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

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ABSTRACT

The transition towards fully Automated Vehicles (AV) can lead to inefficient use of the available infrastructure in the Netherlands, while space is already scarce. - Knowledge from AV impact studies can help the government in the management of available infrastructure. Therefore, in this research a systematic literature review was carried out in order to describe the spatial impact of AVs. Secondly, this research used an interview method, a workshop and a questionnaire, to show how Dutch stakeholders (urban planners of the government and transportation companies) perceive these impacts and what actions they are planning to take in reaction to these impacts. The results showed that urban planners are worried about introducing AVs but despite these worries, the introduction of AVs is not included in most strategies and policies. The actions that are preferred by most of them to manage potential negative AV impacts are stimulating car-sharing, public transport and bicycle use and discouraging private vehicle use by parking policies. These actions are supported in the literature. Recommendations for further research are on estimating the effect of these actions in practice and on evaluating the potential support of citizens for these actions.

1. THE INTRODUCTION OF AUTOMATED VEHICLES TO THE URBAN SYSTEM

The Automated Vehicle transition will cause the gradual shift from human controlled vehicles to self-driving autonomous vehicles over within 15 to 30 years. This might eventually lead to a regulatory automation level requirement for all new cars (Milakis, Arem, & Wee, 2015) and (Levinson, Boies, Cao and Fan, 2016). There is however no certainty about the timeline.

The development of AVs will first have an impact on the transportation sector. AVs are a new mobility concept, that might need other infrastructure than the traditional types of vehicles. This new infrastructure requires land. 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. Lastly, the space to build is scarce in the Netherlands. Both the urban system (consisting of functions like: working, residential, recreation and

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 infrastructure requirements for AVs are currently very uncertain.

Transportation and land-use are interrelated in the urban system. In order for citizen to access functions in urban areas, infrastructure is needed to facilitate mobility (Jorritsma, Tillema, & Waard, 2016). Therefore, the introduction of AVs may change future mobility choices and travel patterns on which urban planners base their decisions for the location of functions. Therefore, urban planners should include this change in use also in their plans (Childress, Nichols & Coe, 2015).

other daily needs facilities) and the mobility system (consisting of infrastructure, like roads and parking) 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.

There are a lot of factors that influence a good implementation of AVs in the urban system. First of all, it is important that the available infrastructure is sufficient for this new mobility concept, in order to prevent congestion. Congestion will lead to a decrease in accessibility. Therefore, it is necessary that AVs make efficient use of the available road capacity. Efficient use can be defined as the maximum amount of people that have access to their daily destinations, served by a mobility concept that uses infrastructure which requires the lowest amount of land. The infrastructure that a mobility concept uses consists of roads while moving from A to B, parking to store the vehicle when it is not used and pick-up points to access the vehicle or drop-off points to access the destination. It is expected that AVs will first require more land for their infrastructure, but eventually over time require less land.
This issue can be summarised as the contradiction between road capacity increase which might evolve from narrower following distances and more efficient parking and the inefficient use of this road capacity. Less car-ownership (stimulated by the increased ease of AV-sharing, because the vehicle can drive itself to the next user) might lead to a decrease in the need for infrastructure. However, vehicle sharing might also lead to more vehicle kilometres travelled (VKT), to pick-up user. In addition AVs might lead to an increased car-travel-demand (increased value of time during trips and non-drivers are enabled to drive) (Thomopoulos & Givoni, 2015). Both will lead to more VKT by cars and thus to more congestion.

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, which eventually might lead to restrictions or even the prohibition of the use of AVs. 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. Therefore, all the stakeholders, both private and public, in the sectors transportation and spatial planning, should be included in the decision making process of the implementation of AVs in the urban plan.

2. DEFINING AN APPROACH TO COPE WITH AVS IN URBAN PLANS.

Even though the timeline is uncertain, It seems wise to integrate the impact of AVs already in urban plans, because the urban and transportation planning sectors are envisioning plans with a time horizon of 2040 and beyond. However, it is not clear if urban and transportation planners consider the development of AVs in their plans.

The impact of AVs is also uncertain. There is a lot written about the assumed impact of AVs. However, there is not yet an clear overview of the impact of AVs, that are specifically related to land use and spatial planning. 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 done to the potential impact of AVs on urban planning.

In addition, spatial and transport planners can steer the development of AVs. Therefore, it is also interesting how they perceive the impact and timeline of AVs. However, the actors in the system have not taken clear positions in this debate and stated how they perceive the impact. It seems that urban and transportation planners might not incorporate the impact of AVs in their plans at the moment, because these new technologies are very uncertain. There is not much data from research on the implementation of AV scenarios in planning methods in the Netherlands. Besides there is no research done to perceptions and related behaviour of other stakeholders in the system. 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 topic, due to competition considerations. In policy document and strategies of organizations is the spatial planning and transportation planning, is very little written about the expected impact and related actions. Therefore, in the second phase of the research, an 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.

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 should therefore 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 however 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. However, 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. However, this is not available yet.

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.

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.

3. RESEARCH METHODS

In this chapter the research methods are described, in order to develop an approach for urban and transportation planners to cope with the irreducible uncertainty of the Automated Vehicles transition.

First, a literature study is conducted in order to gather theoretical insights in the expected impact of AVs and the related proposed actions. 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. In this way the first research question can be answered. The expected impact of AVs on the urban mobility system and the related possible actions are researched 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.

Secondly, a field research is conducted in order to compare theoretical insights with insights of practices in real-world-settings. This approach is based on the 'learning cycle' from Kolb and Fry (1975): by conceptualizing observations from cases and reflecting on it, it becomes possible to use the acquired insights into new situations (Kolb & Fry, 1975). The research makes the connection between planning science and practice, 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 can be answered.

A field research is conducted in the province of North-Holland. North-Holland is an interesting research subject, 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 the metropolitan area Amsterdam is 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 these 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

First, 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 desk research, with/amongst 20 respondents. The questions are open-ended and can be asked in any order. The interviews are transcribed and analysed with the use of the content analysis method. 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.

Secondly, a selection of insights from these results are further explored by conducting a survey and workshop under a selection of participants of the same sample of respondents. The selection is made in order to create more immersion in the answers of the respondents. The survey 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 survey consisted of clear defined positions and multiple choice questions. The survey is answered by 15 respondents, in order to find out which impacts are considered positive or negative. 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.

The workshop is conducted with 9 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 actions. Participants discuss what positive and negative aspects of the actions are and what preferences stakeholders have for certain actions and why. The advantage of this method is that stakeholders are triggered to discuss how spatial planning can influence the transition towards fully AVs. In this way the researcher can observe interactions between stakeholders during a multi-actor decision making process. In addition, the unintended intervention of the conversation (by sub-questions from the researcher to keep the conversation going) is removed, which lowers the risk of informal manipulation. The workshop is held with stakeholders, in order to give recommendations on what actions can be taken in order to achieve the preferred future scenario of AVs. The stakeholders can give feedback on these recommendations, which will accelerate the multi-actor decision making process of the implementation of AVs and creates the connection between the planning science and planning practice.

4. THE IMPACT OF AVS ON URBAN PLANNING

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.

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 can be organised (Litman, 2018).

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, Friedrichs, van Balen, & Wolf, 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, Gerdes, Lenz, & Winner, 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, De Gruyter, Currie, & Delbosc, 2017)
Increase ride-sharing.	D Parking D Lanes	+	++	D	D	D	D	I	D				D	(Childress, Nichols, Charlton, & Coe, 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 = ++

In this research all external factors are combined (summarized in Table 1 on the previous 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).
Parking distances between vehicles can decrease. This will lead to an increase in road capacity.
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. This will increase the overall VKT and the mobility demand for AVs and therefore decreases the road capacity. 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.
Therefore, 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 people might be less inclined to use an AV instead of other mobility concepts. This might lead to an overall decrease in VKT and thus an increase in road capacity. When the waiting time is not considered as an issue by users the amount of VKT will increase and the road capacity will decrease. The mobility demand stays the same.
In addition non-drivers are enabled to drive. This will lead to an increase in mobility demand and VKT. Therefore, the road capacity will decrease.
There might appear a decrease in vehicle-ownership, because it is more easy 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 an shared AV will decrease per person and therefore the mobility demand might increase. Therefore, the overall road capacity will decrease.
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 increase the road capacity.
Lastly, There might be a decrease in the mobility demand for walking, public transport and bicycle use. This is caused, users 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.

The field research showed that , there is disagreement between stakeholders about the time that the AV transition takes. Some think the timeline described in literature is right (9 respondents). However, some assume that it will take longer (6 respondents), especially to implement the technology in city centres, with their complex traffic situations. Some respondents think the transition time will be shorter (2 respondents). Some respondents could not or would not answer the question, because they thought there was too much uncertainty (5R). Some 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. However, there is a shift to a more anxious attitude towards the impact of AVs. Some 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. Many respondents name (3 respondents) the possibility of and some are even worried that, the ownership rates (6 respondents) and vehicle use (13 respondents) might increase and will mitigate positive effects. 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. 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, 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.

5. Proposed actions to cope with AVs

In this chapter the proposed actions found in the literature study and the field research are presented.

5.1 Literature

In this section the possible actions that can mitigate the negative effect of AVs described in literature are summarized.

1. Moving parking garages to outskirts, to reduce land dedicated to parking in city centres. 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. The decreased need for parking solutions in the city centre, can lead to more land available to public functions or homes, thus an increased density in metropolitan areas (Anderson, et al., 2014).

2. Adjust infrastructure and regulation to stimulate 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). 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. Car-sharing and ride-sharing can become popular, when the land that becomes free is used for development of infrastructure dedicated to this mobility concepts, like kiss and ride stops or parking especially for vehicles with multiple users. Shared AVs are likely to decrease vehicle ownership. Case-study results indicate that in a system of shared AVs, a car can be shared between 10 passengers (Milakis, Snelder, van Arem, van Wee, & Correia, 2016), (Fagnant and Kockelman, 2014). Due to the low price of automated car ridesharing, some academics are stating that the government should not invest in public transport infrastructure anymore, because in the future automated cars might replace public transport systems. 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 of shared-cars and public transport can compete (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017). Public transport infrastructure has a long return on investment time and decisions are taken a long time in advance of the development. The investments that are done now, can appear a waste in the future. However, public transport is more space efficient, than shared AV cars. Therefore, public transport AVs should be stimulated, like buses, trains, trams and metro's, in order to compete with private and shared automated cars. In that way, public transport can become cheaper (because no chauffeur is needed) and drive on demand (the vehicle can be called by users via an online platform).

3. Construct drop-off and pick-up lanes. Vehicles that are driverless are able to drop off passengers, redeploy to park or pick up new passengers. 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). 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, in order to prevent congestion on the regular roads (Tillema, Gelauff, Waard, Berveling, & Moorman, 2017).

4. Introduce road-pricing to discourage private vehicle use and empty vehicle travel.
In the situation that the main negative impact is, that the demand of private cars increases, because traveling by private car becomes cheaper, easier and accessible to non-drivers. Careful pricing of roads and rides can prevent that automated congestion arises (economist, 2018). 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). Road space that is no longer needed for storing cars in cities, can also 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). In addition, AVs can stimulate an increase in Empty Vehicle Travel (EVT). AV-sharing would for example incur about 11% more VKT to reach the next passenger (Sivak & Schoettle, 2015). VKT will be increased by 3-9% in 2035 (Trommer, Kolarova, Fraedrich, & Kroger, 2016). When picking-up/dropping-off or wait for new passengers, it might be even cheaper in high density areas for an AV to drive around, instead of paying high parking fees, which increases VKT even more. This is caused by the current parking policies and lack of road-pricing policies of the system. Therefore, Empty vehicle travel should become more expensive than parking.

5. Construct attractive bicycle and pedestrian lanes. 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.

6. Develop mixed functions living areas and stimulate concentration near 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, 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 (Litman, 2017).

5.2. Stakeholders

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. These actions are split up in actions that are taken by the transportation sector or the spatial planning sector. In the transportation sector the following actions are considered. 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 respondents named this as an option) or 2. Discourage private vehicle use and ownership. The option is mostly named by stakeholders from the government. Stakeholders that name the second option, named actions like: stimulating the increase of the number of users per vehicle (10 respondents), by the use of parking policies (10 respondents), the decrease in vehicles sizes (3 respondents) and the introduction of ownership charges (2 respondents) or decrease vehicle use, by the use of parking policies (10 respondents) or road pricing (12 respondents). However, there is not a lot of support for road pricing, some respondents even state that it is a forbidden word (5 respondents). There is also support for repulsing certain types of mobility concepts (10 respondents) and giving priority to some logistic streams in cities (11 respondents). Influencing the mobility choice of citizen is also possible 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 (2 respondents), others named it as an option but are very uncertain about it (7 respondents). In the spatial planning sector, the following actions are considered. 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.

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6. Interactions between stakeholders of the AV transition

From the interviews it became not clear, what actions from all these options, are supported and preferred by most stakeholders. Therefore, a survey and workshop is held, in order to select the most relevant actions.

If there is something everyone would agree on, it is that road pricing [action 4, from literature study] would most certainly discourage vehicle use and decrease VKT (12 respondents). However, road pricing is also considered a forbidden word (5 respondents); a subject people would not dare bring up in conversation. 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.

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 (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). 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 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). Policy related actions that discourage ownership and might increase the number of users per vehicle are: parking policies (10 respondents), increasing ownership charges (2 respondents) and decrease the size of vehicles (2 respondents). 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 actions that stimulate car-sharing are: reserving space for a sharing system buffer (4 respondents) while reducing the number of shared vehicle service suppliers (2 respondents), creating drop-off and pick-up points (3 respondents), develop special parking for shared vehicles (3 respondents).

Literature also states that [4] 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. 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 do not have an apparent downside to it. Therefore, it is a no-regret action.

Lastly, in the field research it is recommended that public transport use is encouraged. Popular actions are: give priority to some logistic streams (11 respondents), 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 (4 respondents), make MaaS-concepts 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).

7. Conclusion and recommendations for future research

In this chapters first a conclusion is drawn from the results of this research. Secondly, recommendations are given on future research.

7.1 Conclusion in this research

First of all, 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. 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 appeared 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 only impact where a lot of consensus is, 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, there is not enough support for this action under stakeholders. The actions that are described in the literature, that have a lot of support of stakeholders in the urban and transportation sector are the following: 1. stimulating the use of public transport and bicycles, in order to increase the use and mitigate the expected increase in car-use and 2. adjust parking norms in order to discourage car-use.

In addition there is a lot of uncertainty about the impact of AVs on car-sharing. Sharing cars will only lead to a decrease in parking space, but not in VKT. Sharing rides will lead to both a decrease in parking space as in VKT. However, car-sharing is always preferred above private car-use. Therefore, it seems wise that car-sharing is stimulated by adjusting parking norms and developing parking sport and pick-up and drop-off points for shared-cars, to decline the amount of Empty Vehicle travel (EVT) and stimulate users to share rides. There are also 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).

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 an increase in the mobility demand and VKT, which will in turn lead to reaching the limits of the current 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.

7.2 Recommendations for future research

Recommendations can be split-up in recommendations in planning practice and planning science. 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). Recommendation for further research are on 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, surveys, serious gaming, etc.).

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