of facilities in low dense areas (3/20R) and develop more housing in dense areas). However, low-priced housing in dense areas is difficult and needs to be subsidized by the government (2/20R). Concentrate functions around PT nodes, in order to create better accessibility (5/20R).

Spread the pressure on the mobility system, in order to town down peaks (3/20R). This can be done by building on the outskirts of cities (2/20R).

Influence the mobility choice of citizen, by urban planning (8/20R). Examples are: take housing type and connected mobility use into account (like: quality and type of public transport locations, bicycle infrastructure and parking norms).

Research to the connection between mobility and urbanization is necessary (2/20R). Examples are: research to the willingness to travel longer distances with the introduction of AVs and research to the social and economic impact of stations on areas.

These insights from the interview results are summerized in table 10 a and b, in appendix B, impact and actions.

4.4 Summary field research

In table 11 on the next page, is a summary presented of the first perceptions on AVs of the respondents. These results are gathered during the interview, when the respondents were asked what impact they expect from the introduction of AVs. The SWOT analysis is used in order to make a differentiation between the impacts that are perceived positive and negative. In addition, a differentiation is made between impacts that are not only related to the automation transition, but also to other trends and the environment.

There are connections between the strengths, weaknesses, opportunities and threats. These connections are researched in more depth during the questionnaire and workshop.

A perceived strength of AVs is the increased traffic safety (Strength 1). However, the increase in safety depends on the environment in which the AV is introduced. Complex traffic situations, in for example city centres, where bicyclist, pedestrians and motor-vehicles are crossing paths, might be considered too difficult for AVs in order to move safely through. While the high speeds on highways, where only motor-vehicles drive, might also be considered too difficult for AVs (Threat 1). Therefore, it seems more likely that in the near future, AVs are designed for one type of environment (Opportunity 6). AVs that can drive on the highway and AVs that can drive on specially developed infrastructure in city centres. This will lead to multiple mobility systems during the transition phase, which require a lot of land (Threat 4). In addition, the increase in road capacity (that is expected when shorter following distances between automated vehicles become possible), might be considered unsafe.

The increase in required land can also be caused be the reduction in the value of time of AV travel, because it becomes possible that the attention to the driving tasks moves to attention for other activities, like working and relaxing (Strength 5). In addition, when automation level 5 is reached non-drivers can use an AV and the accessibility and social inclusion will increase, because elderly, disabled and children get more mobility options. Even though, both are valued as a strength, the side effect of this development can be, that car ownership and private vehicle use (in which you can work and relax quietly and in private) becomes more attractive. This can lead to a situation in which users from public transport and bicycles, switch to the private vehicle (Weaknesses 2 and 3). The sharing transition that everyone desires, will not take off (Threat 3). In order to prevent congestion: the land that is needed for the mobility system increases (Weakness 4) or a payment system is introduced (for example rush-hour taxes), which leads to social exclusion (Weakness 5).

Therefore, it becomes necessary to develop a new integral mobility system (Opportunity 1), in which chain-mobility and Mobility as a Service (MaaS) are central (Opportunity 2). In that case the transition towards sharing might be accelerated, because it becomes more comfortable and easier to share vehicles in the MaaS system (Opportunity 4). In addition, the public transport system can become more efficient, because the vehicles can become self-driving and demand-driven (Opportunity 3). This is especially needed in low-dense areas, were public transport is not cost-efficient, due to the low demand. The decrease in costs for public transport and taxi’s is also caused by the decreased costs for a chauffeur (Strength 3). The increase in sharing vehicles, can lead to a decrease in ownership and thus parking norms (Strength 2). In the MaaS system, private vehicles become unnecessary in city centres and thus can become car-free (Opportunity 5).

Table 11: SWOT-analysis of perceptions of interviewees on impact of AVs.

Strengths	Weaknesses
1. Increase traffic safety	1. Increase car-ownership and -use
2. Decrease car-ownership and parking norms	2. Decrease public transport use
2. Increase accessibility and social inclusion	3. Decrease bicycle use
3. Decrease costs public transport and taxi's	4. Increase land-use for mobility system
4. Increase road capacity	5. Social exclusion, due to payment system
5. Reduction in value of time of AV travel	
Opportunities	**Threats**
1. Development of new integral mobility system	1. Complex traffic situations and high speeds
2. The use of MaaS concepts is accelerated	2. Living quality in city centres comes in danger
3. A more efficient public transport system	3. Sharing transition will not take off
4. Transition towards sharing is accelerated	4. Multiple mobility systems during transition phase
5. Car-free city centres	5. Misconceptions about positive impact of AVs
6. Use of different types of AVs per context	

However, the actions that are needed to develop this integral AV mobility system, are not defined in urban plans. Currently, the strategy related to dealing with AVs of most respondents is not incorporated in documents. However, many respondents state that they include results from research in policy documents that are being developed at the moment. The most important are: "Omgevingsvisie", "Relatie Toekomstbeeld OV (2020-2040)", "Koers Smart Mobility". Researches that are currently carried out during the exploratory phase of the introduction of AVs on the public road, are pilot projects with AVs, research methods in order to make infrastructure digitally available and impact studies. However, according to the "Interprovinciaal Overleg" (IPO) the initiatives for these projects are not governed nationally and the results of these research are not shared and applied on national level. A national approach is needed, in order to translate solutions in one city/province to another. Data and knowledge from research should suffice national standards.

There is a need to analyse: what goals can be achieved or obstructed by the introduction of AVs on public roads. The goals that are stated by the respondents in the field research are: mobility, accessibility, safety, health, sustainability, liveability and profitability. The impact of AVs when they are introduced on the Dutch public roads, are summarized in table 12. The needed actions, to reach the goals that are stated by the respondents of the field research, are connected to these impacts.

According to the respondents, AVs might improve safety and mobility, in the last phase when automation level 5 is reached and most households own an AV. The impact of the decrease in required land for mobility, will derive from the expectation that AVs can make more efficient use of the available road and parking infrastructure (shorter following distances, narrower parking lots and ownership decrease), which increases capacity. This will first have a negative effect on the profitability, because less parking fees and ownership/fuel taxes can be obtained. The land that is not needed for mobility anymore, has to be transformed, to become profitable again. Infrastructure can be transformed to green or water (which improve liveability, sustainability and health) and buildings (which improve liveability, accessibility and profitability).

According to respondents, AVs might decrease accessibility, liveability, mobility and sustainability during the transition towards AVs. The expected increase in required land for mobility, will derive from AV infrastructure that over time will replace the traditional infrastructure, but exists next to each other in the transition phase. Besides, in the first phase of the 9AV transition, it is more likely that car ownership and use will increase, due to the gradual reduction in value of time and the increasing target group by current non-drivers. When everyone gets too attached to this private automated luxury, the sharing trend will never take off. By parking policies, ownership charges and vehicle size charges, the number of persons per vehicle can be increased. Road-pricing can decrease the amount of VKT.

However, in order to transform the current system to a new integral AV mobility system, urban and transportation planners are needed. Urban and transportation planning can give priority to some logistic streams. In addition, the AV transition can be speeded-up by research and adjustments of infrastructure.

In order to prevent travellers to switch from active modes and public transport to the private AV during the AV transition phase, a change in behaviour is needed. The mobility choice for car-sharing can be stimulated by developing a sharing system buffer, drop-off/pick-up lanes. The mobility choice for public transport can be stimulated by an increase in the supply of mobility options that are easy to compare and demand-driven, which make MaaS concepts more attractive. Besides investments in infrastructure and vehicles can speed-up public transport. Bicycle use can be stimulated by developing E-bike infrastructure, creating awareness about health, adjusting schedules of users, adjusting bicycle facilities (parking, traffic lights, tunnels, lanes). This will improve mobility, accessibility, health and sustainability.

Lastly, the increase in urban sprawl, caused by the reduction in the value of time, can lead to more VKT and congestion. Policy solutions to this are stimulating flex-working/working from home and adjust working schedules. Urban planning solutions are concentration of facilities within cities (daily facilities are on walking/cycling distance) and concentration of functions around public transport nodes (transit oriented development) and restrictions on developments in certain areas. Besides, urban planning should become more flexible to adjust over time simultaneously with the AV transition. The connection between transportation planning and urban planning becomes more important, in order to develop an integral design, in which the mobility options are adjusted to the target groups of the building environment. Research to the possible change in travel demand, can be connected to the possible changed location preferences, caused by the reduction in value of time. This will improve accessibility and liveability.

Table 12: The proposed actions related to the impact of AVs.

Impact	Needed Action
Decrease of required land for mobility.	- Transform roads to public green and water. - Transform city infrastructure to buildings.
Increase of required land for mobility.	- Increase number of persons/vehicles by: parking policies, ownership and size charges. - Decrease amount of VKT by: road pricing. - Give priority to some logistic streams. - Speed-up the AV transition by: doing research and adjusting infrastructure to knowledge.
Change in travel demand: Switch from active modes and public transport to private car.	Stimulate the mobility choice for: - Car-sharing by developing a sharing system buffer and drop-off/pick-up lanes. - Public transport by supply and comparison of demand-driven mobility options, more attractive MaaS concepts, investments in infrastructure, spatial planning, speeding-up public transportation. - Bicycle use by E-bike infrastructure, awareness about health, adjust schedules of users, adjust bicycle facilities (parking, traffic lights, tunnels, lanes).
Change in location preferences	- Stimulate flex-working and working from home and/or adjust working schedules. - Broaden the amount of mobility options in an area. - Concentration: facilities on walking/cycling distance. - Integral design: adjust target group to mobility options. - Introduce flexible spatial planning. - Restrictions on developments in certain areas. - Concentration of functions around PT nodes. - Build on the outskirts of cities. - Research to possible changed travel demand and location preferences.

Lastly, there exist different strategies of steering the AV development in order to reach the goals. The ways in which the government can give direction to the AV development, can be perceived as initiative, pro-active and re-active, these are summarized in the table below (see table 13).

Table 13, Proposed strategies to give direction to the AV development

Strategy	Options
Initiative	

		Pro-active Re-active
Stimulate	Invest in AV technologies and infrastructure.	Initiative
	providing test areas and/or investments in the pilot projects.	Initiative
Facilitate	Remove barriers in regulation, that obstruct the development of AVs.	Pro-active
	Facilitate cooperation between parties (create a lobby)	Pro-active
	Make spatial and transportation planning more flexible.	Pro-active
	Make policies and documents more flexible.	Pro-active
Regulate	Make regulation for the use and type of AVs that are allowed on roads.	Pro-active
	Standardize policies/strategies/regulation on European/national level.	Pro-active
Prohibit	Prohibit the access of AVs on public roads.	Re-active
Research	Share data/knowledge with others, to corporate and create awareness.	Pro-active
	Get information from other market-parties about AVs.	Re-active

From section 4.2, it becomes clear that most respondents from the government are preferring a pro-active (5/10R) or reactive (4/10R) steering method. While, transportation and consultancy companies do mostly expect a pro-active (5/8R) steering method from the government. In the questionnaire these stakeholders also expect a pro-active (3/9R) or initiative (2/9R) steering method (together 5/9R). While from the government only 2 of the 6 respondents prefer an initiative/pro-active steering method.

5. Discussion

In section 5.1 the impact of AVs on spatial planning described in literature is compared to the perceptions of stakeholders on the impact of AVs, by answering sub-questions 1.1 and 1.2. Secondly in section 5.2, the overall solutions to prevent the negative impact of AVs on road capacity, proposed by academics and researchers in the literature study, will be compared to the views and opinions of stakeholders given in the field research, by answering sub-question 2.1, 2.2 and 2.3.

5.1 The spatial impact of AVs

The expected impact according to literature and the perceived impact by stakeholders is compared below. The first sub-question was answered by the knowledge gathered during the literature review. The second is answered by doing the field research. The answers are compared according to the category system of the field research. The sub-questions are the following:

1.1 What is the expected impact of Automated Vehicles on the urban system according to academics and researchers?

1.2 How do the stakeholders in the urban planning and transportation sector perceive the need to implement new automated vehicle technologies in urban plans?

5.1.1 Timeline

Currently, it is difficult to predict, how much time it will take before full implementation of AVs. However, some literature anticipates the following timeline for the deployment of fully AVs: in 2020-2045 market availability, in 2030-2060 a regulatory requirement for all new cars and in 2040-2080 a prohibition of non-AVs from public roads at most times (Milakis et al., 2017) and (Levinson et al., 2016).

There is disagreement between stakeholders about the time that the AV transition takes. Some think the timeline described in literature is right (9/20R). However, some assume that it will take longer (6/20R), especially to implement the technology in city centres, with their complex traffic situations. Some respondents think the transition time will be shorter (2/20R). Some respondents could not or would not answer the question, because they thought there was too much uncertainty (5/20R). The respondents from the government are more negative and uncertain about the development of AVs over time, than the respondents from the market parties.

Both literature and stakeholders are very uncertain. However, it is expected by most that between 2025 and 2030 the first AVs will appear on the roads and from 2050 more than half of the households will own a AV. Therefore, it seems wise to take the impact of AVs into account in plans that are being developed at the moment.

5.1.2 Impact on congestion

According to literature, the expected impact of AVs will in most scenarios increase congestion. Therefore, the introduction of AVs has a high risk of being negative for the land use of the urban mobility system. Even though, the new technology might have a positive effect on parking efficiency (due to the possibility of clustered parking on distance and smaller gaps between vehicles) over time and when automation level 5 is reached, road capacity might even increase (due to connectiveness safety measures might decrease and shorter following distances might be accepted).

During the field research, the possibility of clustered parking (6/20R) and parking efficiency (4/20R) is named by respondents. They expect that this might lead to lower parking norms (14/20R). In addition, the new technology might also lead to shorter following distances between driving vehicles and higher allowed speeds, due to improved safety on roads. This might lead to an increase in road capacity (9/20R). This is mostly expected by transportation planners (2/20R) and transportation companies (5/20R).

However, according to literature this might be mitigated or even repealed by an increase in vehicle ownership and use. This increase in vehicle ownership will derive from current non-drivers that are allowed to use an level 5 AV. The increase in vehicle use will derive from the reduction in the value of time, because vehicle users will not have to concentrate on the driving tasks anymore. This might lead to problems in the availability of road capacity. 17 of the 20 respondents expect that there will be an increase in car ownership and/or car use. 13 of the 20 respondents think there will be an increase in car-use and 6 of the 20 think there will be an increase in ownership rates.

The cumulative effect of the increased efficiency and the increase in use/ownership will be a higher volume-to-capacity ratio according to most respondents (6/14R agree, 4/14R are uncertain and 4/14R disagree). Striking is that no one from the government disagrees.

Therefore, it seems wise to mitigate this negative impact by spatial planning actions. A sensible reaction on this matter, might be that stakeholders that are affected by this problem are being informed and take place in the multi-actor decision-making process, in order to mitigate these problems. Although urban planners are becoming more and more aware of the issue, this research shows that this issue has not much priority yet in policies and strategies. In addition, not all transportation organizations (public transport companies and vehicle-renting companies) take the possibilities of competition from this new technology into account in their business model. This brings us to the topic strategy of the stakeholders.

5.1.3 Strategy

The stakeholders in the urban planning and transportation sector perceive the priority to implement new automated vehicle technologies in urban plans, to a lesser extent than the literature. In general, the respondents are very uncertain during the interviews. Most respondents name certain subjects and viewpoints, but they are less inclined to take a position in the debate (agree or disagree to the possibility that an impact will occur or choose for a certain action).

At first, it seemed that stakeholders are dazzled by the promised positive impact that AVs will have on sustainability, safety, sharing rates and road capacity, promoted by the car-manufacturing industry. Due to the fact that there is so little written about the possible negative impacts of AVs in planning documents. However, from the field research a more anxious attitude towards the impact of AVs is encountered. Together the respondents name 72 positive and 60 negative impacts (see table 5b). However, the government is more biased to the positive impacts (they named 48 positive impacts and 35 negative impact), while the market parties are more or less neutral (24 against 25).

As presented in the previous section there are mainly worries, that the ownership rates and vehicle use might increase and will mitigate positive impacts. Despite these worries, the introduction of AVs is not included in most strategies and policies. Some name a policy document in which it is included or will be included (Omgevingsvisie, Koers Smart Mobility, Relatie Toekomstbeeld OV 2020-2040), but they all admit that it is very marginal. Most stakeholders claim that this is caused by the uncertainty in the timeline of the transition and the new technology itself, which is kept secret by car-manufacturers due to competition contemplations. However, it might also be caused by a lack of knowledge on the subject, a lack of consensus between the stakeholders, the sentiment of the subject in the political debate and the strong positions of certain stakeholders in the multi-actor decision-making process.

Therefore, it might be useful to analyse the goals of all the stakeholders and the trends in the society, in order to find a policy window to get policies/strategies related to the introduction of AVs on the agenda. The main goals of the stakeholders are: good accessibility and mobility (12/20R), increased safety (7/20R), increased liability (5/20R), increased sustainability (4/20R), increased health (3/20R) and a stronger competition position (7/20R). These goals can be reached by finding out what actions are needed to mitigate the negative impact and accelerate the positive impact of AVs. There are several options for the government to give direction to the development of AVs: stimulate the development (7/20R), facilitate the development (7/20R), regulation (18/20R of which 3/20R it is unwise to develop too much regulation), prohibition (6/20R think that prohibiting AVs is not a good idea), do research (12/20R). The government is currently leaning more to pro-active and re-active steering methods, like regulating, facilitating and waiting on more knowledge from research, while the market parties expect a more initiative and pro-active attitude from them, like stimulating the AV technology and initiating research projects.

5.2 Proposed action for the implementation of Automated Vehicles.

Proposed actions to prevent the negative impact of AVs on road capacity are compared below. This section will compare the answer on sub-question 2.1, which is gathered during the literature study and sub-question 2.2, which is gathered during the field research.

According to literature, most impacts will lead to an increased mobility demand and amount of VKT. Therefore, if it seems important to steer the development of AVs or to adjust roads, in order to prevent future major congestions. Below is a summary of actions that are proposed in literature:

1. Moving parking garages to outskirts
2. Stimulate car-sharing and ride-sharing
3. Introduce road-pricing
4. Construct attractive bicycle and pedestrian infrastructure
5. Construct drop-off and pick-up lanes
6. Develop mixed functions living areas and concentrate around public transport nodes

5.2.1 Road pricing

If there is something everyone would agree on, it is that road pricing [action 3, from literature study] would most certainly discourage vehicle use and decrease Vehicle Kilometres Travelled (VKT) (12/20R). However, road pricing is also considered a forbidden word (5/20R, which are all from the government); a subject people would not dare bring up in conversation. The reason for this is that there is resistant by some political parties and their voters (Kilometerheffing Nederland.com, 2018) and (Giebels, 2016), because it might lead to a decrease in the national economic prosperity (Schreuder, 2015). So even though, road pricing would probably favour the cause, the possibility that this would easily be integrated in the current system makes it a difficult affair. This is a policy that could be implemented on short-term and might therefore be a last expedient, when planners are not taking the impact of AVs on congestion into account. However, it will lead probably too much resistant of voters. Therefore, it seems wiser to integrate other actions that will gradually discourage car-ownership/use and encourage public transport/shared-vehicle use, cycling and walking over time.

5.2.2 Clustered parking

One way literature states that would gradually discourage car-ownership/use, is by moving parking garages to outskirts [action 1, from literature study]. Although, it might be a hassle to get to your preferred location when there is no parking options available nearby your destination, this does not mean there will be less VKT. Instead, people will first let themselves drop off in the city centre at their destination and let the empty vehicle drive to the parking garage outside the city. After the activity on the destination the user will call the AV and let themselves be picked up by the empty driving vehicle. It might stop some people from taking the car, but based on the popularity of park and ride locations it certainly does not decrease VKT in a significant way.

According to stakeholders, AVs might be able to park themselves (10/20R). This might lead to possibilities of clustered parking (8/20R) that is desirable outside city centres (12/20R), because it leads to less parked cars in city centres and thus an improved living quality (2/20R) and possibly even completely car-free city centres (10/20R). However, it might also lead to more EVT, because vehicles move from destination to parking and back (2/20R). Besides the usefulness of this systems for users depends on the waiting time for the vehicle (3/20R).

To conclude, clustering parking might be a more efficient way of using parking capacity. However, clustering parking will cause more vehicles to drive back and forth between destination and parking location during rush hour, which is increasing VKT. Therefore, this action is only effective when users will not use a private vehicle to reach their final destination. It is more sensible to stimulate the use of shared vehicles and public transport for the last and first mile. Besides, when multiple users are using the same vehicle on different times or share rides (which is easier, when more vehicles are parked at the same location), the ownership rates can also decrease and less parking capacity is needed. However, when shared vehicle services become very popular, there might be scenarios where vehicles are circling around in order to search for users or pick-up and drop-off users. There will be no need for parking lots and VKT are increased. The example of Ubers in San Francisco is used by some respondents to explain this problem (Hijink, 2018) and (Milakis, Cervero, & van Wee, 2015), by four respondents from public transport, urban planning and the government. However, another respondent of the government thinks that this will be different in the Netherlands, because the public transport system is more advanced here.

5.2.3. Stimulate car-sharing and ride-sharing

Another option stated in literature is to stimulate car-sharing and ride-sharing [action 2, from literature study], which leads to less parking and roads necessary.

This would be a great way to decrease VKT, respondents agree, but is currently just not that popular (9/20R). However, with the introduction of AV it could get more popular (14/20R) and it’s definitely something that needs to be stimulated (10/20R). Whether or not popularity will actually increase is uncertain and therefore one cannot rely merely on this tactic.

According to respondents, the popularity depends on: the waiting time for the vehicle (3/20R), the supply of shared-vehicles in the area (3/20R), the emotional attachment to vehicle-ownership (4/20R), the price of the ride (5/20R), the user-friendliness (3/20R).

Policy related actions that discourage ownership and might increase the number of users per vehicle are: parking policies (10R and 6 participants of the workshop, from this point forward the amount of participants is revered to in #P), increasing ownership charges (2/20R and 2/9P) and decrease the size of vehicles (3/20R). The last action is not really increasing the number of users per vehicle, but instead adjusting the size of the vehicle to the usual number of users (from vehicles that are developed for 5 users to vehicles that are developed for the average number of users 1,2).

Spatial planning actions that stimulate car-sharing are: reserving space for a sharing system buffer (7/20R) while reducing the number of shared vehicle service suppliers (2/20R and 2/9P), creating drop-off and pick-up points (5/20R and 1/9P).

Most of these actions are not per se encouraging ride-sharing, while this would be far more effective to decrease the amount of VKT, than car-sharing (which most of the times will only increase VKT to get the vehicle from one user to the next). Therefore, it seems also important to reserve space for drop-off and pick-up places, where users come together to share a ride. This will be explained in more detail in the next section 5.2.4.

5.2.4 Constructing drop-off and pick-up lanes and stops.

Constructing drop-off and pick-up lanes [action 5, from the literature study] would be another option, so that congestion would be brought to a minimum. Getting on and off a vehicle would be more efficiently timed. Only three respondents listed this as a preferable solution for stimulating car-sharing during the interviews. However, it was not named as an overall solution in order to decrease congestion, during the interviews. In the questionnaire, 2 additional respondents named it as an action to discourage car-use and ownership.

Something can be said for the efficient timing of getting on and off a vehicle, it however does not guarantee a big impact on congestion. Cars would still need to drive to and from the drop-off points, which could in turn cause significant congestions in this area. Therefore, separated pick-up and drop-off lanes, instead of stops on the existing roads, would be a better solution. It also does not necessarily reduce the amount of people using a car instead of other available options. However, it will incline users, that the remainder of their journey (last mile) has to be taken by foot, bicycle or public transport.

5.2.5 Constructing attractive bicycle and pedestrian infrastructure.

Literature also states, that constructing attractive bicycle and pedestrian lanes [action 4, from the literature study] would decrease the amount of VKT, by stimulating people to travel by alternative means. This is something 11 of the 20 respondents agree on, during the field research. Of course, it would stimulate alternative travel, but this is by no means a cure-all solution. There are too many factors why people would prefer travel by car to say this would have a significant impact on VKT. However, it is one of the options that could be investigated further, because it does not have an apparent downside to it. Therefore, it is a no-regret action.

5.2.6 Developing mixed functions living areas.

There is also the option of developing mixed functions living areas [action 6, from literature study], as all daily and weekly trips would be close by, mitigating the need for car use. During the questionnaire respondents named a mix of rental and private houses. Besides during the workshop they named community living and the redesign of neighbourhoods as solutions, in order to stimulate car-sharing. These are comparable subjects. Although this would most certainly decrease VKT, it would also mean a complete redesign of a lot of living areas, especially those not in central areas of the city.

Then there is still the place of work, which if not close by, could still convince people to travel by car. Even though some might vision a future where everybody works at home and every meeting is held over a skype call (4/20R named this as a possible future during the interviews see theme: I.4.1.2.), reality is that right now we do not live in such a world and we probably will not for the foreseeable future. To combine such a vision with the already somewhat unpredictable implementation of AV technology would be to bet on two horses at the same time, without knowing whether or not this is how people actually want to live. It is highly doubtful that this solution will be implemented in full scale.

5.2.6 Concentration around public transport nodes

Then there is concentration around public transport nodes [action 7, from literature study], so that people would rather travel by public transport. During the field research a comparable response was found. The answers to Question 8 from the questionnaire are comparable (*"Spatial incentives to stop trend towards increase use of private car: The use of public transport and the bicycle will decrease, due to the increase in the use of private cars, due to the introduction of AVs. What spatial solutions could stop this trend? Multiple answers are possible.").* The answers are 1. Integral design of working/living/recreation locations and public transport nodes (12/14R) and 2. Concentration around public transport nodes (11/14R).

This is a viable option, however, currently a lot of offices are already being built near public transport nodes. The question is how many offices would be necessary to see a significant decrease in VKT. One could go as far as saying we need to build entire business parks around these public transportation nodes, but would this be a place people would like to work? Do businesses want to settle here? By not allowing personal vehicles on the terrain, it would undoubtedly stimulate public transportation use. It might just be a hard sell to a lot of businesses, needing them to settle somewhere the 'outside world' can barely see they exist. Two respondents say that working locations cannot be built in low-dense areas, because the agglomeration power is more important to businesses, than the mobility options for their employees or the land prices (see I.4.3.1.2.).

To conclude, the action of concentrating around public transport nodes is already used in many cases. However, increasing this can also lead to more congestion on this infrastructure. There is not only a risk of congestion on motorways, but also on public transport tracks (de Graeff et al., 2018).

According to respondents during the field research, it would be better to make in a different way use of the available public transport infrastructure, by bundling public transport streams and use demand-driven public transport in low-dense areas as optimal feeders for these thick streams. In this way, there are less stops needed on thick streams and the vehicle could speed up, which creates more space on the track. In addition, MaaS concepts can become more attractive by increasing the number of mobility options available and making it easier to compare them (in price and time). Besides, a differentiation in parking policies per station can give direction to logistic streams to these stations.

5.2.6 Summary of proposed actions

Road pricing, would most certainly discourage vehicle use and decrease VKT. However, road pricing will lead probably too much resistance in the multi-actor decision making process. Therefore, it seems wiser to integrate other actions that will gradually discourage car-ownership/use and encourage public transport/shared-vehicle use, cycling and walking over time.

Moving parking garages to outskirts, will lead to less parking capacity needed in city centres and possibilities for car-free city centres. However, in most scenarios it will lead not to less VKT, due to Empty Vehicle Travel (EVT). Therefore, it is more sensible to stimulate the use of shared vehicles and public transport to drive back and forth between destination and parking location. In addition, it might be necessary to introduce road-pricing in city-centres in order to prevent empty vehicles circling around in order to find and/or wait for users, instead of parking on a long distance for a higher price.

Stimulating car-sharing and ride-sharing, will lead to less parking and roads necessary. The most popular actions are: parking policies, reserving space for a sharing system buffer and creating more drop-off and pick-up points. The last action is most important to encourage ride-sharing.

When the drop-off/pick-up point is developed on a separated lane, congestion can be brought to a minimum and getting on and off a vehicle would be more efficiently timed. However, this action does not necessarily reduce the amount of people using a car instead of other available options on its own. The combination of the actions would be most effective.

Constructing attractive bicycle and pedestrian lanes and parking, would decrease the amount of VKT, by stimulating people to travel by alternative means. This is a popular action, which is useful in all scenarios. Therefore, it is a no-regret action.

Developing mixed functions living areas, as all daily and weekly trips would be close by, mitigating the need for car use, is very costly and takes a lot of time. Besides, there is more research/knowledge needed to the relation between mobility options, accessibility and location preferences. This can be done in future research, in order to get more insight in the costs and benefits of this action.

The action of concentrating around public transport nodes is already used in many cases. However, increasing this can also lead to more congestion on this infrastructure. According to respondents during the field research it would be better to make in a different way use of the available public transport infrastructure.

The combination of the proposed actions

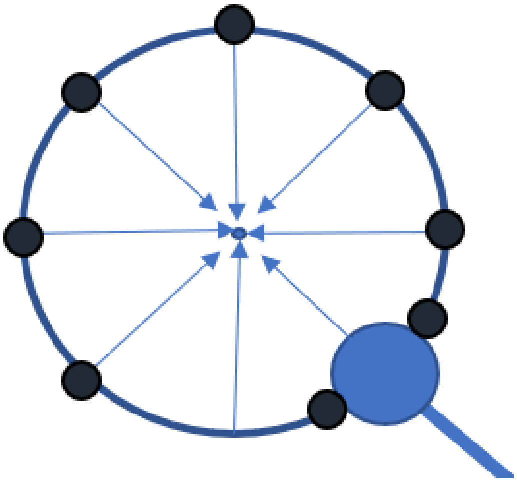
All these proposed actions in literature and by stakeholders can be combined. This brought new insights for a possible solution. This research proposes the following actions, to deal with the expected negative impact of AVs on congestion, based on the results of the literature study and field research.

When the actions of constructing park and ride garages on outskirt of city centres is combined with inner-city road pricing and parking policies, people are inclined to use other mobility options to cover the last mile to the city centre.

When shared vehicles have more and cheaper parking possibilities and sufficient drop-off and pick-up lanes for sharing rides are constructed, users might choose this over the private AV. When bicycle paths are made more attractive and sufficient bicycle parking is available, users will be more inclined to use these more space-efficient mobility option. In addition, there should be more invested in making public transport infrastructure ready for AVs. In that way public transport AVs can compete with private AVs.

The land that comes available, with moving parking to city outskirts, can be used for this new car-sharing, public transport and bicycle infrastructure. Between large cities high-speed public transport can drive, while only stopping on 1 or 2 large stations to pick-up passengers. From low-dense areas users can take demand-driven public transport and shared-vehicles in order to access these large stations or to access park and ride garages on outskirts of cities.

The spatial effect of these actions is presented in the schematic figures on the next page (figure 15 and 15). Together these actions will form a new integral AV mobility system, which stimulates a change in behaviour by travellers, to switch to more land-efficient mobility options.



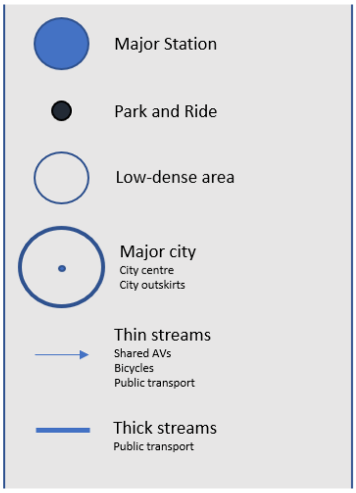
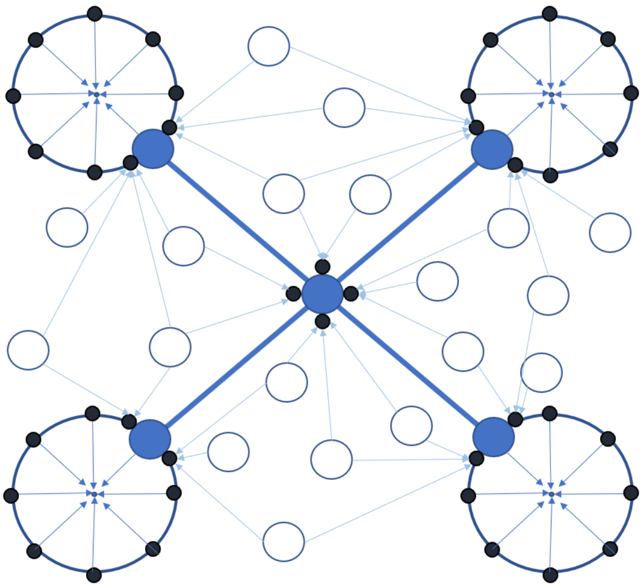


Figure 15, Park and ride garages on city outskirts *Legend*



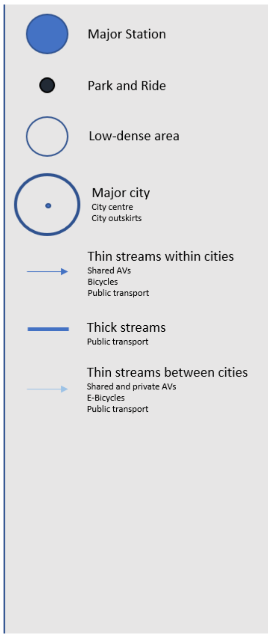


Figure 16, routes to get to major public transport stations *Legend*

6. Conclusion and recommendations

This research consisted of a literature study and a field research (interviews, questionnaire and workshop conducted under a group of 20 respondents in the urban planning and transportation sector). From the results of this research, it became clear what the expected impact of AVs is, how stakeholders perceive this impact and what actions are possible and supported by most to react on this impact. The answers to the main questions in this research, as written in section 6.1, will help to establish a guideline for urban and transportation planners on how they can act in the transition towards fully AVs, as written in section 6.2.

6.1 Conclusion

1. What is the expected impact of Automated Vehicles on the urban system?

The expected impact of AVs according to most literature and most stakeholders is negative for the land use of the mobility system, due to the increase in vehicle use and ownership. This will lead to an increase in the mobility demand and Vehicle Kilometres Travelled (VKT), which may lead to increasing congestion levels.

Based on the findings, it becomes clear that planners in the public sector are becoming more aware of the possible negative impact of AVs and are thinking about the development of a strategy to mitigate this.

However, there is disagreement between stakeholders about the time that the AV transition takes. 9 of the 20 respondents in the field research, think that the following timeline described in literature is right for the deployment of fully AVs: in 2020-2045 market availability, in 2030-2060 a regulatory requirement for all new cars and in 2040-2080 a prohibition of non-AVs from public roads at most times (Milakis et al., 2017) and (Levinson et al., 2016). However, others assume that it will take shorter (2 respondents) or longer (6 respondents), especially to implement the technology in city centres, with their complex traffic situations. 5 respondents are unsure. The respondents from the government are more negative and uncertain about the development of AVs over time, than the respondents from the market parties.

Promised positive impacts by the AV industry, gave stakeholders the impression that AVs will bring mostly benefits for the society (increased sustainability, safety, sharing rates and road capacity). However, some admit now, that there exist misperceptions about the positive impact of AVs, like the assumption that the introduction of AVs will automatically lead to lower ownership rates and that it will lead to more sustainability.

17 of the 20 respondents expect that there will be an increase in car ownership and/or car use and 6 of the 14 respondents think that this might mitigate positive impacts (like the expected increase in infrastructure capacity, by automated parking and driving). Even though, 8 respondents are uncertain about or disagreeing to the increase of the volume-to-capacity-ratio, it is striking that no one from the government disagrees.

Despite these worries, the introduction of AVs is not included in most strategies and policies. Most stakeholders claim that this is caused by the uncertainty in the timeline of the transition and the new technology itself, which is kept secret by car-manufacturers due to competition contemplations. However, waiting on these actors will not solve the problem. Therefore, it might be more useful to analyse the goals of all the stakeholders in the field and the trends in the society, in order to find a policy window to get policies/strategies related to the introduction of AVs on the agenda.

To conclude, there is a lot of uncertainty about the timeline of the development of AVs. However, most researchers and stakeholders expect that the development of the technology cannot be prevented and/or prohibited (10 of the 20 respondents). Therefore, it seems wise that the impact is taken into account in urban planning. There is a lot of uncertainty about the impact of AVs on urban planning. Both in the desk research as during the field research, there appear to be a lot of different opinions and visions on the impact. These lead to the development of multiple possible futures, that are described in different scenarios. The impact that most of the respondents agreed on, is the increased car use (13 of the 20 respondents). This will lead in all scenarios, to reaching the limits of the current road capacity. Therefore, there is a need for mitigating actions, in order to prevent major congestion.

2. How can transport and spatial planners take the transition to fully Automated Vehicles into account in their long term urban and mobility planning?
The most useful actions to mitigate the negative impact of AVs on road capacity described in literature and proposed by respondents in interviews, are summarized below.

Although, there is a lot of diversity in the visions of the stakeholders on the subject (some stakeholders even have internal contradictions in their opinion), there is also consensus on certain themes and related actions.

Many stakeholders see that there is a latent question to mobility and the increase of road infrastructure will only have a short-term positive impact on the road capacity. Therefore, there exist two options according to the stakeholders: 1. Do nothing, the increase in congestion will lead to a new balance between vehicle use/ownership and availability of road capacity (6 of 20 respondents named this as an option) or 2. Discourage private vehicle use and ownership. The first option is mostly named by stakeholders from the government.

Stakeholders that name the second option, want to discourage vehicle ownership (10 of 20 respondents), by the use of parking policies (10 of 20 respondents) and the introduction of ownership and vehicles sizes charges (5 of 20 respondents). They want to decrease vehicle use, by road pricing (12 of 20 respondents). However, there is not a lot of support for road pricing, some respondents even state that it is a forbidden word (5 respondents of the government).

There is also support for repulsing certain types of mobility concepts (10 of 20 respondents) and giving priority to some logistic streams in cities (11 of 20 respondents), by urban and transportation planning. Urban and transportation planners can influence the mobility choice of citizen, by improving Public Transport (12 respondents), Shared Vehicle services (9 respondents) and bicycle (6 respondents) infrastructure. Several options in order to do this, are named by respondents.

During the transition there will exist multiple mobility systems next to each other. This will also require a lot of land. Therefore, some stakeholders want to speed up the transition process, by adjusting the infrastructure (6 of 20 respondents), others named it as an option but are very uncertain about it (6 of 20 respondents) and some do not think this will work (5 of 20 respondents).

In the spatial planning sector, there is a lot of disagreement about the possibility that AVs will increase urban sprawl and whether this is a negative or positive development. However, actions to stop this trend are development restrictions in certain areas and decrease travel distances by spatial planning in order to decrease the needed VKT to fulfil the accessibility demand.

Interpretation of all the results by the researcher
From the interviews it did not became clear, what actions from all these options, are supported and preferred by most stakeholders. Therefore, a questionnaire and workshop was held, in order to

select the most relevant actions. In this research actions that can be taken right now are called: No-regret actions.

An action that is described in literature that can be used on short notice, is road pricing. However, there is not enough support for this action under stakeholders. The actions that are described in the literature, that also have a lot of support of stakeholders in the urban and transportation sector are described in the next section.

The majority of these actions can be summarized to developing an integral automated and shared mobility system, in which private vehicle use is discouraged and cycling/walking and the use of public transport/shared-vehicles are encouraged. When inner-city road pricing and parking policies are combined with improvements on vehicle-sharing, public transport and bicycle infrastructure, people are inclined to use other mobility options than the private car to cover the last mile to the city centre. The land that is needed for this infrastructure, comes available with moving parking to city outskirts. Between large cities high-speed public transport streams are bundled. Automated demand-driven public transport will figure in low-dense areas, as optimal feeders for these high-speed lines. In that way the vehicle does not have to stop as often as it used to do, which creates more space on the track and saves time for users. Parking policies and facilities around stations, can give an extra incentive to use the preferred modality. In addition, urban planning can focus more on concentration of functions and transit oriented development.

There are also differences in opinions about the way in which actions can be taken. These vary from: do research, develop regulation, facilitate the transition or stimulate the transition. Most stakeholders take a remote position, because they are waiting on more information from other parties (car-manufacturers or governmental regulators). However, a more initiative and pro-active attitude from the government is desired by other stakeholders (transportation and consultancy companies).

To conclude, the expected impact of AVs according to most literature and most stakeholders is negative for the land use of the mobility system, due to the increase in vehicle use and ownership. This will lead to an increase in the mobility demand and VKT, which will in turn lead to a decrease in road capacity. Transport and spatial planners can take the transition to fully Automated Vehicles into account in their long term urban and mobility planning, by mitigating the negative impact. In order to mitigate the negative effect on road capacity, it seems wise to stimulate public transport, car-sharing/ride-sharing and bicycle use. This can be done by improving infrastructure for these mobility options. In addition, private car use and ownership can be discouraged by parking policies.

Different stakeholders in the urban planning and transportation sector do not have much interaction about the subject of AVs. In order to keep their competition position, everyone is keeping secrets. This makes it harder for urban planners, to implement transportation technologies in urban development projects at the moment. There are however, a number of actions that urban and transportation planners already can take in the transition towards fully AVs.

6.2 Recommendations

Recommendations can be split-up in recommendations in planning practice and planning science.

6.2.1 Recommendations for planning practice

Based on the findings in this thesis, planners in the public sector seem aware of the possible negative impact of AVs, but do not have much priority on developing a strategy to mitigate this. On account of possible negative consequences that will follow from taking to late or no action described in the conclusion, it is misguided for urban planners to ignore the problem. It is recommended for the planning practice that the multi-actor decision making process is kick-started by the government as we speak.

This strategy can be designed with the help of a multi-actor decision making process. This means that it is desirable that it becomes clearer what the positions of all the stakeholders are and what their vision is on this issue. In this research the goals of the stakeholders are described. These goals can be explored in more detail in order to evaluate what goals are appropriate in multiple possible AV future scenarios. Next, the possible actions to reach these goals can be evaluated.

An negative impact of AVs on the mobility system, is according to both literature and stakeholders, that in every scenario more congestion will appear and thus more road capacity is needed. Therefore an collective goal for all stakeholders can be to achieve that less transfers are needed while providing the same accessibility. It would be smart to use actions that can achieve multiple goals simultaneously. Another goal was for example that the mobility system becomes more sustainable. Spatial planners can reach both goals at ones, by for example stimulating that people work and live in the same area. This will lead to less transfers needed and thus less road capacity needed. In addition, it will lead to less VKT and thus less energy consumption. While, transportation planners can for example make ride-sharing or public transport more attractive. This will lead to less transfers that are needed, because more persons use the same vehicle. In addition, it will lead to less VKT and thus less energy needed. The government can give incentives, by taxing vehicle kilometres travelled by private AVs or subsidising AV-sharing and public transport.

This can be done on national or international level (for example European level), in order to create a strong position for public parties against the strong international competition position of AV market parties. The public parties can develop together with the market parties international AV standards and regulation.

In order to facilitate the decision-making process of the transition towards fully AVs on national and international level, it can be useful to take notice from the impact of AVs and related actions/policies and strategies described in this research. This will lead to a better understanding of the AV transition and gives the stakeholders the opportunity to take a position in the decision-making process. This research also shows what research is necessary in order to move forward in the decision-making process. The results of this research can figure as a starting point for the multi-actor decision making process, but cannot be generalized due to the small sample of respondents. The semi-structured interview schedule and the questionnaire can be used by organisations to study the vision of their employees on the subject and discuss the subject in a productive and efficient way on a larger scale, in order to create a strategy /policy with sufficient support. The results in this research, only give a first indication of the vision of the public and private parties in the spatial planning and transportation sector in the Netherlands. It is recommended to conduct a similar study on larger scale.

In the meantime (during the multi-actor decision-making process), it seems wise that urban planners keep the planning flexible, so that it can be adjusted to new and improved knowledge about the timeline, technology and preferred impact of AVs. This means that only no-regret actions are taken. These are actions that have a positive outcome in all future scenarios.

An example is that some academics are stating that it is misguided, when the government invests in public transport infrastructure, because in the future AVs might replace these systems. The main issue is that public transport infrastructure has a long return on investment time and decisions need to be taken a long time in advance of the development. However, in another scenario AVs and public transport systems can be combined and supplement each other, because the implementation of AV technologies is more easy in separated traffic flows. Only when the automation level 5 is reached the systems can compete (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017). The no-regret-action could be to make public transport systems adaptive and give the possibility to adapt long-term contracts to technical innovations. There is a lot of consensus about the use of scenario planning and making planning more flexible under respondents. According to some respondents urban planning might be flexible enough, when the planning cycle can be shortened from 15-40 years to 5-10 years (for example public transport concessions).

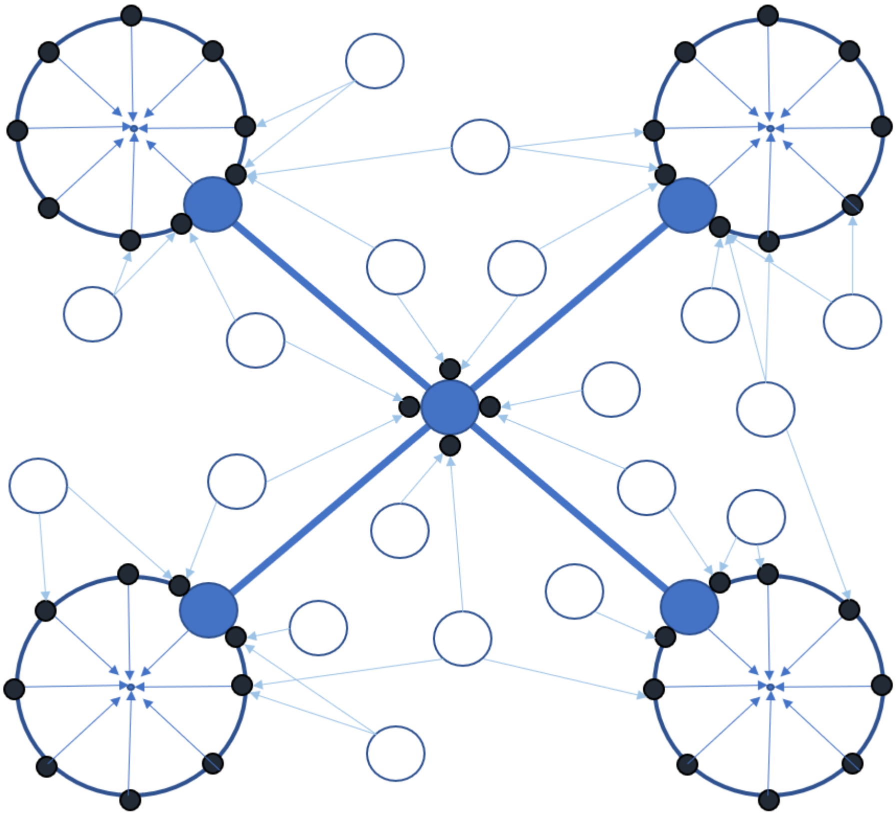
6.2.2 Recommendations for planning science

Recommendation for further research on planning science are: validating the effect of these actions in practice (with the help of models/simulations and pilot projects) and research the support of citizen for these actions (with the help of social research methods like for example interviews, questionnaires, serious gaming, etc.). There are differences in opinions about the way in which actions can be taken. These vary from: do research, develop regulation, facilitate the transition or stimulate the transition. Most stakeholders take a remote position, because they are waiting on more information from other parties (car-manufacturers or governmental regulators). Therefore, it is recommended researchers help the planners with creating more certainty about the development of AVs. Researchers can develop more scenarios and test these in models, in order to make a decision between actions to mitigate negative impact.

In section 5.2.6. a new mobility system visualized. In order to get a situation, in which every user of the mobility system uses the shortest route to get to a public transport station in order to continue the journey to major cities via the high-speed network (visualized in figure 17), research can be done to a pricing mechanism and a time schedule that incentives this. This is in the fields of network management and transportation means. This can be done with simulation models. In addition, the spatial possibilities can be researched on the public resources and the network infrastructure. The technical artefacts, the processes and the institutions can be taken into account, when developing these simulation models.

The connection between planning science and planning practice can be made by for example doing research and testing it in practice. According to the results from the workshop, it is hard to fulfil the mobility-demand by shared cars during rush-hours, because most opposite mobility streams are not equipollent in size to each other over time. Therefore, the first step in the transition is, to measure the number of cars that is needed per location over time and replace the private-cars that are not needed by shared-cars. These are mostly second cars. The second step is in planning practice that the ownership is discouraged by deleting second-car-parking permits. This is just one example of the many options that derive from this research.

To conclude, in order for urban planners to make deliberated decisions about the AV transition, there is a huge demand for research in more depth to the expected impact and the effect of proposed actions described in this research.



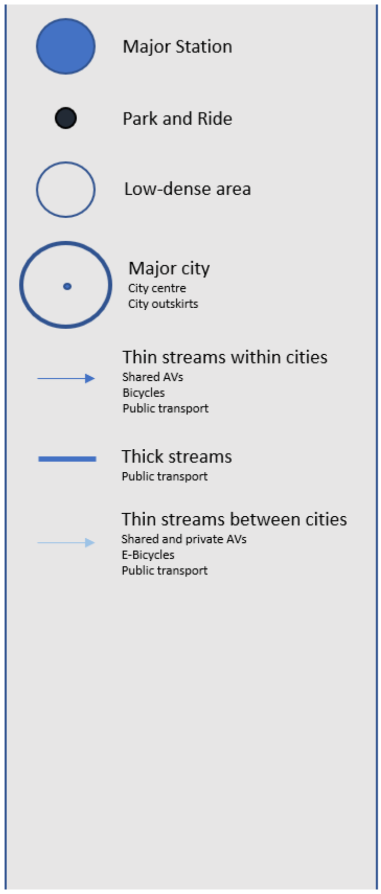


Figure 17, Shortest route to get to every major city using public transport and car. *Legend*

6.3 Reflection

According to participants in the research the greatest challenge is stimulating a change of behaviour in order to accelerate the transition to car-sharing. The need for this change in behaviour can be argued for by politicians, when they connect it to sustainability goals, like the transition to less energy and land consumption.

It is common for both researchers and political parties to focus only on the negative impact of private vehicles on air quality and climate change. When arguing for a less car-dependent society, most researchers and politicians are referring to environmental considerations. In defence many that favour cars, are stating that car infrastructure is important to the economic welfare (Schreuder, 2015). In addition, they state that with the electric vehicle transition, the sustainability problem will be solved. However, there might be a far more important reason, than protecting the environment to stimulate less car use, which also has a positive impact on the economic welfare.

The negative impact of private vehicles on land use, is not solved by the electric vehicle transition, nor by the automation transition. Even the sharing transition will not solve the problem of scarcity in land on its own.

After the housing crisis in which there where hardly build any houses, there appears now a huge demand for housing in the Netherlands, while the supply is not sufficient. The housing prices are at a historic peak. In a country where the land is scarce and housing prices are mostly based on land prices, it seems strange to dedicate such a large part of the land to the mobility system. The road infrastructure network of the Netherlands is one of most extensive networks in the world, with a total road network of 139,000 km, including 3,530 km of expressways (CIA world factbook, 2014). In contradiction the travel distances within the country, are relatively small in comparison to other countries, because the size of the country is marginal.

Therefore, both economics and environmentalists should promote the following message. Urban and transportation planners, can work towards improving sustainability in the transportation and building sector, as well as mitigating the economic welfare crisis in the housing market, by transforming the mobility system and the urban system. In order for urban planners to re-join the essential role of mobility in urban systems, a more intensive and critical interaction and integration between the different disciplines of transport and urban planning is necessary (Bertolini, 2012) and (Brömmelstroet & Bertolini, 2010).

Currently, all the planning and policy documents of the government are still focussed on the private vehicle and developing more infrastructure for this vehicle. While, multiple researchers show that not the volume of the infrastructure has to increase, but the use of the available infrastructure has to become more efficient (Levinson & Kahn, 2011) and (de Graeff et al., 2018).

One respondent described it perfectly. When the private traditional car was invented today and the engineer would proudly tell about this new vehicle. A vehicle that is 90 percent of the day not in use and has to be stored on a piece of land that could store up to 12 bicycles, because it has an average size of 45m2. When the vehicle is in use, it would most of the time only transport one person." No-one would ever say, that this was a brilliant idea. Especially not, when it needs to be fuelled by a carbon based fossil fuel, that will be depleted at the end of this era and pollutes the environment.

Today, we discovered a new technology that could change the entire mobility system. We got the change to reinvent the car. It can appear in a different shape and size, it can get a more intensive use and it can be fuelled by a sustainable source. Do we really want it, to have the same size, the same use and the same fuel?

Car-manufacturers have little incentive to be creative about the size of vehicles. They are not challenged by the market anymore. The infrastructure is already there and gives them both the advantage of the monopoly of the private car on the infrastructure, as it puts a lot of restrictions on the design of new types of vehicles. This might be one of the reasons, that the car-manufacturers that are approached during this research, were the only stakeholders that did not agree on scheduling an interview for this research.

Therefore, instead of being scared for the lock-in-effect, that defining new standards at early stages in the process of the AV transition might bring. It is wiser to understand that the society is already locked-in to the technology of the private car.

The role of urban and transportation planners is to show car-manufacturers, what type of vehicles would make the functions in the build environment more accessible and the users of these functions more mobile. This can be done by proposing new urban and infrastructure designs to car-manufacturers and not the other way around.

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8. Appendix

A. Semi-structured interview schedule

This section shows the semi-structured-interview schedule for respondents from the government, Arcadis and transportation companies and is based on the example of (Miles & Gilbert, 2005). All the interviews have a similar structure, but some questions are adjusted or left out during some interviews. While some other questions might be added, according to the researchers view on usefulness of questions to the research results and the willingness of the respondent to answer the question. All the questions are asked in Dutch, but in this report they are translated to English, in order to make it insightful for more readers.

Interview schedule for stakeholders from the government (questions are asked in Dutch)

Interview design

This document shows a possible logical order of questions. However, the question can be asked in any order and can be adjusted by the researcher per respondent.

Questions A to D are broad questions, that are asked when a theme is introduced for the first time to the respondent. The themes in this interview are current view on the impact of AVs, current strategy of the organization, perceptions on the expected impact described in literature, proposed future actions.

The numbered questions can be used to give the conversation direction within a theme. When the respondent needs help by answering the question, “prompts” can be used (these sentences are italic). In addition, some background information from the literature can be used to inform the respondent during the interview (these sentences are blue). These prompts and background information can help the respondent when he/she does not know what to say. This might happen when the respondent does not understand the question, does not know anything about the subject or forgets what we are talking about. This is important during this research, because AVs are a relatively new technology and details can be unknown to some respondents.

Introduction

I am doing a research to the spatial impact of AVs. The main research question, I would like to answer is: “How can urban and spatial planners take the AV transition into account in their long-term planning?” I will conduct a field research in the area of the province of North-Holland and discuss the issue with stakeholders that are working in this area. This interview will help me to get a better understanding of the vision of *function on the subject.

The interview will be exploratory and we will discuss the subject very broadly. The goal of this interview is to discover what is currently known about to the introduction of AVs within the *name of the organization and if this is included in the strategy of the organization. The questions that will be asked are within the themes: vision, policy, possible impact and actions.

I would like to ask, if I am allowed to record this conversation. I will use this recording only for writing a transcript and I will destroy the recording afterwards.

A. What is your view on the future impact of AVs?

This will give the perspective of the respondents on the impact of AVs, without influencing his/her opinion. 1. Impact, 2. Priority, 3. Actions.

1. **What positive or negative impacts will the introduction of AVs have on the spatial and building environment?**
   Why do you think this will happen?
   What problems can this negative impact cause?
   Can the positive impact be a solution for other issues?
   - Accessibility: The relation between mobility and functions.
   - Densities in cities and their surroundings.
   - Location of functions: living/working/recreation
   - Required land for mobility in the Netherlands:
      - Number of lost hours in the vehicle due to congestion.
      - Amount of vehicle kilometres travelled (VKT).
      - Amount of parking facilities that is needed.
- *Use of the bicycle, public transport and walking*
- *Use of public space.*
2. **Should the development of AVs be stimulated, stopped or is doing nothing sufficient?**
- *Why do you think this?*
- *Who should act?*
3. **Which adjustments in spatial planning and transportation planning are necessary in order to create a smooth introduction of AVs in the Dutch society?**
- *When should action be taken?*
  Like: adjusting policies, visions or taking concrete actions.

Background information from the literature study on which these questions are based.

Uncertainty in time:

Market introduction of AVs is between 2020 and 2045.

Households take AVs in use between: 2025-2030 (1-10% of the households), 2030-2050 (7-61% of the households), 2050 and beyond (60-100% of the households)

Uncertainty in the impact of AVs:

Positive impact:

- *More efficient land-use of vehicles (increase in road capacity)*
- *More efficient use of vehicles (decrease in ownership)*

Negative impact:

- *Increase in the mobility-demand to private AVs and the related congestion assuming the same road capacity.*
- *Decrease in the mobility-demand to public transport, bicycles and walking.*
- *Increased demand to car-infrastructure and a decrease in demand to infrastructure for public transport, bicycling and walking.*
- *Urban sprawl or very high densities in major cities.*

B. To what extent are AVs included in policies and/or strategies of your organization?

Shows the current strategy/policy on AVs of the organization of the respondent.

1. **How is the introduction of AVs represented in the policies and strategies of the organization?**
- *Are there any policy documents, plans and/or visions, that are connected to the introduction of automated vehicles?*
- *Is the organization taking automated vehicles into account in another way? In what way?*
- *Is the organization intending to stimulate, obstruct or steer the automated vehicle development or letting market parties decide what will happen?*
- *On what aspects of the automated vehicle transition would the organization like to act?*
- *Is there already a concrete plan in order to do that?*
2. **What is the relation between the goals of the organisation (more specific the department you are working for) and the introduction of AVs?**
- *Do you expect that these goals can be reached or are obstructed by the introduction of automated vehicles?*
- *How will this happen?*
3. **Are there any adjustments necessary in the current policy documents and plans in order to take AVs into consideration?**
- *What adjustments?*
- *In which documents, plans and visions?*
    - *Transportation/mobility system planning*
    - *Urban/spatial planning*
    - *"MIRT" (the national long-term planning document for infrastructure, land-use and transportation)*
    - *"Structuurvisie" (Comprehensive planning: the national/regional urban planning document)*
    - *"Bestemmingsplan" (land-use planning: zoning regulates the types of activities that can be accommodated on a piece of land)*
    - *"Omgevingsvisie"* (spatial planning instrument that describes the general vision on the mobility and urban system of the Netherlands)
    - *Budgets and estimations*
    - *Research*

Reasoning behind these questions based on the knowledge from the literature study.

According to the literature study (chapter 3), there is not much written, about the impact of the AV transition and how the organization will react on it, in the planning and policy documents of the organization.

C. According to literature certain problems may arise. I will name a few and you can give your thoughts on them.

Wake-up call for organisation. Displays the problems that are being missed by the organization until now and the choices the organisation will make.

The following problems come from different scenarios. What are your thoughts on them?

The following effects arise in all scenarios.

1. ***More efficient road use:*** *narrower roads → space for other purposes*
- *What are your thoughts on this situation?*
- *How should the organization deal with the road design?*
- *How could the newly available space be used?*
2. ***More efficient parking:*** *autonomous parking with less needed space to do so*
- *What are your thoughts on this situation?*
- *What will happen with the current parking policy?*
- *What should happen when it becomes clear less parking space is needed in certain areas of cities?*
- *How will this space be used?*

The following effects arise mostly in automation level 5.

3. ***Growth of car use and ownership (especially in the non-sharing scenario)***
   Easy, comfortable and cheap. Driving will no more be seen as 'lost time'.
   Elderly, children and disabled will now be able to use and own a car.
   Empty vehicle travel to pick people up.
   Roads could get flooded with cars and this will lead to congestion.
- *What are your thoughts on this situation?*
- *How should this be handled? Examples: road pricing, stimulate car sharing, etc.?*
- *Could this be steered by spatial planning?*
4. ***Car sharing (in the sharing scenario)****:*
   Car-sharing is a solution to congestion, caused by the increase in car use and ownership.
   Problems that car-sharing brings:
   - *High parking rate in cities, lead to empty cars driving continuously around.*
   - *Obstructions by people hopping on and off vehicles, lead to congestion.*
   - *Finally, car use could increase because of shared (and therefore) lower costs.*
- *What are your thoughts on this situation?*
- *How should this be handled?*
- *Could this be steered by spatial planning?*
   - *Space for pick-up and drop-off points or lanes?*
5. ***Less use of public transport, bicycle, walking (especially in the non-sharing scenario)***
   Because of low costs and high comfort of shared self-driving cars
- *What are your thoughts on this situation?*
- *Should additional investments be made in infrastructure for public transport?*
- *In which transportation modes should and shouldn't be invested?*
- *Should the government stimulate cycling and walking? How?*
- *Should Mobility as a Service be stimulated? How?*
- *How would this look spatially?*
6. ***Urban sprawl (non-sharing) or higher density in cities (sharing):***
   ➔ *Urban sprawl*
   Reduction of value of time in AV, leads to increase in accepted travel distances.

This might drastically change spatial planning.
The compact city where everything is at walking distance, is no longer the ideal.

➔ *Higher density in cities*

Due to the decrease in public transport in low dense areas, because government expects that the sharing trend will take off, people decide to move to larger cities, because it is *easier to make use of the sharing system.*

- *What are your thoughts on this situation?*
- *Does this suit the goals of the department?*
- *Could this be governed by spatial planning?*

Finally, I have made a table with an overview of the spatial impact of every scenario. What are your thoughts on this? Does this look right by you? See table 4 on page 44.

D. Welke beslissingen en acties moeten nu worden genomen over de komst van zelfrijdende auto's?

Weergeeft het toekomstige actieplan van de respondent

1. **Do you think there is a suitable organization structure in order to take AVs into consideration in policies, visions and planning?**
- *Is there a department that focusses on AVs?*
- *Does the topic of AVs often come up in conversation and meetings?*
- *Is there a good cooperation between spatial and transportation planners?*
- *Could this be improved? And how?*

2. **How are decisions about the introduction of AVs taken?**
- *What did you think about the results of research to the impact of AVs?*
- *Are these impacts and proposes taken into consideration in planning practice?*
- *Do you think that proposes of actions to the negative impact of AVs in research is paying sufficient attention to the goals of the organization?*
- *Are there other sources that the organization uses to make decision about AVs?*

3. **What are the next steps in the transition towards AVs?**
- *What are the most important steps that should be taken at this moment?*
- *Are these actions feasible? Is there budget for:*
  - *Research*
  - *Spatial adjustments*
- *What parties do you consider as allies and with what parties do you want to corporate, in order to take AVs in use on the public road in the near future?*
- *What parties do you consider as enemies and have contrary goals?*

Table XX, Example of cooperation between the government and other stakeholders

	Organisation (Municipality/province)
	Local planning authorities (LPA)
Organisation (Municipality/province)	Partnership (Learn from each other, Invest in research together)
Local planning authorities (LPA)	
Transportation providers	Partnership (Distribution, Investing)
(Public transport/Uber/Lift/Taxi's)	Regulating (Norms, Standards, Laws, Rules)
	Monitoring (Preferred Standardization)
Transportation planners	Partnership (Invest in research together, Give advice to each other, Use mobility instruments and models)
Smart Mobility Researchers	Investing (Research, Trials)
Future users	Influencing (Promoting)
AV technology companies	Incentives (Subsidies, Taxes)
	Monitoring (Preferred Standardization)

Regulating (Norms, Standards, Laws, Rules)

Investing (Preferred technology)

Partnership (production, distribution)

Debriefing

1. **Topics that are not covered by the interview, according to the interviewee.**
   According to me schedule, we covered everything that I wanted to know, but are there more important topics that we did not discuss yet?
2. **Summary of the highlights of the interview.**
   Now, I'll give a short summery of the interview. You may correct me, if I have interpreted something wrong.
3. **Give the respondent the opportunity to ask remaining questions.**
   Are there any questions left, about the interview and the research? You can always call me or send me an email, when something comes to mind later.
4. **Transcript.**
   I will send you a transcription of the interview within 1 week. I would like to receive your accord to the content, within 2 weeks, if that is ok with you? When I will not receive any response, I assume that you agree on the content of the transcription. The transcript will be used as a source for the thesis. Do you want me to anonymize you or can I call your name? Do you want a summary of the results of the research?
5. **Contact information.**
   Do you have my contact information? When you have further questions you can always call me or send me an email. When something comes to mind, that might be important to the research, I would like to hear it.

Transcripts (around 300 pages together)

Transcripts are left out of this research document in order to protect the privacy of organizations and their employees. Transcripts can only be viewed with the explicit permission of the researcher and the respondents.

B. Interview Results

Vision

Detailed explanation of all the codes in the table.

- V1. General Impact: This shows the general impact of AVs. It is not clear if this is positive or negative.
    - V1.1. Preventing the introduction of AVs is impossible.
    - V1.2. The assumed speed of the AV transition.
- V2. Strengths: This shows the weakness of the concept AVs. This are the characteristics of AVs that place the mobility concept in disadvantage relative to other mobility concepts. These are the negative impacts of the introduction of AVs.
    - V2.1. The traffic safety increases.
    - V2.2. The decrease in car-ownership, might lead to a decrease in parking norms.
    - V2.3. Social inclusion increases, due to the improved accessibility for specific target groups (elderly, children, disabled), that become able to drive a vehicle.
    - V2.4. Costs of public transport and taxis might decrease, when a driver wo not be necessary anymore.
    - V2.5. The road capacity might increase, when vehicles make better use of the available space by shorter following distances and higher speeds.
    - V2.6. The value of time of AV transfers might decrease, when driving tasks are automated and drivers become passengers.
- V3. Weaknesses: This shows the strength of the concept AVs. This are the characteristics of the mobility concept that give it an advantage over other mobility concepts. These are the positive impacts of the introduction of AVs.
    - V3.1. Car ownership and use might increase, due to the reduction in the value of time and the broadening of the target group.
    - V3.2. Decrease in public transport use, due to the increased use of the private car.
    - V3.3. Decrease in bicycle use, due to the increased use of the private car.
    - V3.4. Land-use of the mobility system might increase, due to the increased use of the private car.
    - V3.5. Social exclusion, due to the payment system. Some users are not able to use certain types of AVs, because of high costs.
- V4. Threats: This shows elements in the environment that could cause trouble for the introduction of AVs. This are not necessarily negative impacts, but these aspects bring a challenge to the introduction of AVs.
    - V4.1. Complex traffic situations and high speeds are difficult for AVs. Therefore, are automation level 2/3/4 only safe in moderated environments during the transition phase.
    - V4.2. AVs bring the living quality in danger, due to scares space in city centres.
    - V4.3. Due the expected increase in the target group for cars, a decrease in car-ownership is preferred. However, the sharing transition (from ownership to use) is not there yet.
    - V4.4. During/after the transition phase, there might be two mobility systems that exist next to each other; the current system and the AV system.

    - The current infrastructure is not accessible for current AV concepts and possible future AV concepts.
    - V4.6. There exist misperceptions about the positive impacts of AVs, because AVs are confused with EVs (improved air quality and reduction of noise) and the automation transition is connected to the sharing transition (decreased ownership).
- V5. Opportunities: This shows elements in the environment the introduction of AVs could exploit to its advantage. This are not necessarily positive impacts, but these aspects bring an opportunity to the introduction of AVs.
    - V5.1. A new integral mobility system will develop, in which AVs are integrated and use the same infrastructure.
    - V5.2. The use of MaaS concepts is accelerated, because it becomes easier and cheaper to buy a journey instead of paying for a modality.
    - V5.3. A new more efficient (faster/cheaper/better connected) public transport system.
    - V5.4. Transition towards sharing is accelerated. AVs can drive from door-to-door to pick-up and drop-off passengers, which is more comfortable and easier to users.
    - V5.5. City-centres can become car-free, because AVs can park themselves outside city centres and after users are dropped off at the destination or are stepped on to city transport.
    - V5.6. Use of different types of AVs per context. This can be a difference in automation level or in vehicle size/type. It becomes easier to move from vehicle to vehicle.

Table 5b: Summary of the vision and perceptions of the stakeholders on the impact of AVs based on results of the interviews.

Groups		Government										Consultancy				Transportation companies					
Organization		RWS	IPO	Province of North Holland						Amsterdam		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	TP/UP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Vision	V																				
General impact	1																				
Preventing the introduction AV is impossible.	1.1		Y	Y				Y		Y	Y										Y
The AV transition speed in literature is right	1.2				Y	Y	N+	N+	Y	?	Y			N-		N-	Y				
Strengths (Positive impact)	2																				
The traffic safety might increase.	2.1	x	x		x	x				x		x						x			
Parking norms in cities might decrease: - car-free city centers. - parking outside city centers.	2.2	x x x	x x		x x		x	x x	x x	x	x x	x x x	x x	x x		x					x
Social inclusion might increase, due to accessibility.	2.3	x		x	x						x										
Costs PT and taxi might decrease.	2.4			x	x				x							x	x				
Road capacity might increase, due to efficiency.	2.5	x	x					x								x		x			
Value of time in vehicles might increase.	2.6										x	x			x		x				
Weaknesses (Negative impact)	3																				
Car ownership/use might increase.	3.1	Y	Y	Y	Y		Y	Y			Y	x		Y	Y	Y					**?**
PT use might decrease.	3.2	x			x						x		x			x					
Bicycle use might decrease.	3.3				x		x							x	x						
Land-use of mobility system might increase.	3.4				x						x	x	x			x					
Social exclusion might increase, by payment system.	3.5			x	x			?							x	x					
Threats	4																				
Complex traffic situations and high speeds.	4.1	x	x	x		x	x			x				x		x	x				**x**
Living quality might be in danger.	4.2		x	x								x									
Car-sharing is not popular yet.	4.3	x	x	x	x				x		x			x	x	x					
Two mobility systems next to each other.	4.4	x	x	x				x	x						x						
Misperceptions about AVs	4.5																				

AV leads automatically to sharing AV is EV, thus air-quality improves & noise decreases		N				Y	Y	Y		Y						N	N			N	
Opportunities	5																				
New integral mobility system.	5.1		x						x	x											
The use of MaaS mobility concepts.	5.2	x	x	x						x	x										
A more efficient public transport system.	5.3	x	x	x	x				x						x		x				
Transition towards sharing might accelerate.	5.4	x	x	x	x		x	x	x		x			x	x	x	x			x	x
Use of different types AV per context.	5.5													x			x				
Propositions from the survey	6																				
The total impact of AVs on road capacity is positive. Balans or dependent on more factors = ?	6.1			?	N			N	?	?	N	Y N		?	N	N	Y			Y	Y
Sharing is more important than AV transition. ? = they have the same priority	6.2			?	?			?	?	Y	Y	? Y		Y	?	?	?		?	Y	?

Strategy

S.1. **Documents**: Policies and strategies

- S.1.1. "Omgevingsvisie" – Dutch spatial planning instrument, describes the general vision on the mobility and urban system of the Netherlands.
- S.1.2. "Relatie Toekomstbeeld OV (2020-2040) – Dutch spatial planning instrument, describes the vision on the public transport mobility system.
- S.1.3. "Koers Smart Mobility" – Regional transportation planning instrument, describes the vision on smart mobility technologies on the public road.

S.2. **Research** that are currently carried out during the exploratory phase of the introduction of AVs on the public road.

- S.2.1. Pilot projects in real-life-settings (examples are: self-driving public transport buses, self-driving four-passenger cars, park shuttles, etc.)
- S.2.2. Research to methods in order to make infrastructure digitally available.
- S.2.3. Scenario planning – impact studies on AVs.

S.3. **Goals** of stakeholders: There is a need to make a decision on what goals can be achieved or obstructed by the introduction of AVs on public roads.

- S.3.1. Provide accessibility (both economic (good access for economic activities) and basic (good access to basic functions for al citizen) and mobility
    - S.3.1.1. Integral mobility policy: make a better connection between the environment and the use of mobility (related to mobility).
    - S.3.1.2. Short / acceptable travel time (related to accessibility).
    - S.3.1.3. More efficient traffic-flows / use of infrastructure (related to accessibility).
    - S.3.1.4. Free choice in mobility options (related to mobility), in order to fulfil in the wishes and needs of all citizen in a democracy.
    - S.3.1.5. Provide productive mobility options (related to mobility), in order to reduce the value of time of transfers.
- S.3.2. Safety
- S.3.3. Liveability / quality of life / attractiveness of the living environment
    - S.3.3.1 Stimulate less car use / ownership, this is a sub-goal of increasing liveability, sustainability and health.
- S.3.4. Sustainability
    - S.3.4.1 Stimulate less car use / ownership, this is a sub-goal of increasing liveability, sustainability and health.
- S.3.5. Improve health of the citizen, by improving the air-quality and provide mobility options, which require exercise.
    - S.3.5.1 Stimulate less car use / ownership, this is a sub-goal of increasing liveability, sustainability and health.
- S.3.6. Increase the competition position and use the profitability of the use of the AV technology.
    - S.3.6.1. The Netherlands want to be frontrunner in AV technologies, in order to attract businesses to the Netherlands.
    - S.3.6.2. Our organization wants to be frontrunner in AV technology knowledge, in order to attract more clients.

S.4. **Policy Window**: There is a tendency to…., which might lead to an opportunity to get a certain policy related to AVs on the political agenda.

- S.4.1. There is a realization in high dense areas, that there is scares space in the Netherlands, which can be used for other functions than mobility.
- S.4.2. Many organizations wait for more information about AVs from car manufacturers and the RDW, in order to take decisions related to AVs.
- S.4.3. Some governmental organizations are moving from a vehicle ownership-based policy to a vehicle use based policy.

S.5. **Strategy**: How should the government give direction to the development?

S.5.1. Stimulate the AV transition, examples:
  S.5.1.1. Invest in AV technologies and infrastructure.
  S.5.1.2. Give opportunities to pilot projects, by providing test areas and/or investments in the pilots.
S.5.2. Facilitate the AV transition, examples:
  S.5.2.1. Remove barriers in regulation, that obstruct research to…/ pilots of…/ investments in…/ use of…. AVs, etc.
  S.5.2.2. Facilitate cooperation between public/private parties and develop a lobby.
  S.5.2.3. Make (public) transportation concessions more flexible, in order to give more parties a change in the market.
  S.5.2.4. Make policies and documents more flexible, in order to transform with the development during the transition time.
S.5.3. Regulate the AV transition (not too much), examples:
  S.5.3.1. Make regulation for the use and type of AVs that are allowed on the public road.
  S.5.3.2. Regulate the number of different mobility services in the city, in order to for come proliferation. Shared Vehicles (S) and Bike (B).
  S.5.3.3. Standardize policies / strategies / regulation in the European level and/or on national level.
S.5.4. Prohibit the access of AVs on public roads.
S.5.5. Research the impact of AVs, examples:
  S.5.5.1. Do research and share the data/knowledge with market parties, but also with citizen to create awareness.
  S.5.5.2. Get information from market-parties about the development of AV technologies and the use of AVs in organizations.

S.6. **Pitfalls**: points of consideration

S.6.1. The private car is central in most strategies of public/private organizations, danger of favouring certain policies/regulation.
S.6.2. The time horizon of visions and plans is long, which makes it difficult/dangerous to give a detailed vision and makes them shallow.
S.6.3. The maintenance of roads, can already take the introduction of AVs into consideration without a lot of investment.
S.6.4. Investments in large infrastructure projects are of high risk, due to the high level of uncertainty.
S.6.5. The government does mostly only take AVs that drive on motorways into account, they forget water-/ rail-/ cycling-roads.
S.6.6. There will be new and other competitors for several transportation companies, due to the transition in the mobility market.
S.6.7. The AV business model, might not be feasible yet. Especially for PT companies it is hard to invest in this technology.

Table 6b, Current strategy of stakeholders (Documents, Research, Policy windows, Strategy, Pitfalls), based the interview results.

Groups		Government										Consultancy				Transport companies					
Organization	S	RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Documents: Policies and strategies	1																				
Omgevingsvisie	1.1			x		x		x	x												
Relatie Toekomstbeeld OV (2020-2040)	1.2		x														x		x		
Koers Smart Mobility	1.3			x	x	x															
Research: exploratory phase	2	x		x	x				x	x	x			x	x		x	x	x		
Real life pilots.	2.1	x		x	x				x	x					x	x	x				
Making infrastructure digitally available.	2.2			x	x	x									x						
Scenarios.	2.3									x					x		x				
Policy window: Tendency to	4																				
Awakening of scars space in the Netherlands.	4.1		x	x	x			x	x	x						x	x				
Wait for manufacturers/RDW to share information.	4.2		x		x											x	x				
Give priority to vehicle use instead of ownership.	4.3		x	x	x																x
Pitfalls: points for consideration	6																				
Private car is central in most strategies.	6.1			x																	
Time horizon of visions and plans	6.2		x				x	x		x							x	x			
Maintenance of roads	6.3		x			x	x			x				x							
Investments in large infrastructure projects	6.4		x				x				x										
Government only considers motorway AVs.	6.5																	x			
New/other competitors.	6.6																			x	
Is the AV business model feasible?	6.7		?		Y	Y					Y					N	N				N

Table 6c: Goals of stakeholders more detailed

Groups		Government										Consultancy				Transport companies					
Organization	S	RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Goals: decide what is most important	3		x		x												x				
Accessibility (economic and basis) & mobility	3.1	x	x	x	x	x		x	x	x	x	x				x	x		x		
- Develop integral mobility policy.	3.1.1		x								x										
- Provide a short/acceptable travel time.	3.1.2	x									x						x		x		
- More efficient traffic-flows / use of infrastructure.	3.1.3	x				x		x	x			x					x		x		
- Free choice of mobility options.	3.1.4	x		x	x				x								x				
- Provide productive mobility options.	3.1.5																x				
Safety	3.2	x	x			x	x	x		x									x		
Livability / quality of life / Attractiveness	3.3		x							x					x	x					x
Sustainability	3.4		x						x						x		x				
Health (Air-quality and **exercise**)	3.5						x			x					x						
Competition position	3.6							x		x				x	x		x		x	x	
- The Netherlands wants to be frontrunner in AV.	3.6.1							x		x							x		x	x	
- Our organization wants to be frontrunner in AV.	3.6.2													x	x					x	

Impact and Actions

I.1. Decrease of required land for mobility.

I.1.1. **Impact** on Parking infrastructure

I.1.1.1. Cause – Effect: How does AV influence this?

1. AVs might lead to an increase in car-sharing. This might lead to lower ownership rates and thus less parking demand.
2. AVs might be able to park themselves. This might lead to:
   - Clustered parking, which leads to:
     - Less parked cars in city centres and thus an improved living quality.
     - Emptier Vehicle Travel (EVT), because vehicles move from destination to parking and back.
     - The usefulness of this systems depends on the waiting time for the vehicle.
   - More efficient ways of parking, which leads to a decrease in the required space for parking.

I.1.2. **Impact** on Road infrastructure

I.1.2.1 Cause - Effect: How does AV influence this?

1. A steady speed and a shorter following distance between vehicles, might lead to an increase in road capacity.
2. Less unforeseen moments, might lead to less congestion.
3. AVs might lead to an increase in ride-sharing. This might lead to a decrease in vehicle kilometres travelled.

A.1.3. **Action:** How to use this capacity/space?

1. Due to climate change, greener and water storage is needed.
2. Due to urbanization, more concentration is needed.

Table 7a: The expected impact of AVs on the decrease of required land for mobility and related proposed actions, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Impact (I) and related Action (A) categorized.	I																				
Everything depends on the location and context.			x		x					x	x						x				
Decrease of required land for mobility	1.																				
Parking infrastructure	1.1		Y		Y	Y			Y	?	?			?		Y				?	Y
Cause - Effect: How does AV influence this?																					x
1. Lower ownership rates - less parking demand.	1.1.1				x	x		x	x	?		x				x					x
2. Cars park themselves:	1.1.2		x		x	x		x	x		x	x		x		x				x	
- Clustering parking.			x			x		x	x			x		x		x				x	
– Increase living quality.			x			x						x									
- Increase EVT.			x						x												
- Depends on waiting time for vehicle.								x	x			x									
- Efficient parking – less required parking space.						x		x			x			x							
Road infrastructure	1.2					N		Y						Y				Y		Y	Y
Cause - Effect: How does AV influence this?																					
1. Speed/shorter distance – increase capacity.	1.2.1					N		Y						Y				Y		Y	Y
2. Less unforeseen moments - less congestion.	1.2.2							x										x		x	
3. Type and size of vehicle – road profile.	1.2.3		x		x			x		x						x					
Action: How to use this extra space?	1.3																				
Green and water.	1.3.1		x	x				x	x			x									
Concentration.	1.3.2		x	x				x	x												

I.2. Increase of required land for mobility (increased required road capacity and decreased sustainability)

I.2.1. **Impact:** the increase vehicle ownership (# Number of vehicles per person).

I.2.1.2. Cause – Effect:

1. Broadening the target group, might lead to a situation in which people that use public transport or share a vehicle switch to using private vehicles. This is caused by:

- Elderly, children and disabled, that can use a private AV.
- A decrease in AV prices over time, so that more people can buy an AV.

2. Reduction in the value of time, might lead to a situation:

- In which people that use public transport switch to using private vehicles.
- In which people are willing to travel longer distances.

I.2.2. **Impact**: the increase in car use (# Number of vehicle kilometres travelled per person).

I.2.2.1. Cause - Effect:

1. Accommodating easy and comfortable use of shared vehicles from door to door, might lead to:
    - A situation in which people that walk, cycle or take public transport switch to using shared cars.
    - More VKT to pick-up and drop-off every person, this is called Empty Vehicle Travel (EVT).
    - Unnecessary car mobility, because the negative incentive of high prices is removed.
    - Decrease in the price of using a shared vehicle, because there are no driver and more people share the costs.
2. Reduction in the value of time of AV transfers, might lead to:
    - a situation in which people that use public transport switch to using shared cars.
    - a situation in which people are willing to travel longer distances.

I.2.3. **Impact** on the Multiple mobility systems during the transition.

I.2.3.1. Cause – Effect

1. AVs need their own lane, because of difficulties with complex traffic situations, this lane requires a lot of land.

A.2.4. **Actions** in order to prevent the increase of required land for mobility:

A.2.4.1. There is a latent question to mobility.

1. The increase of road infrastructure has a positive and long-term effect on the road capacity.
2. Do not increase the road infrastructure, because new congestion will lead to a new balance in road capacity.

A.2.4.2. Discourage vehicle ownership and the low number of users per vehicle by:

1. Adjusting parking policies (example: increase prices for public parking or decrease parking norms in zoning plans).
2. Increase ownership charges (example: increase taxes for parking permits for a second car or vehicle excise duty).
3. Adjust the size of a vehicle to the usual number of users. Make the vehicle excise duty also dependent on size.

A.2.4.3. Discourage the amount of vehicle use, by road pricing:

1. Discourage travelling during rush hours, by and rush-hour-charge.

2. Increase charges on carbon-intensive-vehicles and vehicle noise, while subsidizing low-carbon-vehicles.
3. Assign toll roads on national or regional level (difference in costs for dense and low dense areas).
4. Currently, the vehicle excise duty is dependent on the weight of the vehicle.
5. Road pricing is a forbidden word in the political debate.

A.2.4.4. Give priority to some logistic streams in cities:

1. Design the mobility system in a way, that there is a differentiation in certain types of logistic streams per transport node.
2. Repulse certain types of mobility concepts (examples: conventional car, carbon-intensive vehicles, buses, etc.)

Table 7b: The expected impact of AVs on the increase of required land for mobility, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Increase of required land for mobility	2.			?	Y		Y	?		?	Y	N	Y	?	Y	Y	N	Y		N	N
Increase in vehicle ownership	2.1				Y	Y	Y		?	Y			Y	?	Y	Y	Y			Y	?
Cause – Effect:																					
1. Broader target group - switch to private AV	2.1.1				x	x	x							x						x	
- price decreases.						x								x						x	?
- disabled, children, elderly.					x		x		?												
2. Increased value of time, might lead to:	2.1.2	?			x				x		x			x	x		x				
- switch to private AV.					x				x						x						
- increased willingness longer travel distances.															x						
Increase in car use	2.2	?	?	Y	Y	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	?
Cause – Effect:																					
1. Door-to-door sharing, might lead to:	2.2.1		x		x	x			x	x	x			x	x	x				x	
- switch from PT/cycle/walk to shared cars.					x	x			x	x	x			x	x	x					
- more VKT by EVT.			x			x									x	x					
- unnecessary car mobility.											x			x		x					
- decrease in price, due to sharing and no driver						x								x		x				x	
2. Increase in the value of time, might lead to:	2.2.2	?	x	?	x						x				x		x				
- switch from PT to using shared cars.					x																
- increased willingness longer travel distances.		N	Y	?		N									Y						Y
Multiple mobility systems during transition	2.3																				
Cause – Effect:																					
1. AV needs own lane – requires a lot of land.	2.3.1			x	x	x	x													x	

Table 7c: The proposed actions to prevent the increase of required land for mobility, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Actions: discourage vehicle use and ownership	2.4																				
Latent question to mobility.	2.4.1			x	x			x			x					x					
1. Increase the road infrastructure.				N	N	?	N		N		Y			N		N					
2. Do nothing, due to congestion new balance.			Y	Y		Y		Y	Y					Y							
Decrease vehicle ownership, by:	2.4.2	x		x	x	x		x	x	x						x	x				x
1. Parking policies (pricing and norms).		x		x	x	x		x	x	x						x	x				x
2. Increase ownership charges.									x												x
3. Decrease size of owned vehicle.					x			x								x					
Decrease vehicle use, by road pricing:	2.4.3	x		x	?	x	x	x	x	x	x			x	x	x					x
1. Discourage travelling during rush hours.		x				x	x		x					x							
2. Carbon/sound charges					x	x	x		x						x						
3. Toll roads on national level or **regional level.**					x				**x**												x
4. Currently on weight of vehicles.								x													
5. Road pricing is a forbidden word.		x		x			x		x	x											
Give priority to some logistic streams in cities.	2.4.5			x	x	x		x	x	x				x	x	x	x			x	
1. Differentiation in nodes and logistic streams.								x	x												
2. Repulse certain types of mobility concepts.				x	x	x			x	x				x	x	x	x			x	

A.2.4.5. Speed up the transition towards the introduction of AVs on the public road, by adjusting the infrastructure:

1. Adjust road alignment/markering (example: use other types of painting or place sensors).
2. Introduce flexible road profile design, that gives access to multiple modalities.
3. Adjust bus and tram lanes in a way that they become accessible for AVs in the future.
4. Redesign crossings and junctions in a way that there are fewer crossing streams of different modalities.
5. Design infrastructure in a way that there is a better separation between pedestrian/bicycle/car paths, in order to increase safety.
6. Develop separated lanes that are specified to AVs, in order to increase safety. Considerations are:
    - The high costs of the investment in this infrastructure and the land that is needed for this infrastructure.
    - There might be a feasible business case for some private parties that are interested to invest in infrastructure for AVs.
7. Research to the relation between the level of complexity of roads and the automation level of AVs (Operational Design Domain).
8. Some moderated environments can figure as test-area for different levels of AVs.

Table 8: Actions that can speed-up the transition towards the introduction of AVs on the public road, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Speed up transition by adjusting infrastructure.	2.4.6	?	?	?	Y	?					Y			?			?			?	
1. Road alignment/markering.			x		x	x								x							
2. Flexible road profiles for multiple modalities.			x								x	x									
3. Make bus and tram lanes accessible for AVs.					x						x						x				
4. Redesign crossings, less crossing streams.						x											x				
5. Separation of pedestrian, bicycle and car path.				x		x	x										x				
6. Specified and separated lanes:		x		x	x	x	x										x			x	
- Cost a lot of money & space.		x			x	x															
- Is there a business model for private parties?					x			x													
9. Research to infrastructure necessities for AVs.		x															x				
- Research to road complexity (ODD).		x																			
- Pilots in moderated environments.																	x				

I.3. How do AVs influence the mobility choice of citizen?:

I.3.1. **Car-sharing use**, might increase due to the introduction of AVs.

I.3.1.1. **Impact** depends on the:

- Waiting time for vehicle (# distance (km) between user and vehicle divided by speed (km/h) of vehicle).
- Supply of shared-vehicles in the area (# number of vehicles in the area).
- Emotional attachment to vehicle-ownership (status and freedom).
- Price of the ride (# price (€) per distance (km)), will be lower because there is no driver needed and more persons can share.

A.3.1.2. **Actions** that can stimulate the increase of car-sharing:

1. Reserve space for a sharing system buffer, in order to fulfil in/increase the demand to shared-vehicles in the area.

For example parking possibilities for only shared-vehicles.

- However, do consider a maximum number of different shared-vehicles services in an area, to for come over supply.

2. Create sufficient drop-off and pick-up points in order to reduce congestion of stopping vehicles on the public road.

Table 9a: Influencing the mobility-demand to shared cars, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Influence on mobility choice	3																				
Car-sharing increase	3.1																				
Depends on:	3.1.1																				
1. Waiting time for vehicle.					x			x				x					x				
2. Supply of shared-vehicles in the area.					x			x									x				
3. Emotional attachment to vehicle-ownership.		x	x		x				x												
4. Price of the ride.				x	x	x								x		x					
5. User-friendliness: comfort and easy use.				x	x			x													
Actions, to stimulate car-sharing:	3.1.2				x	x		x			x			x		x	x			x	x
1. Reserve space for a sharing system buffer.					x	x		x			x						x			x	x
- Reduce the number of different SV services.																x	x				
2. Create drop-off and pick-up points.					x									x							x
Increase number of users per vehicle, by:	2.4.2	x		x	x	x		x	x	x						x	x				x
1. Parking policies (pricing and norms).		x		x	x	x		x	x	x						x	x				x
2. Increase ownership charges.									x												x
3. Decrease size of vehicle.					x			x								x					

I.3.2. **Public transport use**, might decrease due to the introduction of AVs.

I.3.1.2. **Impact** depends on the:

1. Competition between the type of public transport and type of AV, which depends on the average travel distance of the AV.
- Trains (intercity or sprinters), will remain the same number of users.
- Metros, will remain the same number of users.
- Trams, will remain the same number of users.
- Busses, will remain the same number of users.

2. The location of the public transport facility.
- The use of the Randstad-network will not be influenced by the introduction of AVs and remains important.
- The use of PT in low-dense areas will decrease, because it can be replaced by the more cost-efficient demand-driven-PT.

3. The automation level of PT modalities.
- The level of automation depends of the acceptation of public vehicles without a driver (safety and user-friendly considerations).
- The feasibility of the business model (currently the speed and number of users of AVs is too low in relation to the costs).

A.3.2.2. Actions that can stimulate the increase of PT use:

1. Increase the number and supply of PT mobility options.
2. Make MaaS concepts more attractive (examples.)
3. Make mobility options easier to compare, by showing the differences in costs & travel time, in order to make a deliberated choice
4. Invest more in PT infrastructure, in order to accelerate a reversed trend: a switch from private vehicle use to PT use.

Table 9b: Influencing the mobility-demand to public transport, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Public Transport use decreases	3.2					Y		Y										N	N		N
Depends on:	3.2.1																				
1.Type of public transport, travel distance of AVs. -Train (**intercity** or sprinter) - tram. - metro. - bus.		x		x **x**	x x		x x N		x ? N	x				x **x** ? N		x x		x x	x x		
2. Location of public transport. - Randstad-network will not be influenced. - Use in low dense areas decreases, due to costs		x x							x x x	x x	x x			x							
3. Automation of PT - acceptation of vehicle without driver - cost model not feasible yet				x x			x x		x x	x x x							x x x	x		x x	
4. Should we still invest in public transport? Consider costs & bates for now & future.		Y	Y								Y			Y			?	Y			
Actions, to stimulate PT use:	3.2.2	x	x			x	x	x	x		x			x		x	x			x	x
1. Increase supply of PT options.			x			x											x				x
2. Maas-concepts, make it more attractive.		x									x										x
3. Make mobility options easier to compare.			x			x		x								x				x	x
4. Invest more in Public transport infrastructure.						?					Y			Y							
5. Develop parking at PT stations.							x	x	x		x										
6. Don't stop at every station, stop on demand.														x			x				

I.3.3. **Bicycle use**, might decrease due to the introduction of AVs.

I.3.3.1. **Impact** depends on the:

1. Parking accessibility and safety of bicycles in residential areas and at public facilities and stations.
2. The schedules and appointments of bicycle users (mainly: scholars).
3. The development of E-bikes and automated-bikes.
4. The travel distance, bikes are used for travel distances of 5-10 km and E-bikes for travel distances of 5-15 km.
5. The societal considerations of the importance of health and exercise during travels.

A.3.3.2. **Actions** that can stimulate the increase of bicycle use:

1. Stimulate the development and use of E-bikes, in order to create competition on more travel distances.
2. Adjust traffic lights by adding sensors, in order to give priority to bicycles, in order to create competition in travel time.
3. Develop bicycle tunnels, in order to create competition in travel time.
4. Develop bicycle highways/fast-lanes, in order to create competition in travel time and increase safety.
5. Develop wider bicycle paths/lanes, in order to decrease congestion and increase safety.
6. Develop parking at transportation-hubs and bicycle renting locations, to stimulate the switch from car to bicycle.
7. Develop good connections between destinations and bicycle paths, like: same floor level, safe bicycle parking places, etc.

Table 9c: influencing the mobility-demand to bicycles, based on interview and questionnaire results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Decrease in bicycle use	3.3																				
Depends on:	3.3.1																				
1. Parking accessibility				x																	
2. Schedules and appointments of scholars.							x														
3. Development of E-bikes & Automated-bikes.							x														
4. Distance, bike 5-10 km & E-bike 15 km.							x				x										
5. The consideration of health/exercise.		x					x														
Actions, to stimulate bicycle use:	3.3.2		x			x	x				x					x	x				
Should bicycle use be stimulated? – workshop			Y	Y	Y	Y	Y	Y	Y	Y	Y					Y	Y				
1. (E)-Bike-highways – increase travel distance.						x	x				x	x				x					
2. Adjust traffic lights – decrease travel time.						x	x									x					
3. develop tunnels – decrease travel time							x														
4. develop more parking at transport-hubs.							x	x	x		x										
5. good connection, home to infrastructure.												x									

Table 9d: influencing the mobility-demand to shared cars, based on interview/questionnaire/workshop results.

Groups		Government										Consultancy				Transport companies						Work shop
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing		
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP		
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-	
Actions, to stimulate car-sharing:	3.1.2				x	x	x				x			x		x	x			x	x	
1. Reserve space for a sharing system buffer.					x	x	x				x						x			x	x	2/7
- Reduce the number of different SV services.																x	x					2/7
2. Create drop-off and pick-up points.				x	x							x		x							x	1/7
3. Cooperation - government and public transport.																						1/7
4. Transportation nodes at strategic locations.																						1/7
5. Adjust the design of neighborhoods.																						1/7
Increase number of users per vehicle, by:	2.4.2	x		x	x	x	x	x		x						x	x				x	
1. Parking policies (pricing and norms).		x		x	x	x	x	x		x						x	x				x	6/7
2. Increase ownership charges.								x													x	2/7
3. Decrease size of vehicle.					x		x									x						

Table 9e: Influencing the mobility-demand to public transport, based on the results of the interviews/questionnaire/workshop.

Groups		Government										Consultancy				Transport companies						Work shop
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing		
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP		
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-	
Actions, to stimulate PT use:	3.2.2	x	x			x	x	x	x		x			x		x	x			x	x	
1. Increase supply of PT options.			x			x											x				x	1/7
2. Maas-concepts, make it more attractive.		x									x										x	
3. Make mobility options easier to compare.			x			x	x									x				x	x	
4. Invest more in Public transport infrastructure.						?					Y			Y								
5. Develop parking at PT stations.							x	x	x		x											1/7
6. Do not stop at every station, stop on demand.														x			x					2/7
7. Speed-up Public Transport.																						5/7
8. Adjust spatial planning.																						3/7
9. Adjust PT concessions.																						2/7
Give priority to some logistic streams in cities.	2.4.5			x	x	x	x	x		x				x	x	x	x			x		
1. Differentiation in nodes and logistic streams.							x	x														3/7
2. Repulse certain types of mobility concepts.				x	x	x		x		x				x	x	x	x			x		

I.4. Tendency to Urban Sprawl, instead of urbanization

I.4.1. Impact on **travel distance** between work and home:

I.4.1.1. Will increase, because:

- Working during the travel becomes possible, because of automated driving tasks.
- The law of nature of acceptable travel time of an hour (Brever law), might increase due to reduction in the value of time.
- No necessity to move from modality to modality (chain), makes the travel more comfortable.
- People can live in an AV.

I.4.1.2. Will not increase, because there are more criteria than only travel time and value of time of travels:

- People in our society are obligated to schedules and appointments with others.
- Driving will still be unattractive, because the number of tasks that can be done during the travel are still marginal.
- There is also a trend towards flex working and working from home.

I.4.2. Impact on the combination of **urban sprawl** and private vehicle charges can lead to **segregation** in residential areas and mobility options.

I.4.3. Impact on **regeneration** of locations, because:

I.4.3.1. Some functions can move to low dense areas.

1. Parking can be moved to outskirts of cities, because they can park themselves.
2. Working locations can be moved, because they are more dependent on mobility options than agglomeration power.
3. PT stations can be moved to city outskirts, because the last mile can be travelled by shared AVs.

I. 4.4. Impact on **urbanization**: People move from low-dense areas to high-dense areas in order to make use of the sharing-system.

I.4.5. Aspects that influence someone's housing choice:

I.4.5.2. The amount of mobility options in the area.

I.4.5.3. The amount of facilities and functions on walking and cycling distance.

I.4.5.4. The amount of employment in the region.

I.4.5.5. The household composition that is searching and the housing target group.

I.4.5.6. The amount of m2 of the house and the plot.

Table 10a: The relation between the introduction of AVs and urban sprawl, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Impact (I) and related Action (A) categorized.	I & A																				
Urban Sprawl instead of urbanization.	4.	N	N	Y	Y	N -	N	Y-	Y	N	Y	Y+	Y+	N	Y	Y					Y
Travel distance between work and home	4.1																				
Will increase, because:	4.1.1			x	x				x		x	?		x	x	x					x
- increased value of time – working in vehicle.		N			x			x				x			x	x					x
- acceptable travel time will increase (Brever).		N	Y	?		N									Y						Y
- travel is more comfortable - No vehicle change.				x											x						
- people can live in an AV.				x							x			x							
Will not increase, because:	4.1.2	x	x			x	x			x				x							
- obligation to schedules and appointments.				x	x		x							x							
- driving will still be unattractive.														x							
- trend flex working and working from home.		x			x		x							x							
- limit of road capacity, leads to congestion.				x																	
- The living environment is also important.			x	x	x	x				x				x							
Influences on housing choice.	4.2													x		x					
Mobility options.	4.2.2	x	x	x	x	x							x								
Facilities and functions.	4.2.3		x		x					x											
Employment.	4.2.4		x																		
Housing target group, household type.	4.2.5			x		x				x				x							
Amount of space and/or a garden.	4.2.6					x				x											
Locations can be regenerated, because:	4.3																				
Some functions can move to low dense areas.	4.3.1																				
1. parking moves to city outskirts.				Y	Y		Y	N		N			Y	Y		N				Y	
2. working locations - agglomeration power.		N						N				?	Y								
3. PT stations													Y	Y						Y	
Segregation in neighborhoods	4.4							N			Y		?		Y	?					
Increased urbanization, due to sharing system.	4.5													N							N

A.5. Spatial planning **Actions** that can influence the introduction of AVs.

- A.5.1. Introduce flexible spatial planning, to keep options open.
  - A.5.1.1. Develop above ground parking facilities that are flexible in use.
- A.5.2. Concentration: create proximity and accessibility of functions in order to decrease mobility.
  - A.5.2.1. Put restrictions on developments in certain areas, in order to concentrate developments in other areas.
  - A.5.2.2. Decrease travel distance, by spatial planning:
    1. Developing low-priced housing in dense areas is difficult, because the land prices are very high.
    2. Increase the number of facilities and functions in low dense areas, in order to make them more accessible.
  - A.5.2.3. Concentrate functions around PT nodes, in order to create better accessibility.
- A.5.3. Actions in order to spread the pressure on the mobility system, in order to town down peaks.
  - A.5.3.1. Build on the outskirts of cities.
- A.5.4. Influence the mobility choice of citizen.
  - A.5.4.1. The housing type is connected to the mobility use.
    1. Make an integral design of residential areas, PT locations and bicycle infrastructure.
    2. The parking norm in a residential area, influences the housing choice and the mobility use.
  - A.5.4.2. Research the willingness to travel longer distances with the introduction of AVs.

Table 10b: Spatial planning actions that can influence the introduction of AVs, based on interview results.

Groups		Government										Consultancy				Transport companies					
Organization		RWS	IPO	Province of North-Holland						Ams		Arcadis				Public Transport				Sharing	
Sector (transportation = TP, Urban = UP)		TP	UP/TP	TP				UP		UP	TP	UP		TP		TP				TP	
Department/Function		WTE	M/L-U	CM	MA	SM	BP	EV	TN	SM	AP	LS	SC	SM	PM	AV	B	T	-	CR	-
Impact (I) and related Action (A) categorized.	I & A																				
Spatial planning actions	5.																				
Flexible spatial planning, to keep options open.	5.1					x			x		x			x	x		x				
Flexible above ground parking infrastructure.	5.1.1					x					x			x							
Concentration: create proximity & accessibility	5.2		x		x	x			x		x		x		x						
Restrict developers of building in certain areas.	5.2.1					x															
Decrease travel distance, by spatial planning:	5.2.2		x		x				x												
1. Low-priced housing in dense areas is difficult.					x								x								
2. Increase number facilities in low dense areas.			x		x								x								
Concentrate around PT nodes.	5.2.3		x		x						x		x		x						
Spread pressure on mobility system.	5.3			x									x		x						
Build on the outskirts of cities.													x		x						
Influence mobility choice.	5.4	x	x	x	x	x					x				x		x				
Housing type is connected to mobility use.	5.4.1			x							x				x		x				
1. Integral design of residential areas, PT			x	x	x							x	x								
locations and bicycle infrastructure.																					
2. Parking norm influences housing choice.		x		x		x															
Research to connection: mobility & urbanization	5.5												x	x							
Research to travel time willingness.	5.5.2													x							
Research to social/economic impact of stations.	5.5.3												x								

C. Questionnaire (questions and results)

In the result chapter some figures with the results of the questionnaire are showed. In this appendix, additional figures of the results of the questionnaire are presented that are not considered relevant for the main text. The questionnaire consists of 16 questions and is based on the results of the interviews. The questions are divided in five topics: general, car-sharing, public transport, spatial planning and transition phase. The questionnaire is filled in by 15 respondents.

Personal information of respondent

Question introduction
Name: ……….

Answers
Anonymity

Question organization
Organization type:

Answers

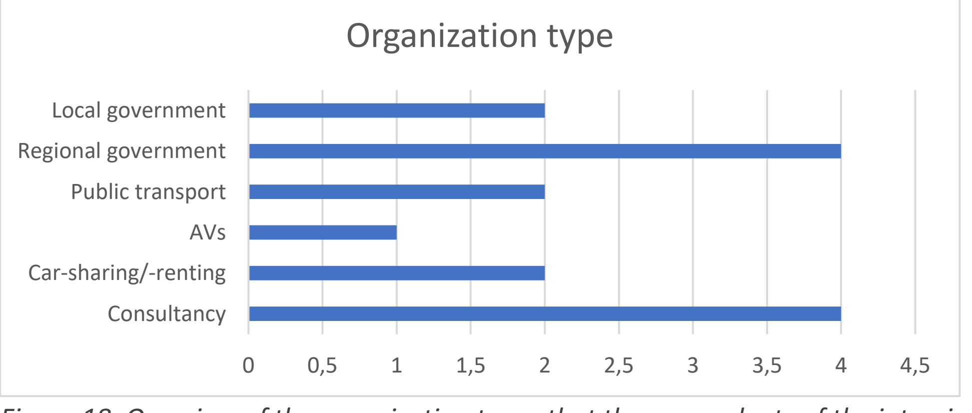

Figure 18, Overview of the organization types that the respondents of the interview are working for.

General

Question 1: Timeline.

Between 2025 and 2030 the first AVs will appear on the roads. From 2050 more than half of the households will own a AV.

1. Disagree, this will take way less time.
2. Disagree, this will take way more time.
3. Agree.
4. It is uncertain, every answer would be a wild guess.

Answers

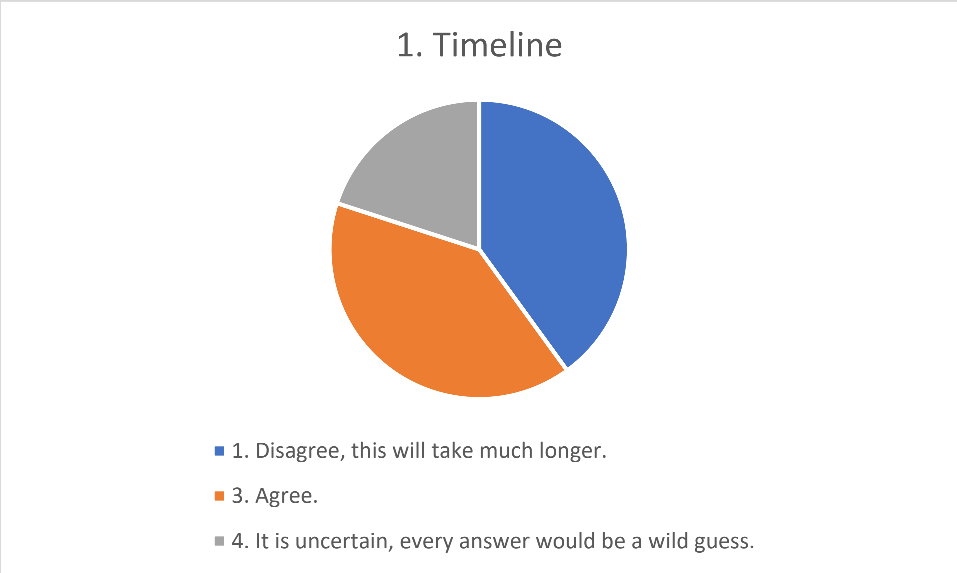

Figure 19, The expected timeline of the development of AV technologies, according to respondents of the questionnaire.

Question 2: Road capacity

Although the road capacity can increase due to a more steady speed and a narrower standard distance between two AVs, is it possible that the road capacity will find its limits, due to the increased car-use and -ownership. What would be the total effect on the road capacity?

1. The first effect will outscore the second effect.
2. The second effect will outscore the first effect.
3. A balance will arise.
Other, namely:
- Car-use will increase, but more vehicles will be shared between users, therefore the overall road capacity will increase.
- It will stay the same as it is at the moment.
- This will differ per road type (the mix of modalities) and the steering of the vehicle (autonomous or fleet restrictions).

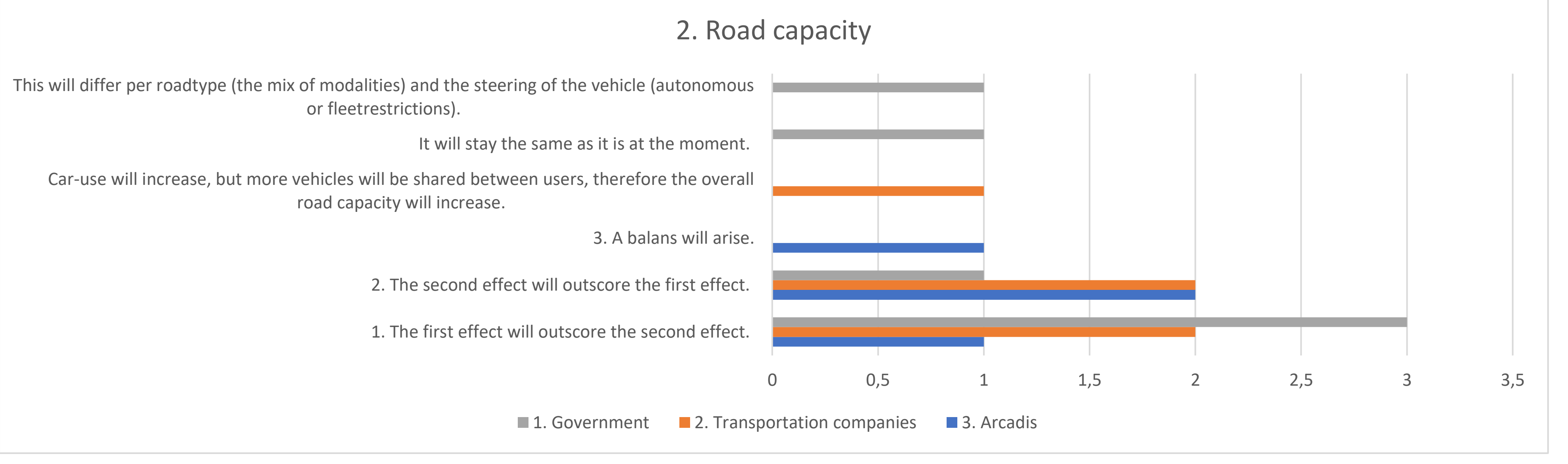

Figure 20, The expected impact of AVs on the road capacity, according to respondents of the questionnaire sorted by organization type.

Question 3: Impact on car-use and car-ownership.

The introduction of the AV will lead to more car-use (vehicle kilometres travelled) and/or car-ownership (number of vehicles), without the intervention of the government.

1. I agree on both.
2. Only car-use.
3. Only car-ownership.
4. I disagree on both.

Answers

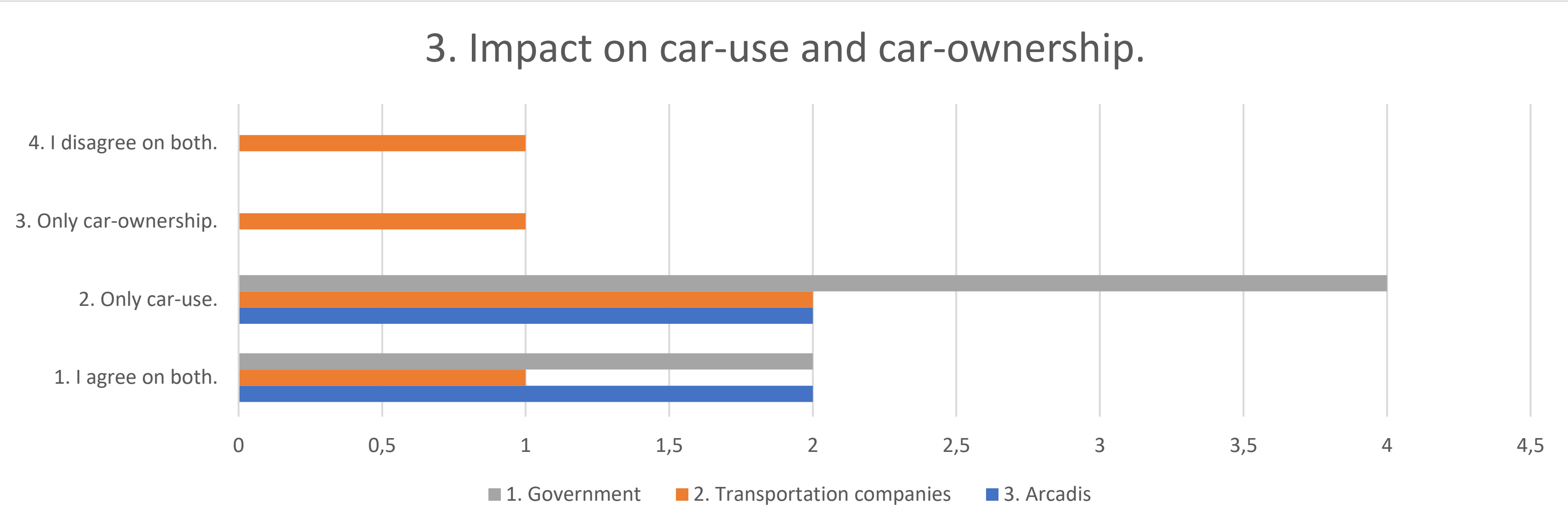

Figure 21, The expected impact of AVs on car-use and car-ownership, according to respondents of the questionnaire sorted by organization type.

Question 4: Sharing transition vs. AV transition.

Although the AV will make car-sharing more easy, the transition towards sharing will not take place without intervention of the government. At the moment it is important that the government will invest in sharing and not in the introduction of AVs.

1. I fully agree.
2. Both transitions need the same attention.
Other, namely:
- The increase of sharing would have a positive effect on traffic, however it is not clear to me how the government could influence this. This is the task of car-sharing companies.

Answers

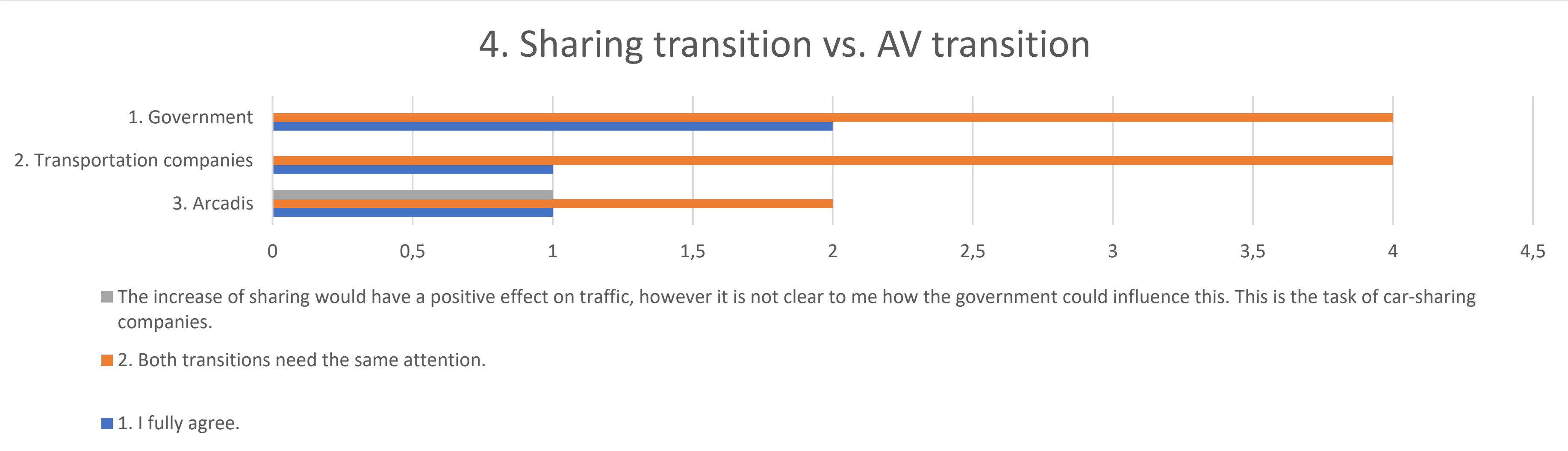

Figure 22, The choice between the priority for the sharing or the AV transition, according to respondents of the questionnaire sorted by organization type.

Question 5: Car-sharing vs. Public transport

Car-sharing is not the solution to all capacity problems. Car-sharing is less efficient, than public transport and it is impossible to fulfill the mobility demand during the rush hours.

1. I fully agree.
2. This is only the case around major transport-nodes.
3. Car-sharing is not less efficient.
4. Car-sharing is also feasible during rush hours.

Answers

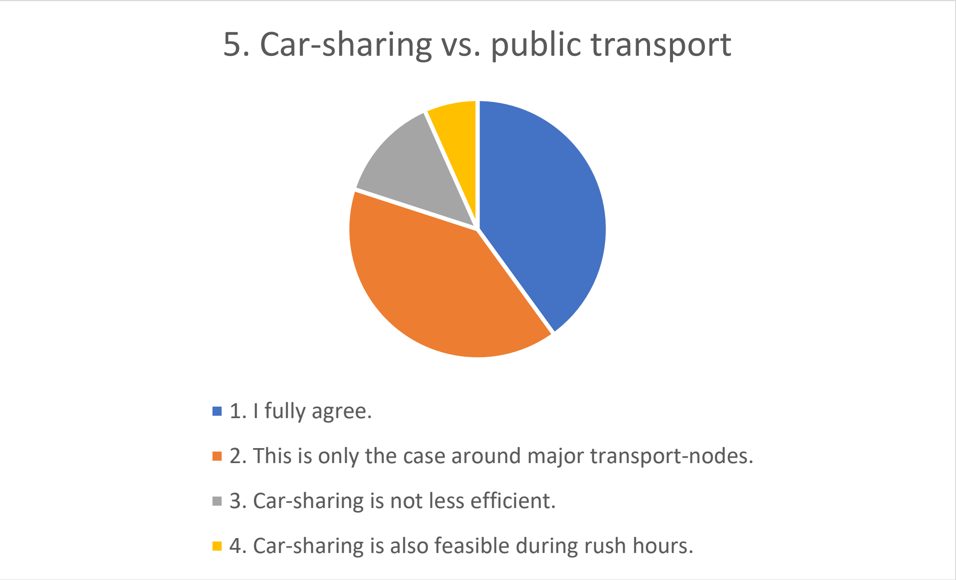

Figure 23, The expectation that car-sharing is less efficient than public transport, according to respondents of the questionnaire.

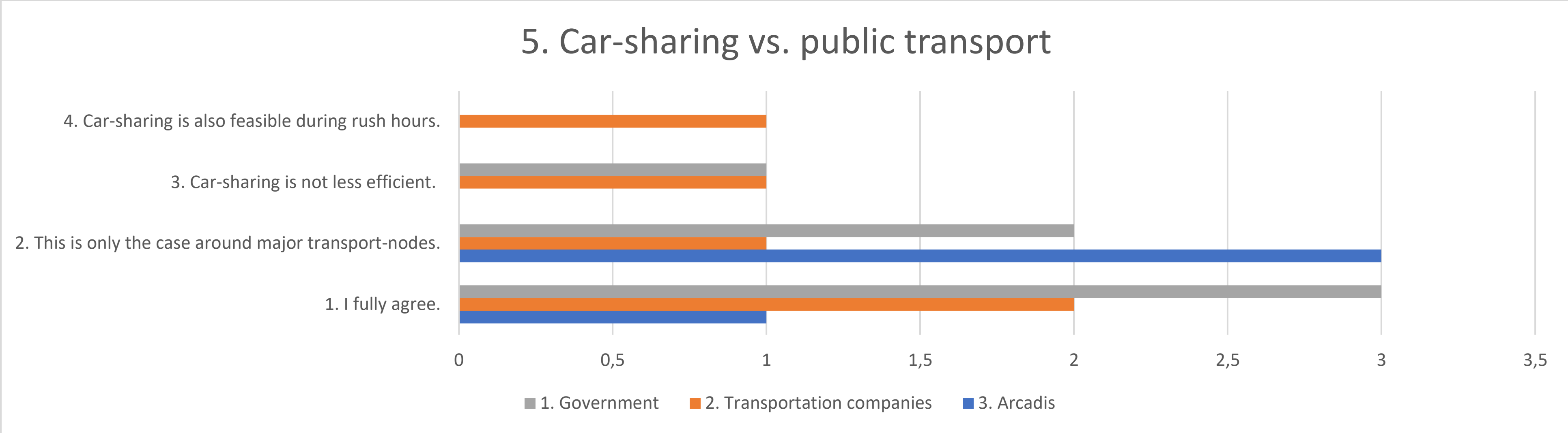

Figure 24, The expectation that car-sharing is less efficient than public transport, according to respondents of the questionnaire sorted by organization type.

Question 6: Car-free cities and parking outside cities.

Due to the introduction of AVs, it becomes possible to make cities car-free and cars can be parked outside the city. Multiple answers are possible.

Is this desirable?
1. I agree, both are desirable.
2. I disagree, AV does not influence this.
3. Only car-parking outside the city is desirable.
Other, namely:
- I cannot decide if it is desirable or not. It is not an individual goal. The scares space in the city has to be allocated in a good manner.
- I agree, because it will be an additional effect. I disagree, because even without AVs steps can be taken.
- It is not about a car-free city. It is about the allowance to park or not.

What are incentives?
4. This can already be incentivized with parking policies.
5. This can be incentivized by spatial planning.
Other, namely:
- Offering an alternative on the public transport free city-centre: HOV on thick streams.

Answers

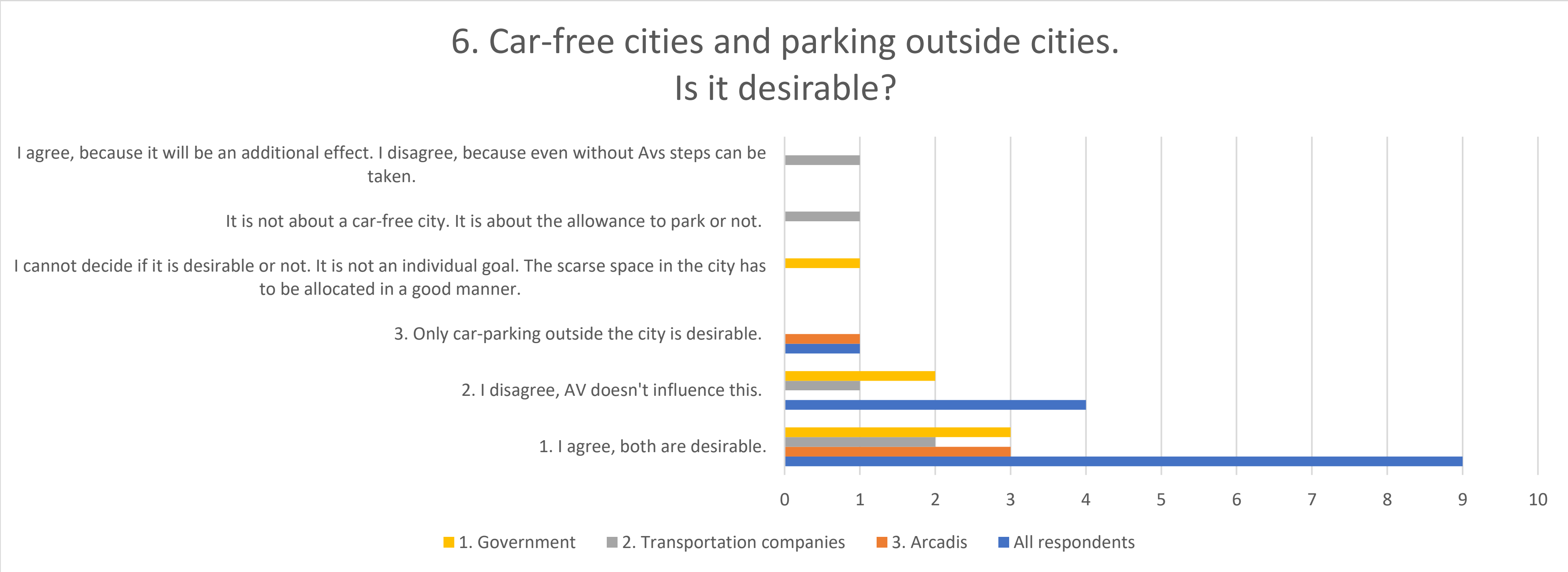

Figure 25, The preference for car-free cities or parking outside cities, according to respondents of the questionnaire sorted by organization type.

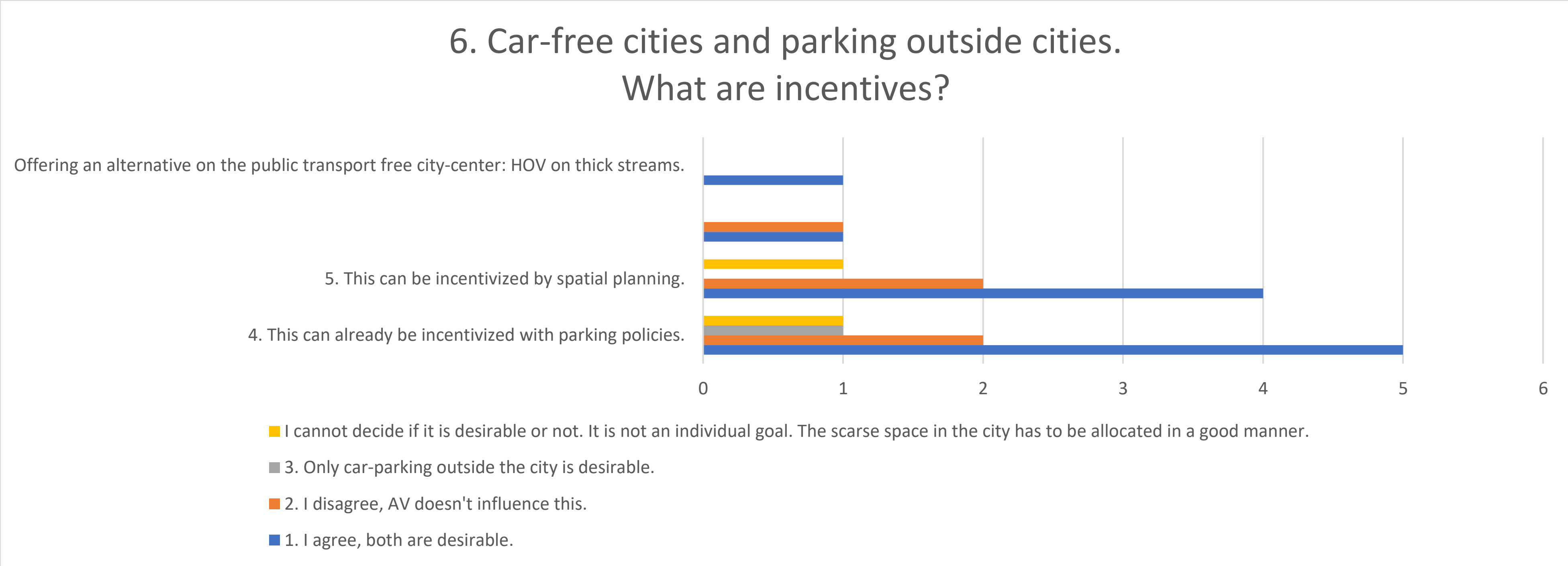

Figure 26, The preference for car-free cities or parking outside cities, according to respondents of the questionnaire sorted by organization type.

Public transport

Question 7: Decrease in public transport and bicycle use.

The use of public transport and the bicycle will decrease, due to the increase in the use of private cars, due to the introduction of AVs. Multiple answers are possible.

1. I Agree.
2. Only the use of certain public transport modes will decrease.
3. Bicycle use will not decrease.
4. Public Transport use will not decrease.
Other, namely:
- Private vehicle use will not increase.
- Public transport will also be different.
- It will depend on the pricing policy: mobility against time.
- Users will search for a combination of modalities, not the one or the other.
- Private vehicle ownership will also decrease.

Answers

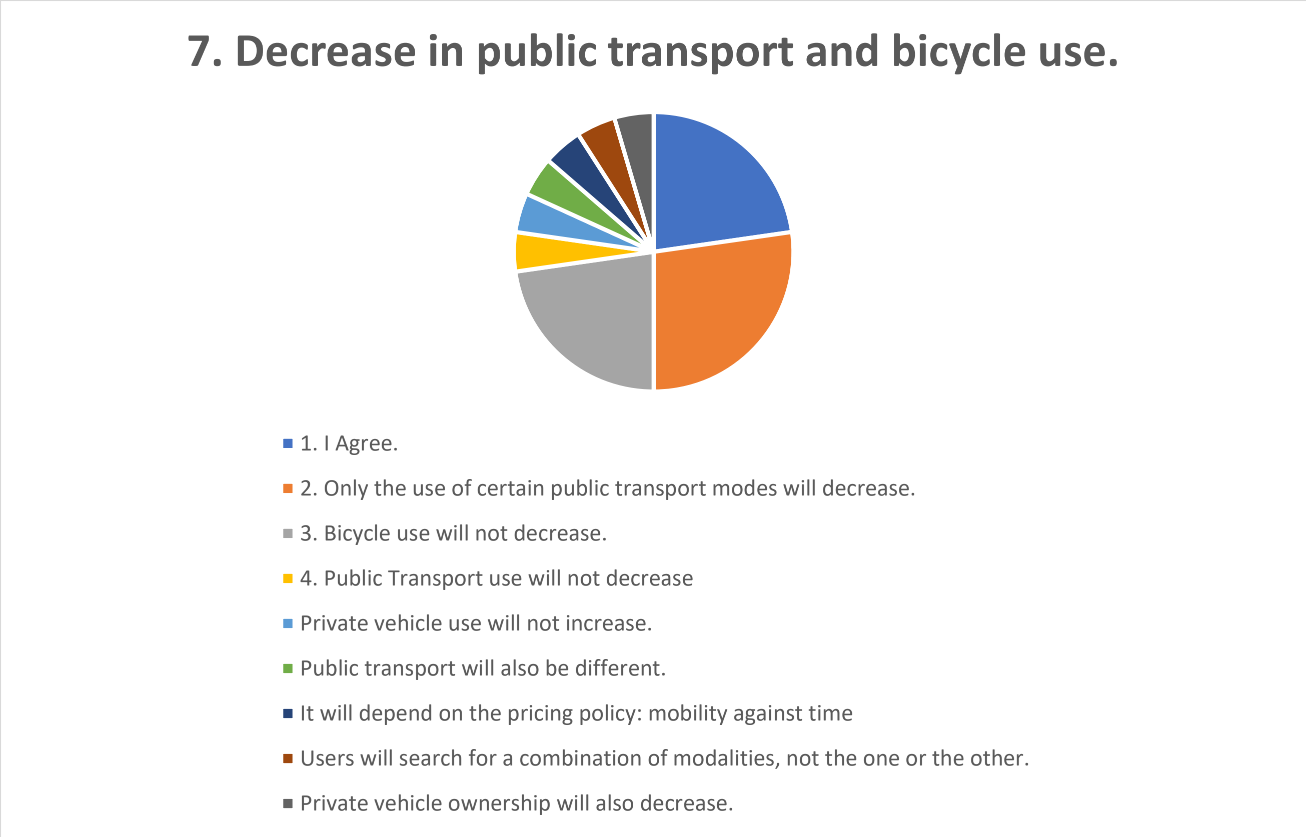

Figure 27, The expectation that AVs will lead to a decrease in public transport and bicycle use, according to respondents of the questionnaire.

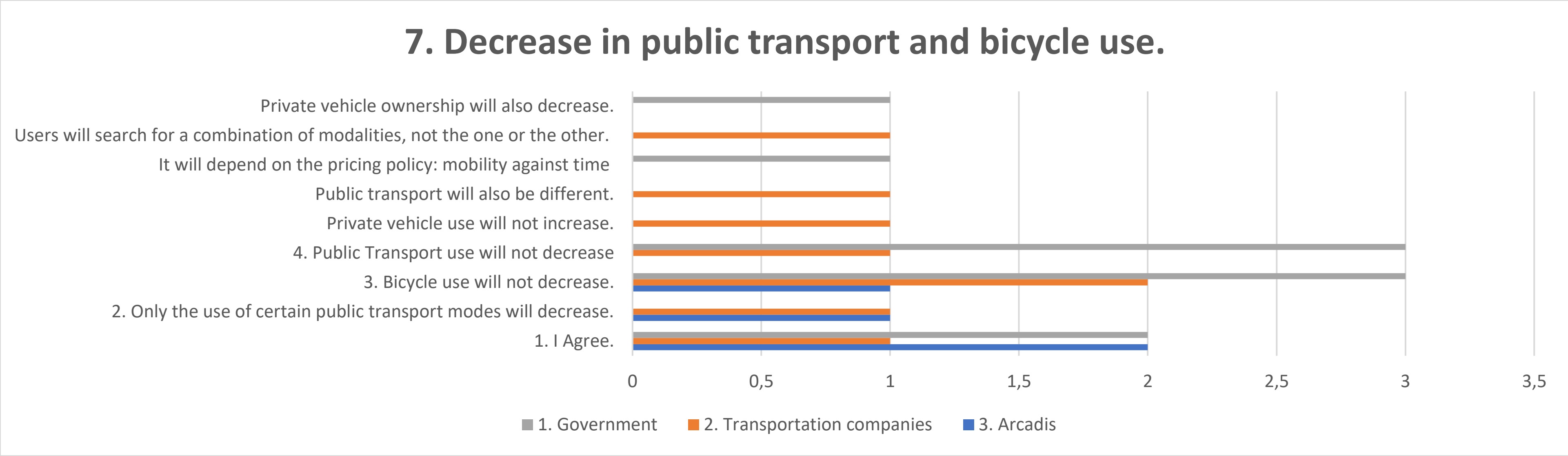

Figure 28, The expectation that AVs will lead to a decrease in public transport and bicycle use, according to respondents sorted by organization type.

Question 8: Spatial incentives to stop trend towards increase use of private car.

The use of public transport and the bicycle will decrease, due to the increase in the use of private cars, due to the introduction of AVs. What spatial solutions could stop this trend? Multiple answers are possible.

1. More priority for the development of bicycle paths/parking.
2. Integral design of working/living/recreation locations and public transport nodes.
3. Concentration around public transport nodes.
4. More pick-up and drop-off points.
5. Lower parking norms in cities.
6. More locations for shared-car parking.
7. Steer with a mix of rental and private sector houses, because the residential target group is connected to the mobility demand.
Other, namely:
- Traffic calming designs.
- Do not focus only on "more" or "less", make a connection between the target group, location and impact-risks.

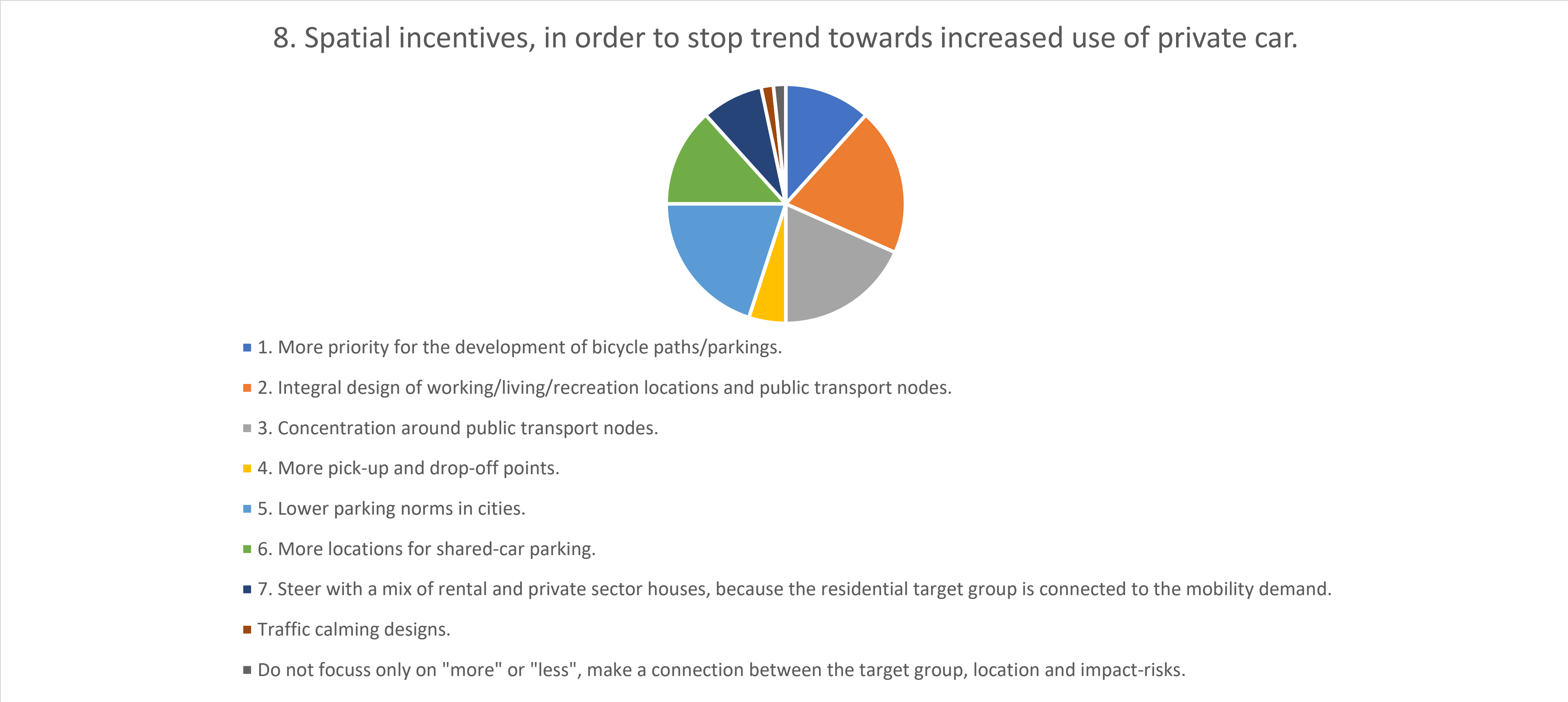

Figure 29, Preferred spatial incentives in order to stop the trend towards increased use of the private vehicle, according to respondents.

Question 9: Market domination of private AV.

Although, the costs of Automated public transport and the (shared) automated taxi will decrease in the future, at the moment is AV mobility not feasible economically for public transport and car-sharing companies. Therefore, the government should also invest in these services, in order to stop the domination of the private AV sector.

1. I fully agree.
2. I disagree, a feasible business model is possible.
3. I agree, but it is not the responsibility of the government to invest in automated public transport.
4. I agree, but the Dutch government is not able to stop the domination of the private car sector alone. Cooperation within the EU is essential.
Other, namely:
- Public transport is never profitable, subsidy of the government are necessary. Therefore, the government can invest via concessions in AV together with the public transport companies.
- Government can start by investing in AV on the separated rail infrastructure (train/metro/tram).

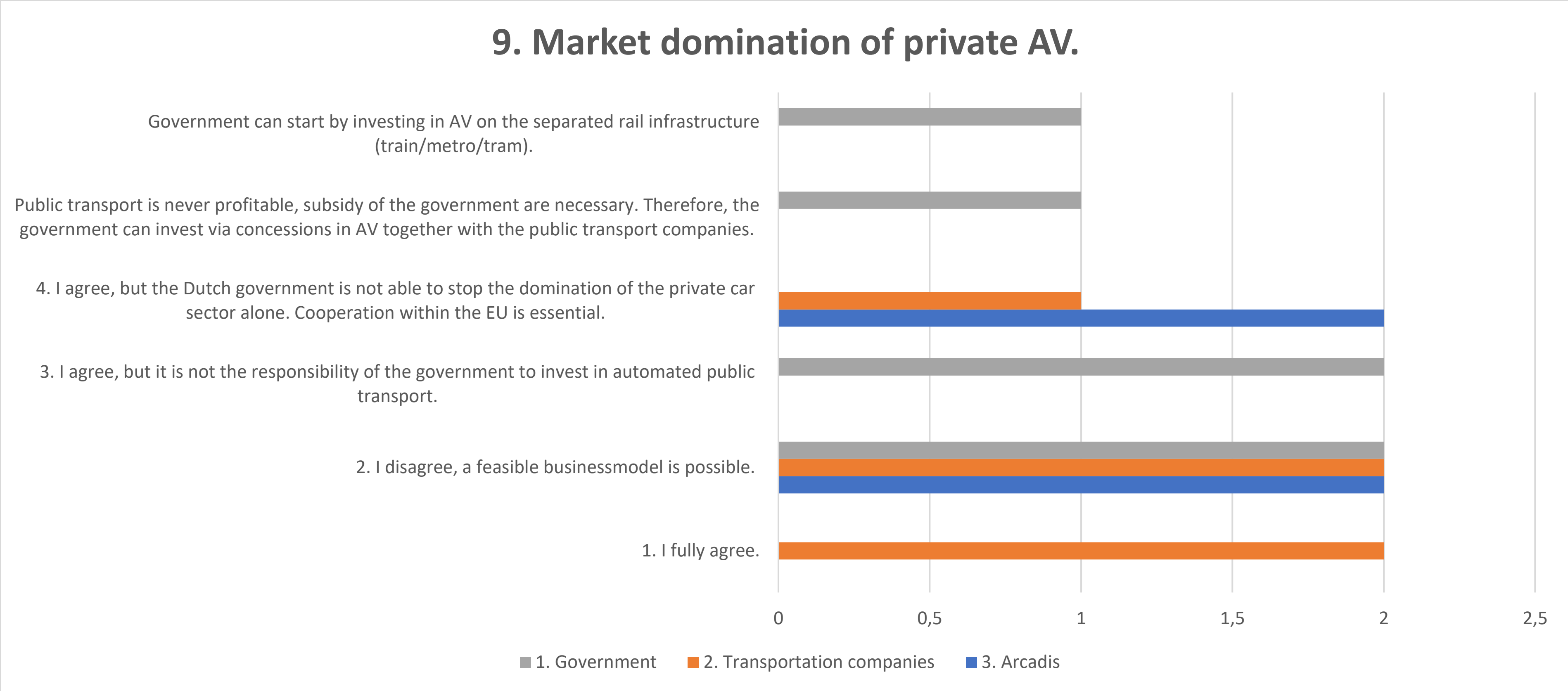

Figure 30, The necessity to prevent market domination of private AVs, according to respondents sorted by organization types.

Question 10: Bundling public transport streams.

In low-dense areas it becomes possible to fulfil the mobility demand by demand-guided AVs. They can figure as optimal feeders for thick public transport streams. Therefore public transport streams can be bundled more effective.

1. I agree, this is an opportunity and can be steered in the right direction by spatial planning.
2. I agree, but there is too much uncertainty in order to steer this in the preferred direction.
3. I disagree, this will not have an impact on the design of the public transport system.
Other, namely:
- I do not understand the question.
- There is a relation, but not as dominant as stated. Because, Automated public transport still needs a lot of investments. Besides the target group for public transport in low-dense areas is very specific and therefore it is not a common alternative.
- This is already happening, see the fish-bone model North-South-metro line in Amsterdam.

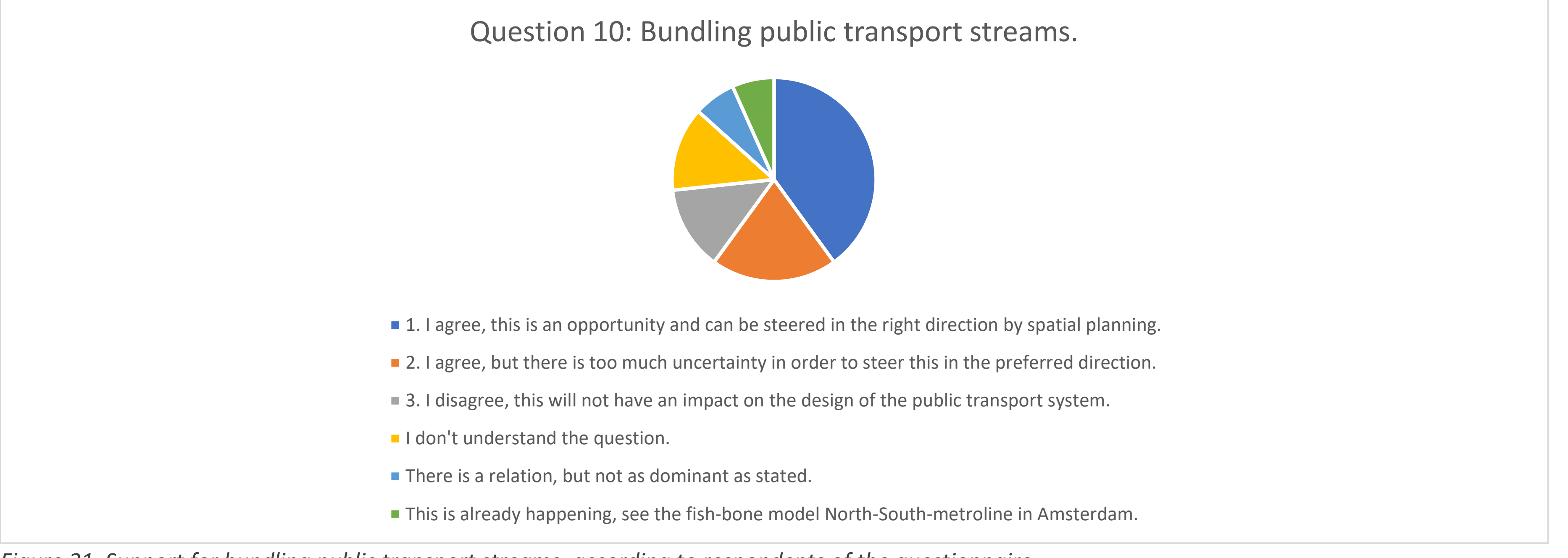

Figure 31, Support for bundling public transport streams, according to respondents of the questionnaire.

Question 11: Train stations and car-parking

In a future with AVs it might be, that some stations will be used less. The stations where it is assumed that the number of users will decrease in the future, can be assigned a new function. An example is car-parking. In low-dense areas it becomes possible to fulfil the mobility demand by demand-guided AVs. They can figure as optimal feeders for thick public transport streams. Therefore public transport streams can be bundled more effective.
1. P&R location could be used as AV-buffer outside the rush hour.
2. It is not necessary to park AVs close to a station. They can be parked further away on cheaper ground.
3. In the future only automated shared-vehicles will be used. These vehicles (almost) do not need to be parked, they keep circling/driving.
Other, namely:
- Maybe some stations are not used less in the future.
- Divers functions.
- Less stations will lead to an increase in (private) AVs. Stations should not be closed. Instead they should be used for better prior/after transport in order to stimulate an increase in users.

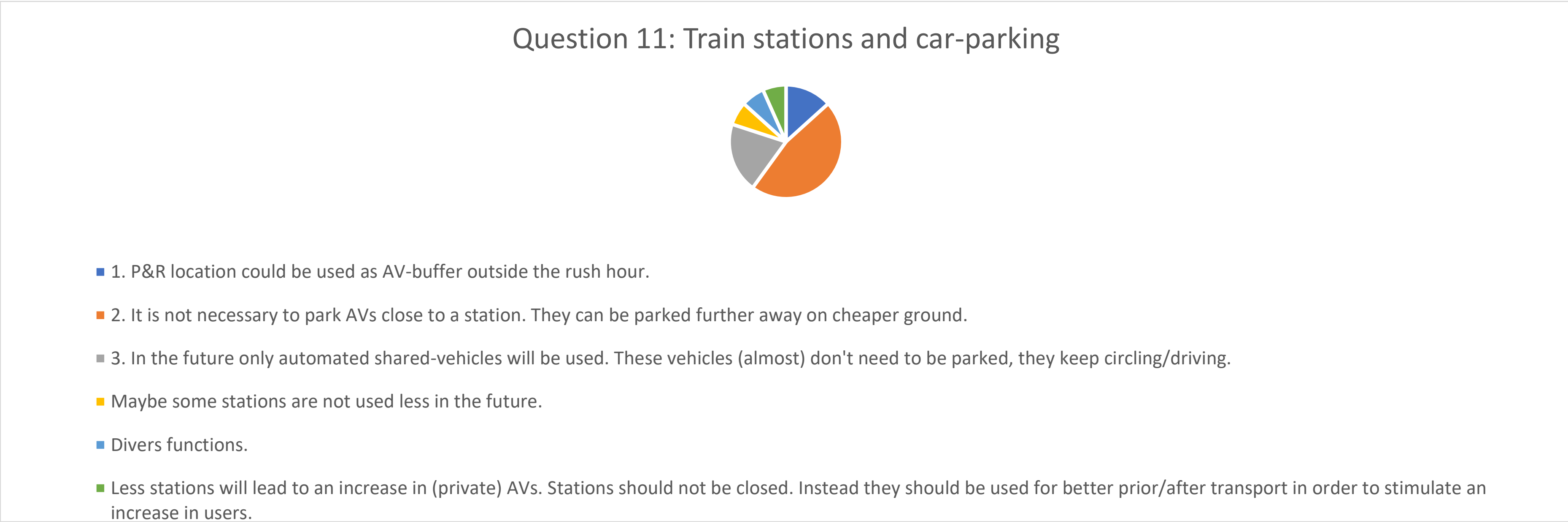

Figure 32, Support for actions related to parking at train stations, according to respondent of the questionnaire.

Question 12: Differentiation in the use and accessibility of all stations.

In a future with AVs, it becomes possible to assign different functions to all stations in the public transport system. An example is that some stations become more accessible by bus and bicycle and others for AVs. What spatial adjustments are necessary?

1. In order to achieve this, the infrastructure needs to be used in a different way by steering different logistic streams to different stations.
2. In order to achieve this, the parking norms around stations need to be adjusted.
Other, namely:
- I do not believe in this differentiation.

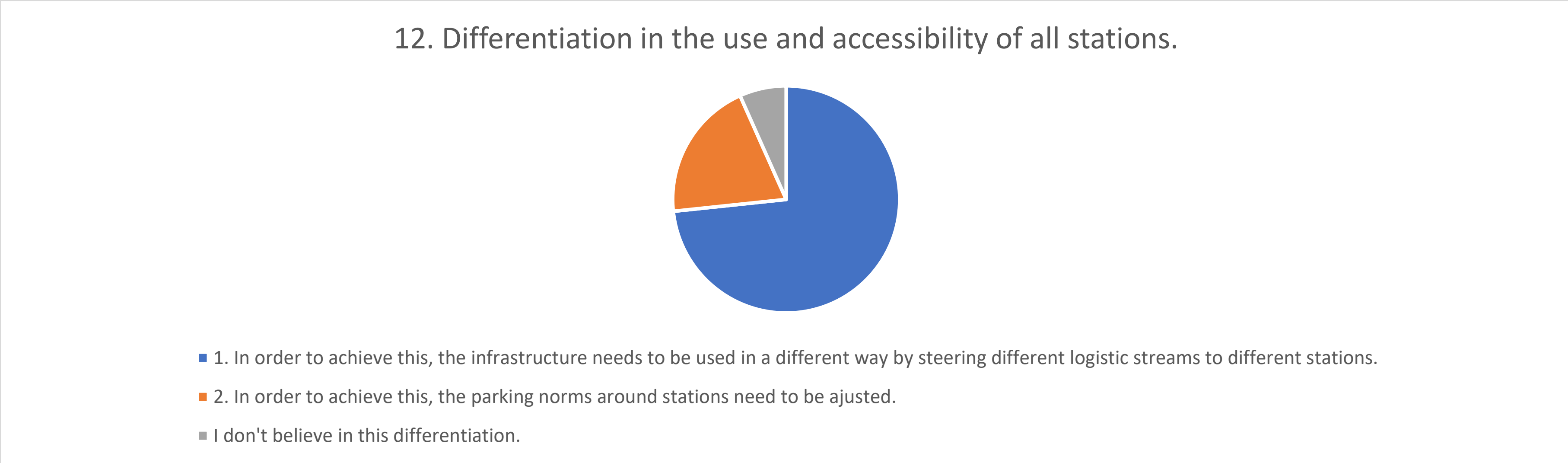

Figure 33, Support for the differentiation in the use and accessibility of all stations, according by respondents of the questionnaire.

Question 13: Social exclusion and income segregation.

When AVs are introduced social exclusion can arise, due to the economic system behind it. The spatial impact can be that income segregation will arise in residential areas, because the mobility offer influences the housing preferences. How can this problem be solved?

1. I do not think that segregation in residential areas will appear.
2. Steer by adjusting the mix of housing types.
3. Steer by adjusting the mobility supply.
Other namely:
- Steer by designing mixed living and working areas.
- Invest in mobility services for specific target groups.

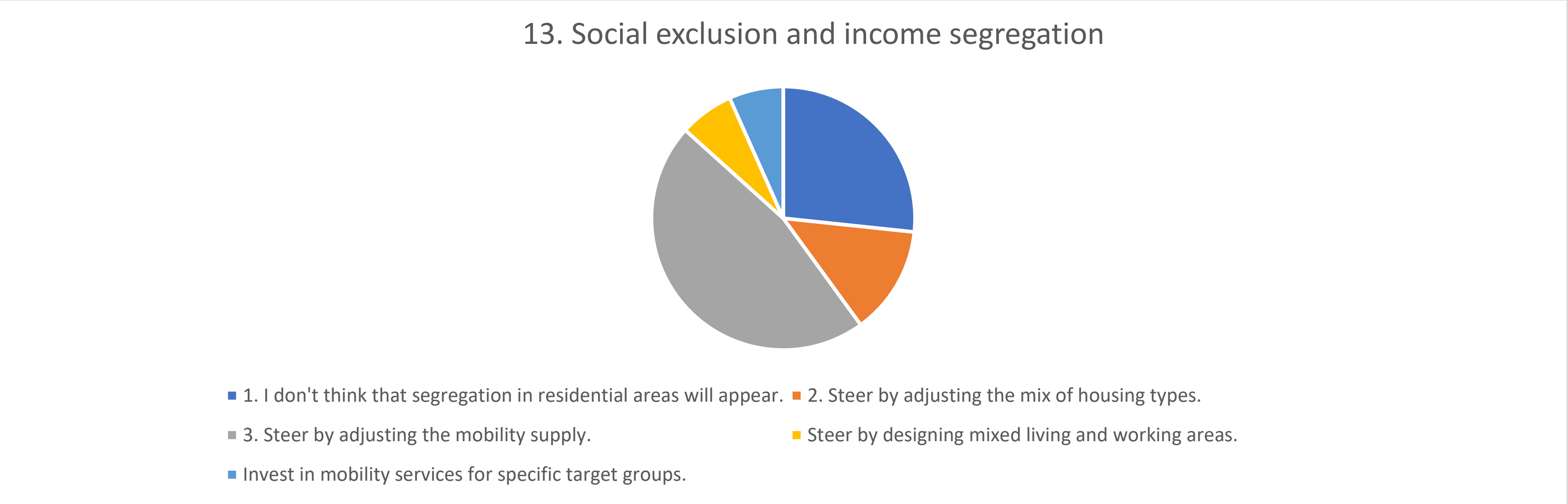

Figure 34, Expectations about social exclusion and income segregation and preferred actions, according to respondents of the questionnaire.

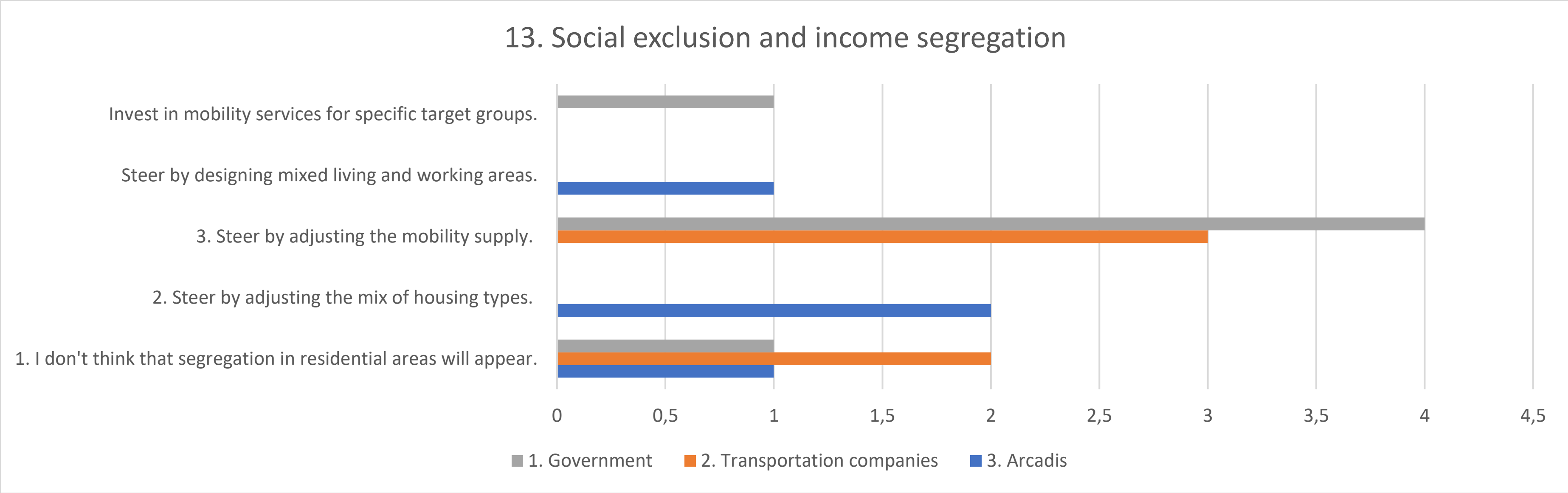

Figure 35, Expectations about social exclusion and income segregation and preferred actions, according to respondents sorted by organization type.

Question 14: Social inclusion and spatial planning.

When AVs are introduced social inclusion can arise, due to the improved accessibility and expanded mobility offer for elderly, children and disabled. The possibility to use a car can have the effect that they are less depended on family members and public institutions. Functions and facilities do not necessarily have to be on walking/cycling distance and the lay-out of the city can be adjusted.

1. I agree, spatial planning should already incorporate this in plans.
2. I agree, but it is not necessary to incorporate this in plans already.
3. I disagree.
Other namely:
- I agree, but this future is too far away. During the transition phase this could have a negative effect for stakeholders, when they have to live further away when new mobility concepts are not in use yet.

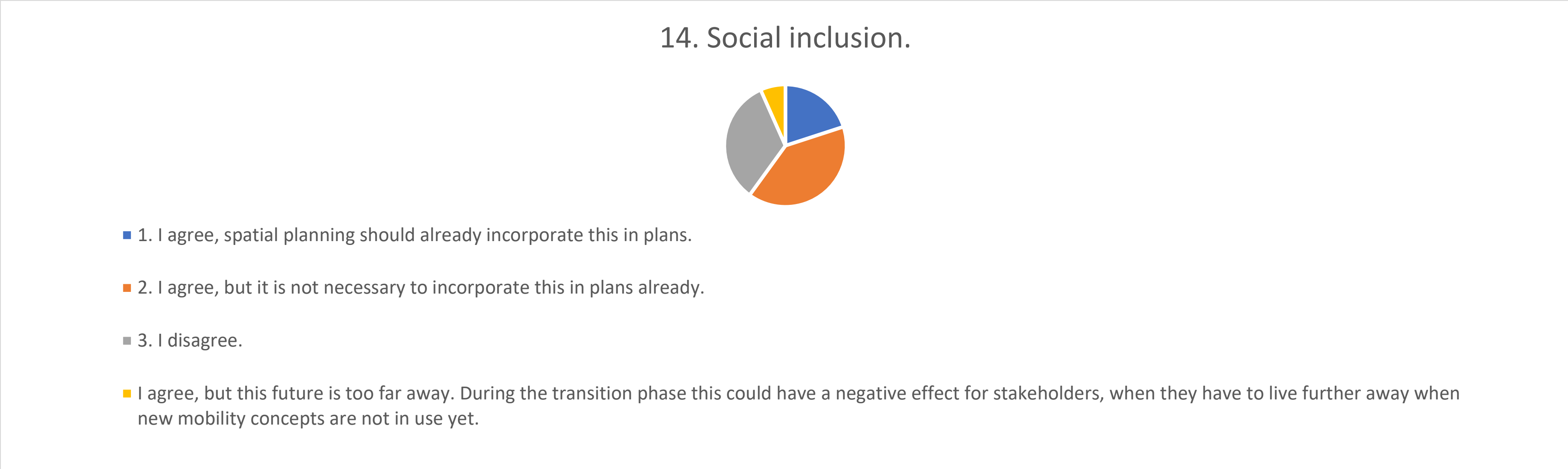

Figure 36, The expected impact of AVs on social inclusion, according to respondents of the questionnaire.

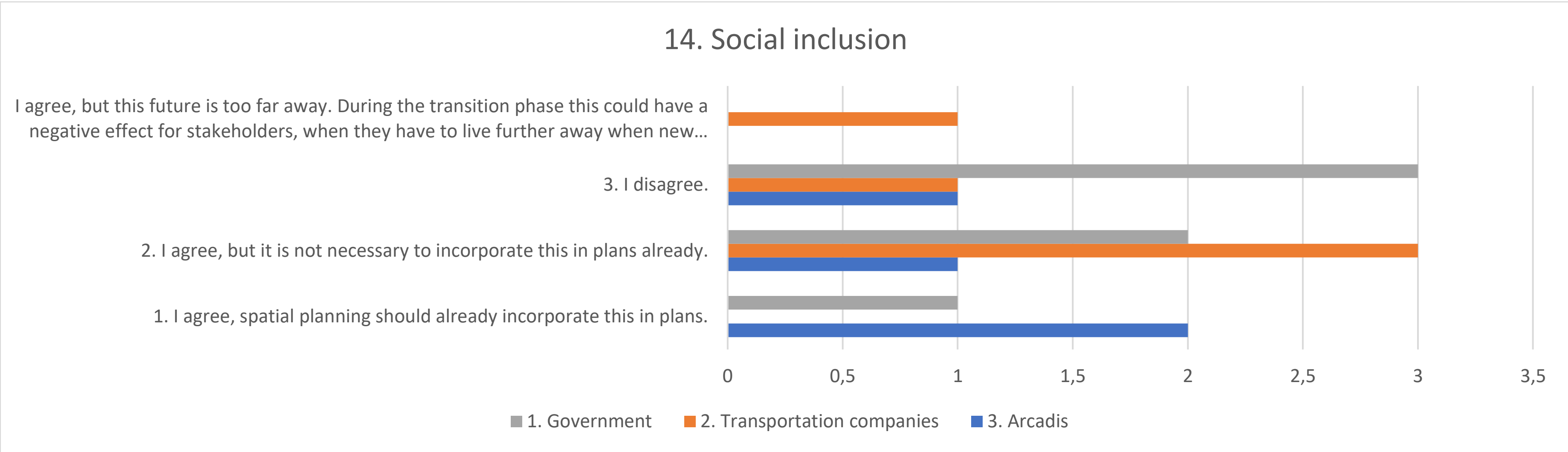

Figure 37, The expected impact of AVs on social inclusion, according to respondents of the questionnaire sorted by organization type.

Question 15: Transition phase and adjustments to the infrastructure.

Is it necessary to come up with spatial solutions for the transition phase from automation level 1 to 5. (adjustments in infrastructure) or is it possible to use different types of AVs per context?

1. It is already necessary to adjust infrastructure to AVs.
2. It is only possible to adjust infrastructure, when it is flexible in future use.
3. The different types of AVs can be used in different contexts on the public roads. Example: highway- and park-shuttle.
Other, namely:
- I think both. Currently it is possible to use different types in different contexts. On the long term adjustments in infrastructure are necessary.

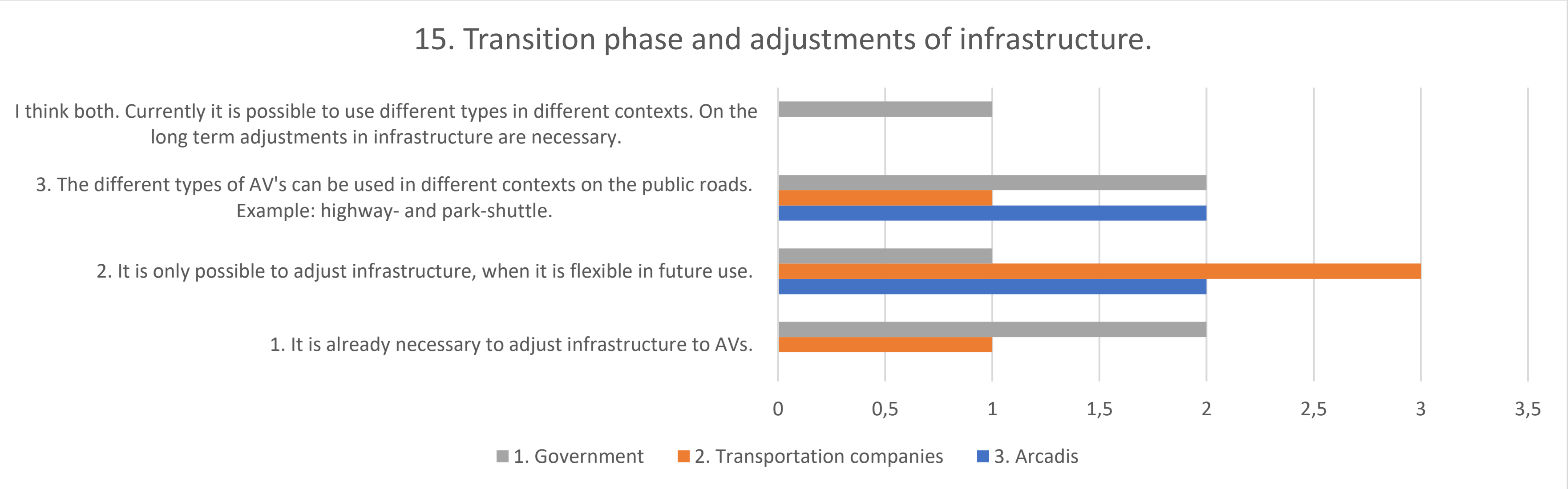

Figure 38, Support for adjustments of infrastructure for the transition phase of AVs, according to the questionnaire results sorted by organization type.

Question 16: Speed up transition process by spatial planning.

Is it necessary to come up with spatial solutions, in order to speed up the introduction of AVs? How can this be done with the use of spatial planning? Multiple answers are possible.
1. No.
2. The road surface marking needs to be adjusted.
3. Separated public transport roads need to become suitable for both AVs and current public transport vehicles.
4. Design broader bicycle paths, for the potential future use of AVs.
5. Design junctions with less crossing streams.
6. Make better separation between pedestrian-/bicycle paths and car roads.
7. Design separated roads for AVs.
Other, namely:
- First step: The government should adjust laws and policies. Technical and spatial adjustments are already available and easy to implement.
- The introduction needs accompaniment.

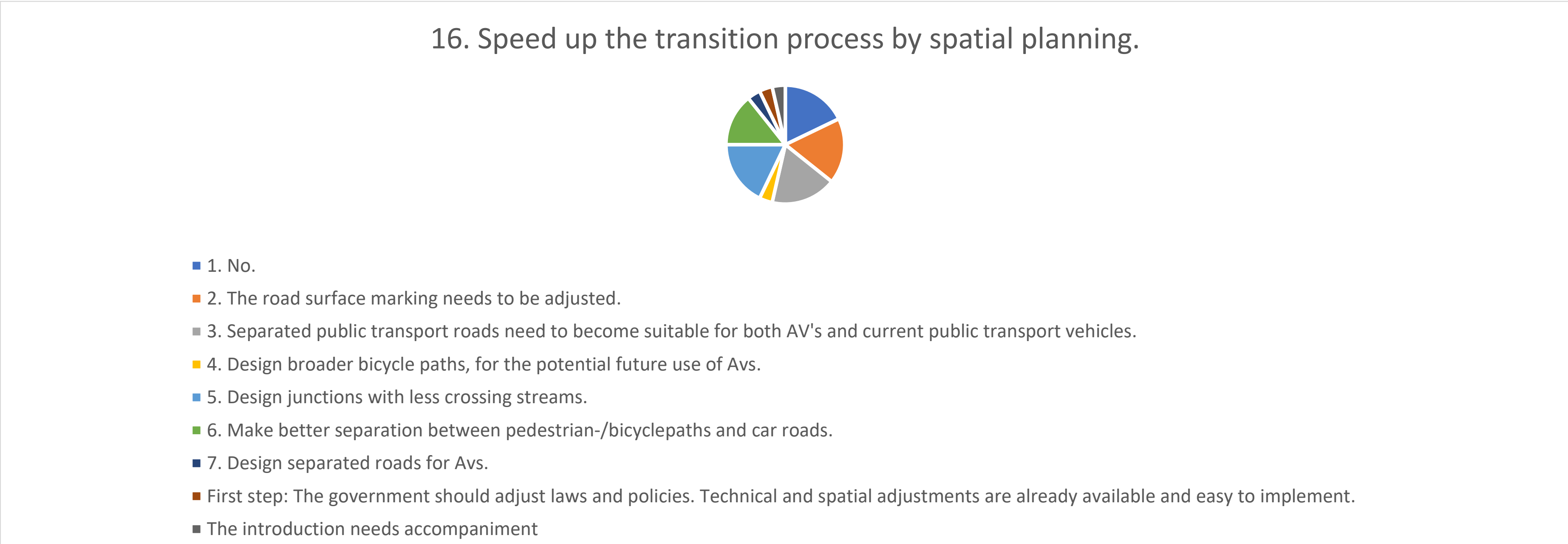

Figure 39, Support for proposed spatial planning actions in order to speed-up the AV transition process, according to respondents of the questionnaire.

D. Workshop Transcript

The original transcripts are left out this research document in order to protect the privacy of organizations and their employees. Transcripts can only be viewed with the explicit permission of the researcher and the respondents. The summary of the transcript is translated from Dutch to English.

1. Discussion about the actions that can speed up the transition phase.

Costs for the development of infrastructure per modality are too high.
The costs (land and money) for the development of infrastructure per modality are too high. Infrastructure from other/outdated modalities should be replaced, when it is decided that the transition needs to be accelerated. Operation and maintenance of AVs in the existing infrastructure is also possible. With smaller adjustments over time it might also be possible to make the infrastructure accessible for the new technology. This is a relevant discussion, because some modalities are already banned from city centres (private cars, next is public transport), because there are too many mobility concepts at the moment.

Shared space 2.0
Instead of designing vehicles for the existing infrastructure, it might also be possible to re-design this basic structure/grid for the preferred type of new vehicle (what profile fits what mobility concept?). It might be an option to design according to the speed of the vehicle.

Policy window: deviation from the trend
When there will be a change in the appreciation of the scarce land in cities there will be a change in travel behaviour. This deviation from the trend of high land-use for mobility, might lead to a policy window for discouragement of vehicles ownership (second car parking permit, good offer of public transport and shared-cars).

Car manufacturers
Car-manufactures might not be encouraged to participate in the multi-actor decision-making process, because they are currently free-riders. They do not need to pay the full price of the infrastructure their vehicles need. They do not need to re-consider to size of their vehicles, because the infrastructure capacity is large enough and will be expanded when there is too much stagnation. It is more likely that they do not participate in the multi-actor decision-making process, because they are afraid of losing their competitor position. They notice that ownership rates might drop and are trying to re-design their business model and sell mobility concepts instead of vehicles.

2. Discussion about the actions that can be taken to stimulate car and ride-sharing.

Car-sharing companies
The difference between car-sharing and car-renting is small. Car-sharing and car-renting are similar in use, except in the amount of users per day. The current issue were car-sharing companies are struggling with are: that The location of shared-cars and the type of car are not adapted to different costumers. In addition they have Difficulties with getting a parking permit for shared-cars. Parking permits for shared-cars can be more flexible in use in the whole Randstad, in order to get a feasible business model. Car-renting/sharing companies have conversations with other transportation companies. Shared-cars can be a part of the chain-mobility, for example combined with train-travel.

Delivery services
The transition towards car-sharing, will also have an impact on delivery services. When users of shared-cars cannot park in front of their door, neighbourhoods can be clocked by delivery service vehicles, that deliver products. A central pick-up point could be a solution.

Incentives for car-sharing: create scarcity.
It is possible to create scarcity by giving negative incentives to discourage private car ownership, but it is important to give sufficient mobility alternatives. However most locations have already plenty mobility alternatives, but users still prefer the private car.

How to accelerate/catalyse the transition towards sharing.
The focus needs to be on a change of behaviour in order to accelerate the transition to car-sharing. The need for this change in behaviour can be argued for by politicians, when they connect it to sustainability goals, like the transition to less energy and land consumption.

Feasibility of shared-cars covering the mobility demand during peak hours
It is hard to fulfil the mobility-demand by shared cars during rush-hours, because most opposite mobility streams are not equipollent in size to each other over time. Therefore, the first step in the transition is, to measure the amount of cars that is needed per location over time and replace the private-cars that are not needed by shared-cars. These are mostly second cars and the ownership can be discouraged by deleting second-car-parking permits.

3. Discussion about the actions that can encourage the use of public transport.

Prevent the increase in the use of the private AV, with adjustments in special needs target group transport.
To prevent an increase in the use of the private AV, you might reconsider target group transport. Target groups transport (for elderly and students) can be replaced by an AV taxi-bus that brings them to the nearest station. However, Target groups with special needs cannot use the regular AV, but students and elderly can.

MaaS concepts and area types.
MaaS concepts are mostly discussed in the perspective of high-dense areas. However there might also be a feasible business model in low-dense areas. An issue might be that commercial peer-to-peer ridesharing services, are not be interested to deploy there service in low-dense areas. Therefore, the costs might be higher in these areas. In addition, it is important to take the possible negative impact of a shared-mobility system into account like stagnation and urban sprawl.
<u>High-dense areas and MaaS.</u>
In high dense areas are peer-to-peer ridesharing systems very successful. However it can lead in some areas (without a good PT system) to more congestion.
<u>Low dense areas and MaaS.</u>
It might be necessary to reconsider the public transport system in low dense areas and the business model behind it. When all this money is invested in the relocation of residents or facilities, it might decrease the mobility demand. However, when no action is taken by the government, self-organization of the residents of low dense areas might also be the solution to the scarcity in mobility.

Size of cars
Current AVs are very similar to the traditional car. However, in the future it might not be necessary to own one car that will be used for every trip (from holiday trips with the whole family vs. individual trips to work). AV-sharing might give people the opportunity to adjust the demand for a certain type of car to the type of trip. This is more comparable to public transport.

In order to summarize the answer to the question. What spatial actions are feasible?
<u>*Automated trains and metro's.*</u>
The automated train and metro also needs to be taken into account. On thick streams these lines can be split-up and operate more frequent without a driver. It becomes important to consider the part of every station in the whole chain. Do not only focus on a good PT in the Randstad. Regional PT will still be necessary. Otherwise private car use between high- and low-dense will still result in congestion in the large cities. However, it will be possible to make less stops between large stations and middle large stations in order to save time. Most people make mobility decisions on aspects like comfort and ease and not on the greater good for the whole community. Only when the problems become too big, but than it is already too late.

E. Relevancy of the research to the master program

It is a relevant research within the Complex System engineering Master program, because it is embedded within several scientific disciplines, namely: urban planning, renewable energy and mobility and thus is about the management of stakeholders with widely diverging interests. The research employs methods for creatively designing and assessing the impact of technical solutions on the urban system and therefore contains both effective management strategies and system engineering approaches. Besides, it is scientifically as well as societally relevant, because the main causes for the rise of smart mobility and energy neutral buildings are new technologies (technological relevance) and the changing attitude of society towards sustainable solutions (societal relevance). Lastly, it is considered that the government adjusts policies and regulation to these innovations (institutional relevance). Scientific research is being done on smart mobility techniques, but not on the urban effects of smart mobility and how we can integrate this in urban planning in order to create energy neutral cities. There is a lot of scientific research being done to energy neutral buildings, but not on how we can integrate the new smart mobility techniques in the design of our buildings. Lastly, there has not been much research on the interaction between public and private organizations that are working on these projects.