Hoe helpen autonome voertuigen de mobiliteit in de stad van de toekomst vooruit?

Luuk de Vries – Sweco – luuk.devries@sweco.nl
Jeroen Quee – Sweco – jeroen.quee@sweco.nl
Matthijs Withagen – Sweco – matthijs.withagen@sweco.nl

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Samenvatting

Mobiliteit is aan het veranderen. Nieuwe technologieën volgen elkaar in een rap tempo op en worden steeds belangrijker en ook als oplossing gezien op twee belangrijke ontwikkelingen in het verkeer: het aantal ongevallen in het verkeer is weer aan het stijgen, en files en filezwaarte nemen steeds verder toe. Traditionele oplossingen zijn verkeersmanagement en aanpassingen in het beleid. Parrallel hieraan ontwikkelt zich nu een nieuwe trend: (volledig) automatisch rijdende voertuigen. De verwachting is dat deze in de komende decennia het straatbeeld gaan veranderen. Het zelfrijdende voertuig heeft het potentieel om de stad van de toekomst bereikbaar, veilig en leefbaar te houden. Het is belangrijk om meer onderzoek te doen naar zelfrijdende voertuigen om het potentieel te kwantificeren.

De meeste studies naar zelfrijdende voertuigen worden uitgevoerd vanuit de gedachte dat met deze technologie mobiliteit in de toekomst zal veranderen. De algemene conclusie van deze studies is vaak dat om het potentieel van zelfrijdende voertuigen te benutten aparte infrastructuur noodzakelijk is. Dat terwijl vanuit de beleidshoek steeds meer stemmen opgaan om het verkeersnetwerk niet verder uit te breiden. In ons onderzoek volgen we een radicaal nieuwe aanpak, waarin juist de positieve eigenschappen van het zelfrijdende voertuig op de mobiliteit in (en vanuit het oogpunt van) de stad van de toekomst centraal staan. We voeren dit onderzoek samen met de Universiteit Utrecht uit. Het doel van ons onderzoek is om die positieve eigenschappen te kwantificeren. Onze scope is de stedelijke omgeving. We geven een uitwerking van de parameters die voor het voertuiggedrag om zelfrijdende voertuigen in microsimulatiemodel te simuleren (in Paramics).

We identificeren aan de hand van de resultaten van een literatuuronderzoek naar zelfrijdende voertuigen de belangrijkste effecten en ontwikkelingen. Vervolgens hebben we diverse experts binnen het vakgebied van de mobiliteit geïnterviewd over de toekomstige binnenstedelijke mobiliteit. Aan de hand van deze resultaten is een viertal toekomstscenario's gedefinieerd voor de stad van de toekomst en de rol van het zelfrijdende voertuig daarin. De scenario's zijn getiteld: 1) Moderne Stad, 2) De leefbare stad, 3) De intelligente stad en 4) De comfortabele stad. Ieder scenario vraagt om een andere set aan eigenschappen van zelfrijdende voertuigen. Op het moment van schrijven van dit paper zijn we bezig met de laatste onderzoekwerkzaamheden, betreffende het vertalen van deze eigenschappen in parameters voor microsimulatie en het doorrekenen van de effecten op het Paramics-model van Eindhoven. We zullen uitkomsten en nadere analyse presenteren op het colloquium.

Mobility is changing rapidly as new technologies are recently becoming more and more accessible and available. In the Netherlands ten million commuter trips are made every in 2013/2014. The average daily travel distance was 32 km and 73% of that distance was covered by cars (Centraal Bureau voor de Statistiek, 2016). Dutch citizens spend a lot of time in their cars. Mobility is very important to Dutch society, but participating in traffic is not without risks. In 2015, 621 people died as a result of traffic accidents and in 2014, 20.700 were seriously injured (Centraal Bureau voor de Statistiek, 2016). This alarming number of casualties shows the importance of the need for new technologies in order to improve traffic safety.

Besides the amount of accidents, there is a second problem to address, which is the time loss caused by traffic congestion. Recent years show an increase in the level of traffic congestion. Compared to 2014 the number of vehicle hours in 2015 rose by 22% while the total traffic in that period only rose by 2%. It is expected the travel time lost because of e.g. traffic jams, will continue to increase in the future. Bluntly expanding the road network has proven to be unsatisfactory in the past. Additional mobility management measures are needed to reduce the increasing of traffic flows (e.g. road pricing, road user charges, investments in other modalities etc.). Some of these measures however are complex and do not guarantee success in limiting mobility, traffic growth and congestion.

Parallel with the development of mobility management policies and traffic management systems the automotive sector shows the development of autonomous functions in cars. It is expected that these technologies will gain acceptance within some 10 years and will lead to a rigorous transformation of the mobility system (Gruel & Stanford, 2016). It may be considered as the contribution of the automotive industry to the problems that mobility faces today. Autonomous vehicles are considered to have the potential of being a solution for keeping urban environments accessible, safe and livable in the future.

Another angle to approach developments
Most studies within the area of autonomous vehicles take the technology of autonomous driving as a starting-point (e.g. CPB (2015), Fagnant (2015), Kennisinstituut voor mobiliteitsbeleid (2015), BCG (2016) and Milakis et al. (2017)) and investigate the consequences of the introduction of this new type of transportation for mobility and traffic. This may however not be a desired approach to address the possibilities the new technologies bring to the mobility syzstem, because it is often seen the studies result in expansion of infrastructure to accommodate all transportation types. Local and regional transportation policies however do not seek ongoing road expansions.
In this paper we propose a radically different approach as it seems far more intuitive to consider how features of autonomous driving can actually contribute to mobility within the cities of the future in a positive way. Through study of literature, interviews with experts within the subject of future mobility and autonomous vehicles, four future scenarios are produced. The final result of this paper is an overview of the development and a characterization of these scenarios.

Towards quantification

To add new insights to our developing knowledge of the future mobility with autonomous vehicles this research is also aimed at quantification of the future mobility with autonomous vehicles. The focus is on the *urban* environment. This study aims to give an insight into the parameters that characterize traffic flow and their valuation to make simulations of autonomous vehicles in microsimulation traffic models possible. This will lead to insights in the development of traffic models which include autonomous vehicles. State-of-the-art inclusion of autonomous vehicle behavior within simulated urban environments. This will give policymakers the opportunity to make better decisions to keep the cities of the future livable and accessible.

This paper gives a first overview of the proceedings of the research as it is executed by Sweco in cooperation with Utrecht University. Paragraph 2 of this paper describes a theoretical background and derives relevant effects of autonomous vehicles. Paragraph 3 describes the further approach of the research and introduces the building of scenarios. In paragraph 4 the scenarios are presented and quantified. In paragraph 5 the approach using microscopic simulation is described. In the last paragraph 6 preliminary concluding remarks are made and on ongoing research is described (period until November 2017).

2. Theoretical background and focus on the effect of autonomous vehicles

2.1 Levels of automation

It is important to understand the definition of levels of automation used in this (and most other) research. The Society of Automotive Engineers (SAE) International has conducted a classification of six levels of automation: from 0 to 5 (figure 1). At the levels 0, 1 and 2 the human driver monitors the driving environment and controls all the driving tasks. At the other 3 levels the automated driving system monitors the environment and has the possibility to take control of all the dynamic tasks. It is only at level 5, which is fully automated, that the driver is not expected to check anything at any time during the trip. At level 3 and 4 the driver still needs to be available for occasional controlling (SAE International, 2014). In this study level 5 - the highest automation level, representing the most radical changes in the urban mobility - is used as basis for the research and model simulation.
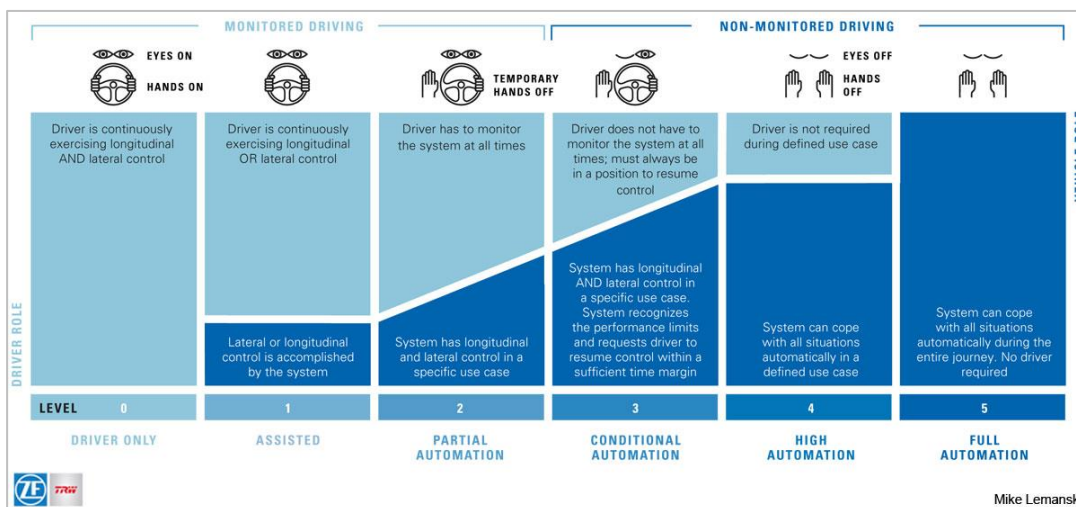

Figure 1: Illustration of levels of automation

2.2   Implications in ripple scheme

Autonomous vehicles can have a huge impact, depending on the level of automation achieved. The Society of Automotive Engineers (SAE) defines four driving tasks that can be (partially) taken over by an automated driving system.

When more of the driving tasks become automated, more positive effects are expected in future mobility. This effect is described by Milakis et al. (2015) as ripple scheme effect, in relation to the level of autonomation achieved. Every ripple is divided into categories that are influenced by the level of autonomation. This categorisation provides a guideline in order to go more deeply into the possible effects of automated vehicles with respect to sustainable mobility in the city and its effects on e.g. safety, living space, public health, energy consumption and environment.
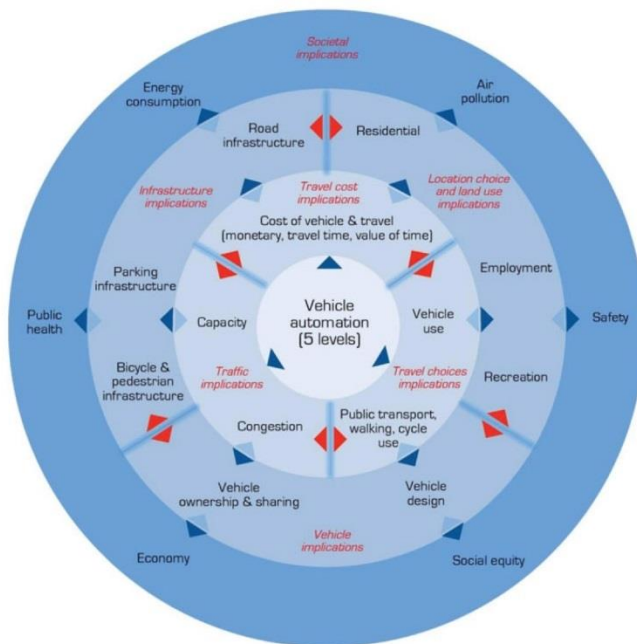

Figure 2: Ripple scheme of implications of autonomous vehicles, the inner ripples describe the most forward levels of automation from conditional automation and up (as defined by SAE (2014)) the outer ripples will be influenced as well (Milakis et al., 2015).

2.3   Effects of Autonomous Vehicles

The most successful new technologies do not only help to solve problems, but also contribute to the travellers' comfort (Milakis et al., 2015). One of the technologies for which this is valid is the development of autonomous vehicles (Gruel and Stanford 2016). The automotive industry aims to respond to traffic and transport problems such as congestion, unsafety and environmental impact. At the same time the industry aims at the market opportunities resulting from the increase of the drivers' comfort.

One of the first ideas and predictions with respect to cars that could drive by themselves came from the General Motors' highly influential Futurama exhibition in New York in 1939. They argued that from 1960 onwards it would be possible for cars to correct human faults while driving (Townsend, 2014). Although these predictions have proven not to be realistic, it seems that the technology of automated driving now has come to a

level that makes live implementation possible. The automotive industry has invested in autonomous vehicles, governments allow pilot programmes and ICT companies put a lot of effort into the technology backbone. Autonomous vehicles have the potential to increase the road capacity, contribute to a safer mobility system, reduce travel cost, provide mobility to elderly and disabled people, save fuel and lower greenhouse gas emissions and reduction of infrastructure. Besides this, there are a lot more advantages, when sharing rides and vehicles becomes 'normal' and may lead the automotive sector to become an on-demand service (Fagnant and Kockelman 2015).
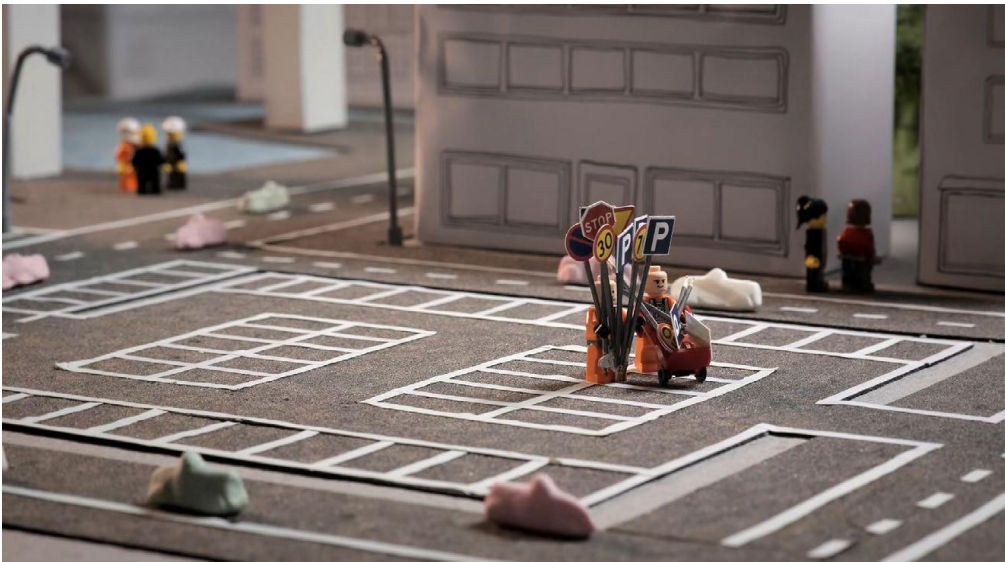

Figure 3: The Drive Me project visualised possible implications of automated vehicles. Above, a still from the video 'Drive Sweden – our vision – A new approach to mobility' shows the removal of superfluous signage and parking places

Currently, new entrants on the market such as Apple, Tesla, Uber and Google have started to influence the automotive industry towards more ICT based solutions (Fagnant and Kockelman, 2015). Experts expect that the development of autonomous driving will go fast and that fully automated vehicles will reach the market between 2020 and 2030 (Underwood, 2014; Litman, 2014; Zmud et al., 2015). A research of Kyriakidis et al. 2015 explored the public opinion based on an internet questionnaire survey with 5000 respondents from 105 countries. 69% expected fully automated vehicles to reach a 50% penetration rate by 2050. Tony Seba, lecturer at Stanford University predicts in 2030 all mobility will be autonomous and shared. His vision on the disruptive development of energy and mobility urges to look at mobility and the autonomous vehicle in a fundamental way (Seba, 2014).

So autonomous driving seems to be a promising technology to keep the city attractive in the future. But is this true? Several articles are skeptical and point towards the difficulties during the transition phase towards 100% autonomous driving. Also some researchers investigated scenarios that showed that the implementation of autonomous vehicles does not lead to the results car manufacturers promise (Milakis et al., 2017; CPB 2015). Aspects such as possible increasing peak-hour travel volumes should be seriously addressed, according to a case study performed for the city of Lisbon as a result of a research by the international transport forum (2015).

The introduction of autonomous vehicles may change the entire mobility 'landscape' in our cities. That the major part of our mobility will be provided by clean, electric, autonomous vehicles may not be uncertain any more. But how will this affect major factors in the travel patterns, one of the most important of which is the change in the value of travel time. This again is related to travel patterns, on which ICT will have a strong influence. The way our society will develop in relation to these effects is yet uncertain but more insight is needed to define paths towards our 'desired' cities……

3. Scenario building

3.1 Scenarios and how to make them

To bring structure in the wide variety of possible 'futures' for mobility in cities for this research an approach using scenarios is chosen.
In this chapter the scenario-building theory is summarized with the intention to distillate interview questions and plausible future scenario's with respect to the effects of autonomous vehicles.
In this research the framework proposed by Börjeson et al. (2006) is adopted. In this framework scenarios are divided into three main categories. These are based on principally important questions for the use of scenario analyses and come down to the following:

- What will happen?
- What could happen?
- How can a specific target be reached?

The categories that are linked to these questions are *predictive*, *explorative* and *normative* scenarios. Each category is divided into two types of scenarios:

- *Predictive* scenario's: forecasts and what-if scenarios.
- *Explorative* scenario's: external and strategic scenarios.
- *Normative* scenario's: persevering and transforming scenarios.

Each of these categories has its own features and is therefore only applicable in a certain situation. First of all it is important to choose the most useful type of scenario analysis for this research. The purpose of conducting scenarios is to create optimized prospective situations concerning mobility and infrastructure. Secondly we have to find out how automated vehicles can contribute to the realization of ideal circumstances. The design of scenarios seems to be the most useful one within this context as it helps answering the question on how to optimize the circumstances (Börjeson et al., 2006). For this purpose the eleven steps of scenario building are thoroughly followed. In brief, these steps are characterizes as follows:

The first step: determining the issue of concern and make explicitly clear, what the reason of scenario building in this context is and also what the time frame will be in which the scenarios can be executed.
The second step is to challenge the perception of scenario building participants.

The third step is to identify the key driving forces influencing the issue of concern. Driving forces can be events or trends that might influence the issue of concern.
The fourth step is to identify the key stakeholders.
Step five is about ranking the driving factors.
The sixth step is to cluster the driving forces. In order to form clusters, synergies or causal relations between driving forces should be investigated.
The seventh step consists of the initial construction of the scenarios.
The eighth step is to construct a narrative structure for the scenarios (Chermack, 2007; Ratcliffe, 2002).
The ninth step is to check the scenarios of plausibility. It should be possible to actually unfold the scenarios as described (Chermack et al., 2001; Heinecke & Schwager, 1995; Wilson, 1998).
The tenth step is to flesh out scenarios that do not perform in all subdivisions of step nine. Even after having completed this step it is still possible to redo a part of the process again if necessary.
Finally, *the eleventh step* is using the scenarios. When the scenarios are used, the elaboration will be monitored and again the process could be repeated, because when using the scenarios new possibilities might arise.

Based on this eleven-step framework the next steps in the research are taken in the form of interviews with experts followed by the development of the actual scenario's.

KIM scenario's
In 2015/2016 the Kennisinstituut voor Mobiliteitsbeleid (KiM) has developed scenarios for the development of autonomous vehicles (KiM, 2015). The scenarios in this research can be considered as further development aimed at application in simulation models.
The scenarios for this study are developed for fully autonomous vehicles (level 5) and zoom on the mobility and traffic patterns in cities.

3.2   Interviews with experts as input for scenarios

Interviews with professionals working on the topic of automated vehicles show that expectations are still widely varied. In the interviews the focus was set on level 5 of automation. On the level of local communities there are ideas that lead to vision on strong improvement of the city life. For example in the city of Eindhoven, the belief in the development of automated vehicles seems to be influenced by the cities' actual policies and financial scope. For instance the decline of income from parking fees is seen as a serious disadvantage. The introduction of vehicles with autonomous driving up to level 4 is expected within 10 years, level 5 is expected to be introduced in a later period of time.

However, cities want 'to be ready' for autonomous vehicles and are seeking possibilities to offer (road)space for experiments and test sites.

The positive effects for the livability of the city seems not to be very widely recognized. Professionals of the PBL (Planbureau Leefomgeving) show some skepticism towards autonomous driving and emphasize the step-by-step introduction. Technical development and regulation are important issues to be addresses and this may slow the introduction of automated vehicles in the city.

In the world of universities there is much enthusiasm for the development of automated vehicles (for instance Delft, Eindhoven, Utrecht and Hasselt). Universities are working on the quantification of travel time and time loss caused by congestion as well as improved traffic safety. Also universities are working on the implementation steps and develop views on road networks for situations with mixed (automated and non-automated) vehicles as well as situations with only level 5 automated vehicles. The 'mixed' situation may prove to bring more problems than a future with only full automated vehicles. The rapid introduction of ICT and Artificial Intelligence in daily life is – as for instance seen by the University Utrecht – a catalyst for 'mobility as a service' systems facilitated by automated vehicles.

The sharing of vehicles, which can be optimally used in combination with automated vehicles, may be a strong factor in the introduction in cities.

Not but not least the vision of automated vehicle professional Lauren Isaac from San Francisco emphasizes the giant positive effect of 'driverless cars' for mobility. In the not so far future people will show disbelief thinking there was a time the drivers had to operate the vehicles themselves. Still she points at the possible overflow of the traffic system caused by the multitude of new trip possibilities.

Figure 4: Increased value of time due to comfort and the ability to spend time freely on work or recreation

4. Scenario's for the city with autonomous vehicles

4.1 Scenario building in eleven steps

In this paragraph four (extreme) opposite scenarios are built as a result of the interviews with experts and by applying the scenario building methodology of Börjeson (2006). The scenarios form a basis for the next step in the research: quantifying the expected autonomous vehicle behavior for modeling within a micro simulation environment. The following steps explain how the scenarios have been established.

Step 1: Setting the issue of concern
The issue of concern is that scenarios are developed which represent the mobility of the future city from which characteristics of automated vehicles can be derived. These characteristics of the scenarios will be used to find suitable parameters of autonomous vehicles which will mimic driving behavior of autonomous vehicles in the future. Probable parameter changes are expected for e.g. the influence of acceleration, deceleration and speed limit on the traffic flow, the behavior of the vehicle types, expressed in aggression and awareness, the vehicle features, such as minimum gap, gap acceptance and main headway and last of all the route choice, expressed in familiarity, cost factor and the route choice formula. The timeframe within which these scenarios are set to be reality are at the time that automated vehicles are dominating the street view. Which could be as early as 2030 (Seba, 2014).

Step 2: Challenge the perception
During the development of the scenarios, a building scheme was taken into consideration and brainstorm sessions with experts gave shape to the several possibilities. The sessions were informal, which gave room to participants' (extreme) creativity and a bigger variety of described future scenarios.

Step 3: Identifying key driving forces.
In this step the thought up scenarios are investigated for key driving forces. With the issue of concern leading towards application in a microsimulation traffic model, key factors identified are related to: changes in activity patterns, changes in motivation as far as travelling and changes in possibilities for movement.

Step 4: Identifying key stakeholders
The following key stakeholders are identified: (new) residents, elderly, young families, the public transport sector, tourists, students, highly educated, entrepreneurs, long-time residents, expats, and governmental institutions. All these stakeholders influence the mobility policy and direct or even indirectly, the key driving factors.

Step 5 & 6: Ranking and clustering key driving forces
In step 5 the key driving forces are ranked according to likelihood and impact. In step 6 the synergies and causal relations between the driving forces are explored and clustered. Important driving forces are: activity patterns, trip motives and trip possibilities.

Steps 7 to 10: Initial construction, narrative creation, check scenarios and Selection.
From this point onwards, we slightly deviate from the scenario building methodology as a more suitable iterative approach is adopted. In this iterative approach, the steps 7 to 10

are merged and cycled through iteratively with expert judgement, results from the interviews and investigated literature. For the construction of dimensions, two opposite dimensions are found to be the most suitable within the scope of this research. This leads to four opposite scenarios. In this iterative process six different possible and suitable dimensions are found:

- high tech – low tech;
- connected – unconnected;
- traditional behavior – new behavior;
- car ownership decrease – car ownership increase;
- individual – collective;
- efficiency – experience.

Many of these dimensions have been tried out iteratively in different combinations and continuously checking with the adopted issue of concern. The two final dimensions adopted are: *individual – collective* and *efficiency – experience*.

Step 11: using the scenarios, is described in more detail in the next paragraph.

4.2   Overview of the scenarios
As a result of the described work method four scenarios are developed:
1) The Modernist city
2) The Pleasurable city
3) The Intelligent city
4) The Comfortable city.

Figure 2 shows a visualization of the categorization with the vertical-axis (Efficiency versus Experience) and horizontal-axis (Individual versus Collective) is provided below. A more detailed and vivid characterization for each of the scenarios, is provided in paragraph 3.4.
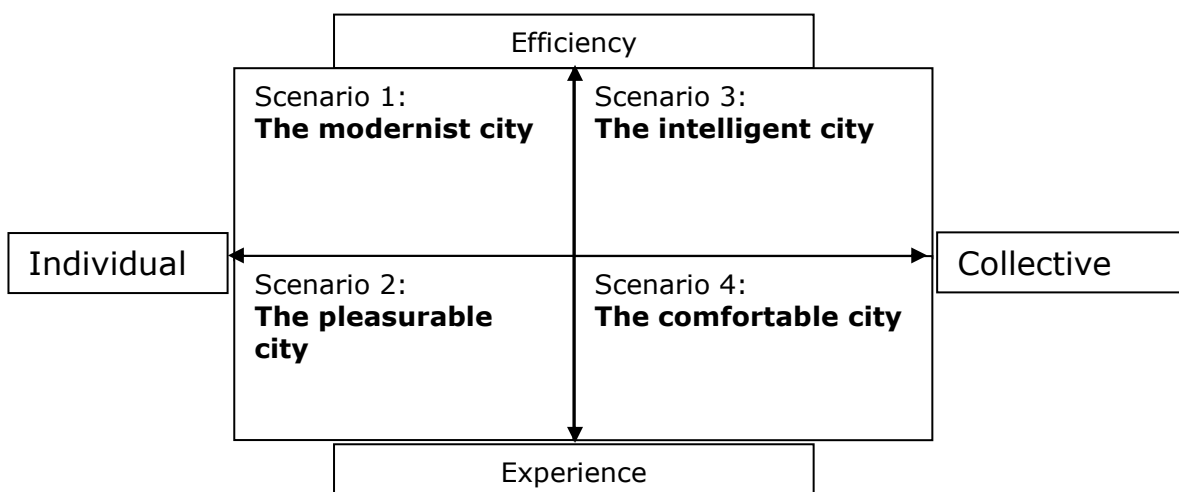
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                         ┌───────────────────────┐
                         │       Efficiency      │
                         └───────────────────────┘
          ┌───────────────────────┬───────────────────────┐
          │ Scenario 1:           │ Scenario 3:           │
          │ The modernist city    │ The intelligent city  │
┌──────────────┐                  │                       ┌──────────────┐
│ Individual   │◄─────────────────┼──────────────────────►│ Collective   │
└──────────────┘                  │                       └──────────────┘
          │ Scenario 2:           │ Scenario 4:           │
          │ The pleasurable       │ The comfortable city  │
          │ city                  │                       │
          └───────────────────────┴───────────────────────┘
                         ┌───────────────────────┐
                         │      Experience       │
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Figure 1: Overview of the drafted four scenarios for autonomous vehicles and the city of the future.

4.3   Description of the scenarios

The narrative of each scenario contains of a description of the mobility 'landscape' and a characterization with five main indicators.

4.4   The modernist city

In this scenario fast traffic is one of the backbones of urban policymakers. About 15% of the citizens share their mode of transport and connectivity between vehicles is restricted. All inhabitants have their own low tech vehicle. Vehicle behavior is expected to be within the low autonomation region. The behavior of autonomous vehicles is therefore more comparable to the current state of autonomous vehicles than to future full-autonomous vehicle behavior. The driver is still in charge of his own behavior like the aggression and awareness of the vehicle. Also route choice is flexible. The mobility in the city is built around and for autonomous vehicles, pedestrians don't have the attention and space they want. Travel times for vehicles are optimized.

Table 1: Summarized characteristics for the modernist city scenario

Slow traffic	**Fast traffic**
Partly Shared mobility	Only shared mobility
Unconnected	Connected
Traditional behavior	Advanced behavior
Low tech	High Tech

4.5   The pleasurable city

In this scenario the mobility of the city is designed to achieve a pleasurable experience for the inhabitants. In the city it is attractive to walk and cycle because traffic moves at low speeds. Every form of mobility form is shared. Around 25% the road-infrastructure is downgraded to create additional space for recreation within the city environment. The model split shifts towards more use of (electric-)bicycles. With augmented reality the trip can be made even more enjoyable and passengers are able to work and/or relax during their travels.

Table 2: Summarized characteristics for the pleasurable city scenario

Slow traffic	Fast traffic
Partly Shared mobility	Only shared mobility
Unconnected	Connected
Traditional behavior	Advanced behavior
Low tech	High Tech

4.6   The intelligent city

In this scenario efficiency, collective transport and information is important. Citizens do not own vehicles, but can order vehicles that arrive at their front door. Autonomous vehicles are the preferred mode of transport, because they are the most convenient and fastest. The vehicles and road network are super intelligent and technology ensures mobility is safe and traffic flow is fluent. All the cars are connected to each other and work together. With *a drop on and drop off system* every location is easily reachable. Additional infrastructure for pedestrians and cyclists is not necessary because, this way of transport is slow and considering the fast moving autonomous vehicles, more

dangerous. Through efficient use of vehicles, less parking space is required and thus a lot of space becomes available for e.g. recreational parks.

Table 3: Summarized characteristics for the intelligent city scenario

Slow traffic	**Fast traffic**
Partly Shared mobility	**Only shared mobility**
Unconnected	**Connected**
Traditional behavior	**Advanced behavior**
Low tech	**High Tech**

4.7 The comfortable city

In this comfortable city, the focus lies on experience and comfort of travel. Besides shared autonomous vehicles, other modes of travel are conveniently used. Every mobility form is connected and use of it is regulated by a mobility service. Vehicles are made to experience a nice trip by providing entertainment with augmented reality or the possibility to have work meetings. The vehicles avoid crowded places and shopping areas. This enhances the liveability of the city. The trips may take slightly longer then compared to the past, but this is compensated through a higher level of service.

Table 4: Summarized characteristics for the comfortable city scenario

Slow traffic	Fast traffic
Partly Shared mobility	**Only shared mobility**
Unconnected	**Connected**
Traditional behavior	**Advanced behavior**
Low tech	**High Tech**

Figure 5: Autonomous vehicles appear in public space

5. Towards the next step in the research: microscopic simulation

For simulation purposes vehicle parameters have to be adjusted and updated to adequately simulate the autonomous vehicles described in each of the scenarios. Therefore specific features for each scenario, with respect to mobility in combination with automated vehicles are determined.

Features of interest are selected through expert judgement based on the findings gathered from the interviews and further brainstorm sessions with these experts. These are: fast traffic vs slow traffic, partly shared mobility vs forced shared mobility unconnected vs connected and traditional behavior vs advanced behavior. These features are given the value true or false (see table) for each of the scenario's respectively.

The simulation software chosen for this study is the microsimulation-package of S-Paramics, frequently used for traffic studies in urban environments by Sweco in The Netherlands. Editable parameters in this package are: acceleration, deceleration, headway, aggression, awareness, minimum gap, gap acceptance, mean headway, speed limit, cost factor, route choice, route choice formula, familiarity and perturbation.

While initially default values are provided by the software developer, within Sweco these parameters are recalibrated for usage in Dutch infrastructure projects. Currently within the vehicle types categories, the autonomous vehicle-type is still absent. Though when (even parts of the) previously defined scenarios become reality, autonomous vehicles will influence road characteristics, vehicle behavior and traffic flow. And thus include key decision variables as for example road capacity, throughput and travel time (loss).

In this research values of the previously mentioned parameters therefore have to be calibrated and validated. The scope of this research is limited to a sensitivity analyses due to changes in parameters and their effect on vehicle hours. As a case study, the urban area of Eindhoven is adopted. Within this study area the parameters of: acceleration, deceleration, headway, aggression and speed limit of vehicles is changed within each of the scenarios. For statistic relevance, each simulation period is run ten times, after which the total sum of vehicle hours is reported. The changes in parameter values are determined through expert judgement in collaboration with experts at Sweco.

The determination of the 1st order effect of a parameter with respect to vehicle hours is exercised first. Additionally cohesion between parameter changes (2nd order effects) are investigated. Finally conclusions are drawn on the final parameter settings per scenario, its effect on (autonomous) vehicle behaviour and on the general mobility in the microsimulation case study area.

6. Preliminary results and follow-up

At the current time of writing, research is still ongoing. In this paper the current proceedings are reflected. In the next weeks, further results are expected in relation to sensitivity analysis of parameters, statistic relevance of parameters towards effects on vehicle hours and cohesion between parameters. We will present these results during the presentation sessions at the colloquium in November.

Preliminary results reveal that adjustment of acceleration and deceleration has little to no effect on the amount of vehicle hours within the Eindhoven case study area. We are currently investigating whether the parameter changes are perhaps not extreme enough or that other traffic flow related theories can explain the result (e.g. increasing the acceleration and deceleration within a city environment can be compared to real-life aggressive driving, with intuitively little to no effect on travel time within a city).

Additionally we will explore the effects of combining multiple parameters changes, the adjustment of infrastructure within the microsimulation to enable maximal effects of autonomous vehicles and where within the study are the change of vehicle hours is most apparent (e.g. in congested parts, free flow, near traffic lights etc.). Finally we will present an advise for a set of parameter changes and adjustments needed within the microsimulation package of Paramics, to integrate autonomous vehicle behavior within the software for each of the scenarios.

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