# D3.1 Social Scenarios for Autonomous Vehicles

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| Authors | Leen De Paepe (Ghent University)<br>Hossein Azadi (Ghent University)<br>Frank Witlox (Ghent University) |
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# 1. Introduction

## 1.1 The environmental issue

Transport contains a strong social and social-economical component because it is important in the everyday life of people and since it is a large economic sector in the European Union (EU). However, the transport sector today uses various fossil fuels which produce $CO_2$ and polluting emissions complemented with congestion (Eurostat, 2020). The demand for transport will only rise in the future, contributing to more emissions which cannot be cancelled out by green transport alone. In urban areas the demand can rise with 60-70% and $CO_2$ emissions with 26% by 2050 (International Transport Forum, 2018). The EU would like to cut 60% of the greenhouse gas emissions from transport in 1990 by 2050 to become climate neutral. The aim is to reduce transport emissions with a total of 90%. Focusing on inland passenger transport in the EU in 2017, the share of passenger cars is the greatest with 82.9%, followed by buses and trams (9.4%) and trains (7.8%) (Eurostat, 2020). If no measures are taken, it is expected that the number of passenger cars especially in cities will keep growing (International Transport Forum, 2018).

## 1.2 Electric shared autonomous vehicles

According to the International Transport Forum (2018), the most effective way to decarbonise urban passenger transport is to use electric shared vehicles and integrate them with public transport. Electric and shared vehicles in urban areas could lower $CO_2$ emissions with 60% (International Transport Forum, 2018). It is expected that the combination of electrification, sharing, and automation can reduce urban $CO_2$ emissions even more with 80% by 2050 worldwide. This will probably also lead to a reduction in traffic congestion (Fulton et al., 2017). Autonomous, self-driving, driverless, or highly automated (level 3 or more) vehicles can consist of cars, shuttles, or buses (Transport Systems Catapult, 2017). There are also a variety of services possible based on the bundling of vehicles, e.g. personal, small grouped, large grouped transit (Szigeti et al., 2017; He & Csiszár, 2018). Autonomous vehicles (AVs) can be connected with the surrounding infrastructure (vehicle-to-infrastructure or V2I) or to other vehicles (vehicle-to-vehicle or V2V). However, connectedness is not a necessary prerequisite for the operation of an AV.

Electrification, sharing, automation, and connectedness can have reinforcing effects on each other (McKerracher et al., 2017; Milakis et al., 2017). Shared vehicles can accelerate electrification, with a higher mileage the vehicles can become cost competitive and need to be replaced sooner which can advance the development of electric, autonomous, and connected vehicles. Different AV options can be offered in one service making the business model competitive with passenger cars. Electric shared AVs might be used differently which can influence the need for electric charging infrastructure. Increasing the generation of green electricity will also make electric vehicles more appealing to use. AVs might facilitate the use of technologies which will improve the connectedness (McKerracher et al., 2017).

An important remark is that these reinforcing effects can have a negative impact on public transport, especially if electric AVs can be privately owned. It is essential that electric shared AVs should be integrated with public transport, as the International Transport Forum (2018) also suggests, and that the majority will be shared and not privately owned. The integration of electric shared AVs can be facilitated if they are implemented as first and last mile solutions in the public transport network (Cavoli et al., 2017; He & Csiszár, 2018). To ensure a personalised service for the user and an efficient service for the provider, an on-demand and door-to-door service can be offered (Cavoli et al., 2017; Liyanage & Dia, 2020). This requires a certain level of connectedness. The user can get access to AVs by using Mobility as a Service or MaaS. MaaS is a platform that gathers information about the location and time of different travel modes to plan a trip integrating booking, paying, and ticketing in one system. A MaaS service could lower private car dependency if it is possible to provide a customised journey (He & Csiszár, 2018). This implies that different business models should be provided. The provider requires a broader view with a higher level of connectedness. This can be described by the 'Internet of Things' (vehicle-to-everything or V2X) (He & Csiszár, 2018). If this can be provided, many neighbourhoods that were previously underserved by public transport will be served which will reduce transport poverty.

## 1.3 The need for social scenarios

Electric shared AVs will have to be integrated in our society and this raises some important questions related to the acceptability (i.e. attitudes) and acceptance (i.e. behaviour) of AVs and future travel behaviour of different social groups. Attitudes related to travel tend to change more easily than behaviours, but this might take some time unless an important life event occurs (Kitamura, 1988; Scheiner & Holz-Rau, 2013). According to the BREVER law from Hupkes (1977) travel time and trips rates stay more or less the same, i.e. approximately 1 or 1.5 hours of travel per person per day and 3 to 4 trips per person per day. However, it is not clear what the effects of electrification, sharing, automation, and connectedness will be on this law and travel-related attitudes and behaviours. Furthermore, there are also other events like COVID-19 and the accompanying measures (e.g. teleworking) that might have an impact on our attitudes and behaviours. To analyse this complex relationship between electric shared AVs on the one hand and attitudes and behaviours of different social groups on the other, there is a need for different social scenarios. Scenarios are a flexible method to address social issues and are often applied in a context of trend breaks, rapid changes, and uncertainties (Banister & Hickman, 2013). Depending on the field and practice, there is a great variety of scenarios with different definitions, methods, and aims (Banister & Hickman, 2013; Ramirez et al., 2015). Below we will describe the definition, approach, and objective that will be deployed to build social scenarios for AVs, followed by some existing scenarios for AVs. Afterwards, the social key factors and designed social scenarios for AVs will be described. This is complemented by a reflection of some findings related to COVID-19. The implications will be mentioned in the conclusion.

# 2. Social scenarios for autonomous vehicles

## 2.1 Defining scenarios

Scenarios can be understood as a narrated description of a small number of structured plausible conceptual future contexts for a specific purpose or person (Ramirez et al., 2015). It is important to highlight that scenarios are not predictions. Becker (1988) made an early attempt to describe the whole scenario process which, according to him, constitutes of six components: analysis of the baseline (problem), analysis of the contextual scenario process, analysis of the future process, design of strategies to minimise problems, assessment of strategy impacts, and post evaluation. Schwartz (1991) describes the development of scenarios in more detail and distinguishes eight different steps. First, a decision or issue must be identified (step 1). This is followed by the selection of key factors (step 2) and driving (political, economic, socio-cultural, technical, and environmental, according to the PESTE Schema from Wilson, 1998, in Kosow and Gassner, 2008) forces (predetermined elements and critical uncertainties [assumptions of the predetermined elements]) (step 3). The two or three most important and uncertain factors or trends will be ranked (step 4) which will facilitate the design of scenarios (designing axes of crucial uncertainties and explaining them based on the key factors and trends) (step 5-6). The scenarios and original decision or issue will be reviewed together which will make it possible to identify implications (step 7). To conclude, it is useful to assign indicators to monitor the decision or issue in trying to ensure relevant strategies and decisions (step 8). Later, the scenario design process was generalized and narrowed down by Kosow and Gassner (2008) in five phases: identification of the scenario field, identification of the key factors, analysis of the key factors, scenario generation, and if necessary scenario transfer. While Cederquist and Golüke (2016) describe a more practical approach and distinguish seven steps and four phases in scenario work: identification of the driving question, conduct interviews or conversations together with the analysis of the interviews (awareness phase), identification of the two most uncertain drivers (alignment phase), designing plotlines together with stories with titles (engagement phase), and applying the scenarios (action phase). If the scenarios are being applied, it is possible to: adapt, shape, or transform strategies.

If the scenarios are validated, they can be analysed by applying for example an impact analysis, a cost-benefit analysis, a SWOT analysis, or an actor analysis. This can be integrated in a workshop (Kosow & Gassner, 2008). The final step in the scenario process is the translation, transfer, and implementation of knowledge (research) into policy measures (action) and bridging the 'implementation gap' (Banister & Hickman, 2013). This work includes the design of social scenarios for autonomous vehicles (AVs) while following project deliverables will include the development of a social impact assessment of AVs, and the implementation of necessary strategies.

## 2.2 Approaches to analyse scenarios

Here, an intuitive top-down desk research is applied as a foundation before involving important stakeholders and due to the limitations caused by COVID-19. Kosow and Gassner (2008) make a distinction between explorative and normative as well as qualitative and quantitative approaches. We applied an explorative (or descriptive) approach to identify development paths and key factors for AVs. The starting point is the present and scenarios are designed by certain developments, driving forces, and possible consequences (Eurofound, 2003). The results of the explorative approach (research) can be used as input for the normative approach (i.e. policy and planning). Further, a qualitative approach is applied because it allows us to give a better overview of details and nuances and since the current available data is too limited to perform a thorough quantitative approach. There are also different qualitative and quantitative methods to analyse scenarios (Kosow & Gassner, 2008). A qualitative creative-narrative scenario technique based on intuitive logics is applied. This technique is described by Kosow and Gassner (2008) and is especially useful for communication and participation. A possible quantitative method is a multi-criteria analysis that weighs and compares variables. However, we are convinced that a combination of different qualitative and quantitative approaches will yield the most information, especially in this social context since social change has multiple and unstable drivers (Berkhout & Hertin, 2002).

Scenarios are built upon imagination and reasoning to produce a number of internally coherent and conceptually valid representations of possible future changes (Ramirez et al., 2015). The number of scenarios is very important. Schwartz (1991) prefers four scenarios, since three scenarios will direct a choice for the middle option and more than four scenarios can start to blur distinctive characteristics. Eurofound (2003) and Banister and Hickman (2013) confirm that four scenarios are often applied to keep the complex context comprehensible. When using an exploratory approach, this is mostly presented with a 2x2 matrix with two dimensions (Banister & Hickman, 2013). The aim is to encourage thinking (knowledge). The deductive scenario method from van der Heijden (2005) also uses a 2x2 quadrant with four scenarios. The advantage is that different (un)certain and (in)direct factors can be explored in a broader context and different assumptions can be identified and analysed (Ramirez et al., 2015). We also chose to apply two social key factors to create a 2x2 quadrant matrix with four social scenarios.

## 2.3 Objectives of scenarios

Changing the current transport system can create various new and positive opportunities but this can also be challenging for authorities because of possible uncertainties, risks, and vulnerabilities. Change is possible if we deal with uncertainty because you cannot change things that are certain (Cederquist & Golüke, 2016). By designing social scenarios for AVs, local and transport authorities will be better informed which kind of pilot they should apply and what the consequences for user groups (with attention for vulnerable groups) might be.

A huge advantage of scenarios is the possibility to involve iterations, this makes it possible to revise assumptions, results, and measures. In this way, scenarios become more accessible, transparent, comprehensible, testable, and contestable (Ramirez et al., 2015). The most challenging aims are shaping and transforming strategies since they require the recognition of strengths and weaknesses, possible directions, and decisions (Cederquist & Golüke, 2016). Thus, scenarios are not stationary and can have different trends.

A scenario is often not a final objective but a tool to provide input for further work such as research and planning (Ramirez et al., 2015; Rowland & Spaniol, 2017). They can also have different objectives: identifying and creating knowledge, aiding communication, setting goals, and examining effectiveness (Kosow & Gassner, 2008). Concerning research, it is useful to apply scenarios to test theories, build new concepts, and gather knowledge about alternative and innovative possibilities (Ramirez et al., 2015). Scenarios can facilitate communication and negotiation that might lead to strategic thinking and actions (Becker, 1988; Rowland & Spaniol, 2017).

It is important to identify and involve different interdisciplinary stakeholders. Many studies on scenarios (e.g. Banister & Hickman, 2013; Ramirez et al., 2015) or scenarios focussing on AVs (e.g. Fraedrich et al., 2015, Cavoli et al., 2017, Keseru et al., 2019) include experts, researchers, practitioners, or representatives of user groups. However, it is also important to involve the users. Some studies found significant discrepancies between the opinions about public transport by local authorities, transport authorities, users, and non-users (Duleba et al., 2012; Ghorbanzadeh et al., 2018).

## 2.4 Existing scenarios for AVs

Different social, economic, and environmental scenarios for AVs need to be considered. Research on AVs is still quite new. However, currently the focus is more on technological aspects and scenarios. We will illustrate three studies about AVs that are in line with the chosen definition, approach, and objective. Fraedrich et al. (2015) start from a technological perspective but discuss the implications for the socio-technical system. They distinguished three scenarios: 'evolution', 'revolution', and 'transformation'. In the 'evolution' scenario driver-assistance systems are getting more integrated in personal vehicles, while there is a sudden transition to use automated vehicles in the 'revolution' scenario, and the 'transformation' scenario includes automated mobility on-demand integrated with public transport (Fraedrich et al., 2015). The technological scenarios are followed by economic scenarios. Cavoli et al. (2017) for example describe two 'roll-out' ownership scenarios: 'business-as-usual' and 'shared mobility'. Within the 'business-as-usual scenario' AVs replace current travel modes while in the 'shared mobility scenario' AVs complement public transport and will be shared (Cavoli et al., 2017). A more socio-political perspective was applied by Keseru et al. (2019) who followed the structure of Kosow and Gassner (2008) for building scenarios for future transport and mobility in 2030 in Europe. They focus on societal trends and user needs and identified the 'policy and legal' (unsupportive, protectionist, and fragmented vs. supportive, innovation, and interoperable) framework and 'user or lifestyle' (unlimited consumption, individualism, global citizens, and flexibility vs. responsible consumption, cooperation, local citizens, and sharing) behaviour as the key driving forces based on the highest uncertainty and greatest impact. These two key driving forces were used as input for four scenarios: 'data world', 'digital nomads', 'slow is beautiful', and 'minimum carbon' (Keseru et al., 2019). These studies provide an interesting perspective on potential social scenarios for AVs.


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## 2.5 Social key factors

Social scenarios are intended for specific social groups. These groups can be identified based on different socio-economic and demographic variables. A review by Narayanan et al. (2020) indicates that users of AVs will probably be younger, male, higher educated, having a higher income, living in an urban environment, students, and have a flexible working schedule (Bansal et al., 2016; Haboucha et al., 2017; Wang & Akar, 2019). Zmud and Sener (2017) discovered that characteristics like age or income will probably have no influence on the acceptance of shared AVs and that experience and affordability are more important. According to the review, it is possible that shared AVs will attract sustainable travellers who are currently using public transport, car-sharing, cycling, and walking (Bösch et al., 2018b; Cyganski et al., 2018; Pakusch et al., 2018; Soteropoulos et al., 2018; Wang & Akar, 2019). Also, multi-modal users seem to be more likely to use shared AVs, with public transport users shifting to car-sharing systems and car-sharing users to ride-sharing systems (Krueger et al., 2016).

Special attention should be given to vulnerable and disadvantaged groups like children, elderly, women, single parents, people living in deprived areas, people with reduced mobility, low-skilled people, unemployed people, low-income groups, ethnic minorities, migrants, etc. Vulnerable and disadvantaged groups are more likely to experience transport poverty and social exclusion. AVs might reduce inequalities, but they might also reproduce or even deepen these inequalities (De Paepe et al., 2021b). According to a literature review by De Paepe et al. (2021b), younger individuals, men, larger households or households with children, and individuals with a higher level of education are more in favour of shared AVs. Nonetheless, the review also expresses that same variables proved to be insignificant in other studies, especially income. However, it seems that shared AVs might be good alternatives for possible vulnerable groups like children, households with children, and unemployed people (De Paepe et al., 2021b). A couple of driving questions are: 'What do social groups think of AVs?', 'Why are some social groups more negative or positive towards AVs?', and 'How can we make AVs acceptable, available, accessible, affordable, and attractable for as many social groups?'. A conceptual social scenario model is designed based on two social key factors that consist of multi-level factors. The key factors are: 'complexity' and 'social acceptance'.

### 2.5.1 Complexity

The factors for 'complexity' are: space, time, and AVs (type and service). This is inspired by time(-space) geography of Hägerstrand (1970), which perceives space and time as basic conditions to analyse dynamic processes such as social and environmental interactions, social and environmental change, etc. (Thrift & Allan, 1981; Carlstein, 1982; Sui, 2012). Within the space-time framework, individuals can follow a path that will be guided by authority, capability, and coupling constraints. Authority constraints are being controlled by an individual or group, capability constraints are limitations by the required tools or abilities of an individual, and coupling constraints are the restrictions to produce or use objects in space and time (Hägerstrand, 1970). Frisoni et al. (2016) described some possible scenarios for AVs using time (short, medium, and long term) and the type of vehicle (passenger vehicles, freight vehicles, and [urban mobility and] public transport) as key factors, while Walker (2017) made a distinction between private and shared AVs (similar as Cavoli et al., 2017), and Faber and van Lierop (2020) between private AVs, shared AVs, automated public transport, and on-demand public transport and their features (capacity, ownership, privacy, and pricing complemented by the operation space, booking information, first and last mile, and park information).

The factors space, time, and AVs depend on the local and transport context and can also interact with each other. Concerning space and type of AV, autonomous public transport will probably be used in urban areas and autonomous shuttles in suburban or rural areas (Bösch et al., 2018a). Time and type of AV can also influence each other, for commute trips the time (pick-up and arrival) seems to be a big issue (Lavieri & Bhat, 2019; Philipsen et al., 2019) which will influence the number of people that can join a shared AV. Space, time, and type of AV can also have an influence on each other because travelling in urban areas during peak is probably more interesting (e.g. financially) by public transport such as trains, buses, and trams. While travelling in suburban and rural areas and during off-peak will probably be more interesting using a shuttle (Hazan et al., 2016). To ensure comprehensibility, we will focus on some of the most prominent criteria below (see Table 1) and apply some assumptions. The assumptions include that all the AVs are electric and shared, not necessarily connected, the shuttles provide between 4 and 16 seats, have an average speed of 15 km/h, cover a distance between 500 m and 1,5 km, and provide a feeder function from one transport hub to another (public transport or parking) that is currently not on-demand and door-to-door.

### *Space*

Different criteria of the spatial environment are important. Because of the current limited distances (500 m - 1,5 km) that are being covered by AVs, the micro and meso level (as defined by Jones and Lucas, 2012) is the most important. The micro level relates to the road(s) which can be private or public. The traffic on the road(s) can be separated (different lanes) or mixed (combination of different travel modes). The route can be fixed or free, currently this is mainly fixed. Across this trajectory there could be multiple stops between the origin and destination. Accessibility to and at these stops is important, especially for more vulnerable groups. The meso level relates to the neighbourhood. There should be a safe way to get to the stops (e.g. sidewalk) and board the vehicles (e.g. platform). AVs can be integrated with personal vehicles (parking) and public transport at different locations, e.g. industrial parks, hospitals, campuses, airports, resorts, amusements parks. There was no distinction made between urban, suburban, and rural spatial environments since we focus on the micro (road) and meso (neighbourhood) level.

### *Time*

Next to space, time is an important factor. The duration of a pilot will have an influence on the perception of social groups. Ranging from a week to months or years, will mean that social groups will test this new transport service or implement this in their travel behaviour. This can be complemented by the operating time since many AVs have an operator on board with fixed hours and electric AVs need to be recharged at certain times. The speed, frequency, and reliability will also influence the use of AVs. There also might be differences between peak and off-peak hours which can be connected with the timetables of other travel modes, e.g. public transport.

### *Autonomous vehicle*

#### Type

The type of vehicle can vary from a car, shuttle to a bus. The vehicle can be used privately or shared, while the ride itself can also be private or shared. Accessibility of the vehicle itself by providing boarding and exiting facilities (e.g. ramps, elevators) is also important, especially for more vulnerable groups. The type of vehicle will also influence the number of seats and the space that will be available for storing supplies.

**Table 1: Overview of social key factors for AVs and their multi-level factors**

| Key factors | Factors | | Criteria | Levels |
|---|---|---|---|---|
| **Complexity** | Space | | • Distance<br>• Road<br>• Traffic<br>• Route<br>• Stops<br>• Access<br>• Integration<br>• … | • Short or long<br>• Private or public<br>• Separated or mixed<br>• Fixed or free<br>• Location and number<br>• Sidewalk, platform<br>• Parking, public transport |
| | Time | | • Duration pilot<br>• Operating time<br>• Speed<br>• Frequency<br>• Reliability<br>• Integration<br>• … | • x weeks, x months, x years<br>• Between xx:xx and xx:xx<br>• x km/h<br>• Every x minutes<br>• On time or late<br>• Public transport |
| | Autonomous vehicle | Type | • Vehicle<br>• Vehicle use<br>• Ride<br>• Access<br>• Seats<br>• Space<br>• … | • Car, shuttle, or bus<br>• Private or shared<br>• Private or shared<br>• Boarding and exiting facilities<br>• Number<br>• Storing |
| | | Service | • Novelty<br>• Integration<br>• Information<br>• Booking<br>• Payment<br>• … | • Additional or replacing<br>• Feeder or whole trip<br>• Planning and pricing<br>• Free use or reservation<br>• Free of charge or charged |
| **Social acceptance** | 'Performance Expectancy' | | | |
| | 'Effort Expectancy' | | | |
| | 'Social Influence' | | | |
| | 'Facilitating Conditions' | | | |
| | … | | | |

#### Service

The service of the AV can be to provide a new connection or replace an old one. Attracting customers to a new service might be difficult while replacing an existing service might also lead to critical comparisons. Furthermore, the integration with other services like public transport is also important, currently AVs mainly serve as a feeder system while they could also cover a whole trip. The service should also provide information regarding planning and pricing, booking, and payment and ticketing which could be integrated in a Mobility as a Service or MaaS platform that also includes public transport and other travel modes.

### 2.5.2 Social acceptance

According to De Paepe et al. (2021a) 'social acceptability' of shared transport services is related to attitudes and 'social acceptance' to behaviour. Acceptance consists of several factors: 'performance expectancy', 'effort expectancy', 'social influence', 'facilitating conditions', etc. (Venkatesh et al., 2003). Based on research about transport poverty, De Paepe et al. (2021a) distinguished four conditions that are important if we want to ensure 'social acceptance' of shared AVs by vulnerable groups: 'availability' (of transport options, resources like a smartphone, …), 'accessibility' (of destinations, due to physical health, …), 'affordability' (of transport options, …), and 'attractability' (safe, healthy, …) or the 4As. If there are issues with these 4As, the likelihood of 'social acceptance' will be low unless measures are being taken (De Paepe et al., 2021a).

The 'social acceptance' will depend on the previous mentioned 'complexity' (space, time, and AVs). Apparently, people tend to perceive shared AVs as a form of public transport or car- or ride-sharing and hence associate the same positive and negative aspects with shared AVs (Zmud & Sener, 2017). In this context, availability of an AV in space and time, seats in the vehicle, and digital devices like a computer or smartphone can be identified as important criteria. According to Zmud and Sener (2017) shared AVs are perceived as less available compared to private AVs. Concerning accessibility, we will apply the micro (location and vehicle) and meso (neighbourhood and network) level as defined by Jones and Lucas (2012). Criteria are the access of the stop and vehicle. Barbosa et al. (2017) used a couple of accessibility criteria in their work on public transport: boarding/exiting facilities, but also information about the trajectories, operating time, and frequency. Affordability was applied by Zmud and Sener (2017) and they concluded that shared AVs are most of the time seen as more affordable. Attractability is related to travel conditions and can be related to comfort such as the boarding quality, lighting quality, noise, and seats but also reliability (Barbosa et al., 2017).

## 2.6 Social scenarios for AVs

The number of studies including social scenarios seems to be very scarce, not only for AVs or transport but also in general. This makes the need for social scenarios for AVs even more pronounced. Based on the social key factors 'complexity' and 'social acceptance' four social scenarios were designed: 'Showcase Visitor', 'Curious Tripper', 'Easy Rider', and 'Sustainable PT Commuter'. The social scenarios are shown in Figure 1 and are being described and discussed below. The representations of the social scenarios approach the pilots that will be developed in this project. The scenarios are still quite broad to allow adaptations to the specific local and transport context as well as different social groups. The interpretation of the social scenarios will keep five types of innovation adopters in mind: innovators, early adopters, early majority, late majority, and laggards (Rogers, 1962). However, these types will not be mentioned explicitly.

### 2.6.1 'Showcase Visitor' scenario

The set-up of a pilot with electric shared AVs in this scenario is limited in duration and can be perceived as a demo or showcase. The operating times are more focused on peak demand such as the morning and evening rush or before and after events. The frequency of the service and the number of vehicles are quite low. This makes the services more vulnerable for delays. The AVs will be deployed in a less complicated spatial environment, such as private roads, separated from other traffic, a limited number of stops, and covering relatively short trip distances. The ideal vehicle is a shared shuttle or bus. In most cases, this will be an additional service integrated with public transport and part of a leisure activity with a less restricted time window than mandatory activities. On the other hand, the trip can also be perceived as an activity in itself if it is just used to try out the service. The main aim is to create awareness among the public. This scenario will attract local citizens or tourists, that can be characterised by age, e.g. families with children and elderly, who want to try out the service. Because of the short use case, it is unclear what the effect will be on the long-term. It is expected that the acceptability will be quite high and the acceptance rather low. The showcase will be a good first experience but there is more required to integrate AVs in peoples' travel behaviour. The negative as well as positive impacts for vulnerable groups will stay limited. This scenario approaches the pilot of Almere (the Netherlands).

### 2.6.2 'Curious Tripper' scenario

This scenario has some similarities with the 'Showcase Visitor' scenario. This scenario is a demo or showcase that is limited in duration, operating times, and frequency. However, the vehicle will drive in more complex spatial environments such as public roads, mixed traffic situations, having multiple stops, and covering longer trip distances. Because of the more complex spatial environment, a shuttle is perceived as a more suitable type of vehicle since this will limit the possible disruption of the traffic situation. It is expected that there will be more negative effects or impacts if the service is replacing a traditional one and cannot guarantee the integration with other transport facilities (e.g. parking or public transport). The aim is similar as in the 'Showcase Visitor' scenario. The same social user groups are now complemented by an important group of non-users consisting of pedestrians and cyclists who might interact with the AV. The acceptability will probably be high among users and non-users but more is needed for the users to accept AVs on the long run. The negative as well as positive impacts for vulnerable groups will stay limited. The prospects towards the future are again not clear. This scenario approaches the pilot of Varberg (Sweden).

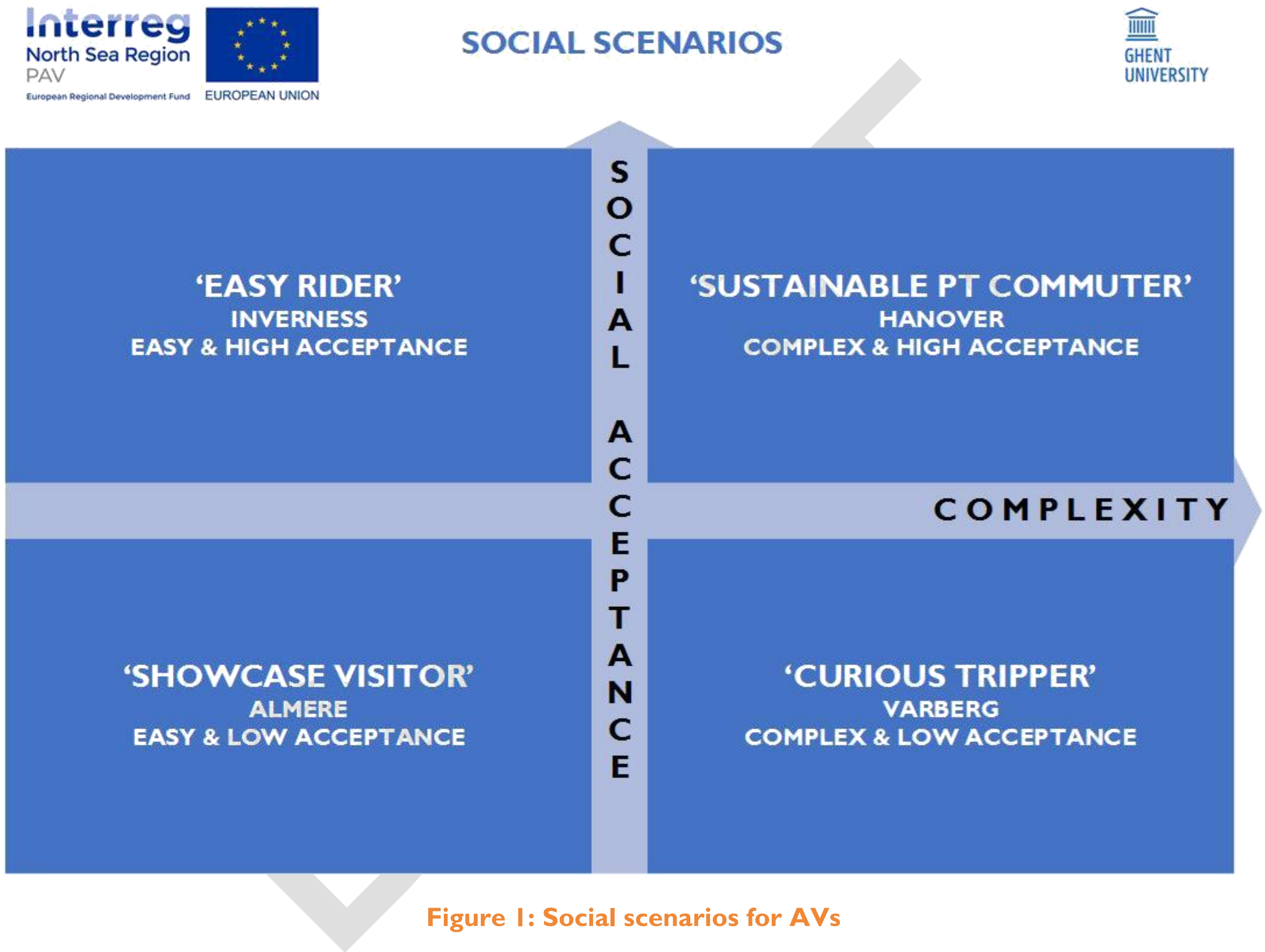


**Figure 1: Social scenarios for AVs**

### 2.6.3 'Easy Rider' scenario

This scenario is similar in complexity regarding space and AV as the 'Showcase Visitor' scenario but differs regarding the time factor. The scenario has a longer duration and can be perceived as a pilot at first, that might turn into an actual service. The operating hours are probably also longer and the frequency is possibly also higher. The reliability might be low in the beginning, but this will improve after gaining more experience with running an AV. Similar to the 'Showcase Visitor' scenario, the AV will be deployed in easier spatial environments (private roads, separated from other traffic, a limited number of stops, and covering relatively short trip distances). The ideal type of vehicle is a shared shuttle because of the feeder service to cover the first and last mile of a trip with a small number of users. The trip can cover a missing link between public transport or the distance between a parking area for passenger cars and a specific destination. The main aim is to provide an integrated transport solution for the users. The interest in the AVs might be higher in the beginning because of its novelty while this might even out on the long-term with a more stable number and profile of users. The service can also specifically be provided for people with reduced mobility who otherwise experience issues to access certain destinations. Depending on the targeted users, the trip can be part of a mandatory or leisure trip. This scenario might be more interesting for vulnerable groups since this is a service on which they can rely because it has been tested and earlier problems are probably already solved. It is expected that the acceptability as well as the acceptance will be quite high for this transport solution. This scenario approaches the pilot of Inverness (Scotland).

### 2.6.4 'Sustainable PT Commuter' scenario

The 'Sustainable PT Commuter' combines the spatial complexity of the 'Curious Tripper' scenario and the time complexity as well as social acceptance of the 'Easy Rider' scenario. The AV will drive in more complex spatial environments like public roads, mixed traffic situations, having multiple stops, and covering longer trip distances. The vehicle will also be deployed for a longer period with longer operating hours and a higher frequency. It is expected that the reliability will also improve over time. If successful, the service can be implemented as a permanent service. Due to the more complex space and time factors, a shared shuttle or even a bus are the most convenient type of AV. Similar to the 'Easy Rider' scenario, this service can fulfil a feeder function covering missing links. The aim and evolution of the interest are probably similar to the previous scenario. The complexity provides different social as well as vulnerable groups the opportunity to use an AV for different trip purposes, even a more complex trip such as a commute trip. However, it is very important that integration with other transport facilities is ensured, especially if the service is replacing a traditional one. This facilitates the implementation of this service in users' travel behaviour. So, it is expected that the acceptability and acceptance will also be high for this sustainable transport solution. This scenario approaches the pilot of Hanover (Germany).

## 3. Influence of COVID-19

The influence of COVID-19 on future social scenarios with autonomous vehicles (AVs) is unclear. The roll-out of different pilots with AVs around the world was delayed because of COVID-19. The focus of transport authorities shifted to a primary service provision (Hausler et al., 2020). In a future with AVs, it would be easier to customise the type of vehicle according to the demand. Currently, the number of customers on public transport and AVs is often restricted because of COVID-19 rules. The ridership of public transport and shared transport services such as ride-sharing and car-sharing has fallen during the pandemic. However, it is expected that the occupancy will rise again when the rules are eased again joined by longer operating times and a higher frequency (Hausler et al., 2020). Due to teleworking, there might be fewer commuting trips in some sectors (Hensher, 2020) but these trips might also be replaced with other ones (as seen with Hupkes, 1977). COVID-19 also pushed a digital shift which will have a positive influence on the service aspect. Many people are now accustomed to digital booking and cashless payments, elements that are included in Mobility as a Service or MaaS that will facilitate the use of AVs. The certainty of having an available seat for example also contributes to a more positive attitude towards AVs (Sun et al., 2020). Many people with reduced mobility experienced difficulties to travel to the vaccination centre. Various cities and countries (United States, Belgium, etc.) provided subsidies to take a taxi but with shared AVs these subsidies might not have been necessary because they are expected to be more affordable. It was already estimated that providers of AVs will have to spend a large part of their budget on cleaning (Bösch et al., 2018a; Hensher, 2020) which will certainly be necessary after the COVID-19 pandemic.

# 4. Conclusion

Electric shared autonomous vehicles (AVs) can provide green and efficient transport and inclusive mobility if implemented in a good manner by local and transport authorities. Based on the social key factors ‘complexity’ (space, time, and autonomous vehicles) and ‘social acceptance’ four social scenarios were designed: ‘Showcase Visitor’, ‘Curious Tripper’, ‘Easy Rider’, and ‘Sustainable PT Commuter’. These scenarios approach respectively to the pilots with AVs in Almere (the Netherlands), Varberg (Sweden), Inverness (Scotland), and Hanover (Germany). These conceptual social scenarios can be the start of discussions with stakeholders from different disciplines. The ideal outcomes are to choose the most suitable AV pilot for the local social groups and if necessary take strategic actions. Policy intervention will be necessary which is also confirmed by Walker (2017). As we have seen in the social scenarios, AVs are an ideal extension of public transport or passenger cars. However, to fully replace passenger cars in the future an advanced service including an on-demand and door-to-door offer of AVs ideally integrated in Mobility as a Service or MaaS is necessary.

There is still a considerable road ahead before AVs will be integrated into our traffic system. AVs were perceived as a revolution but since the first trials we see that it is better to speak about an evolution. AVs will need to be tested more and in diverse scenarios and even then, the scenario might turn out otherwise depending on the specific location. In these scenarios and pilots, it is crucial to have attention for users as well as non-users with special attention for vulnerable groups and their acceptability and acceptance towards AVs. It is also important to foresee some possible contradictions, e.g. slow might not necessarily be perceived as something bad but rather as safe (especially in the beginning), while an operator on board of an AV is sometimes seen as human interference of the vehicle the operator can also explain, help, and safely operate the vehicle if necessary (more as a steward).

Scenarios can contribute to identifying social, economic, and environmental effects and assessing their impacts. On the one hand electric shared AVs can have a positive effect on our society but on the other hand if the negative effects are significant this may have a detrimental social impact related to accessibility, environment and health, safety, liveability, and employment. The aim is to develop policy measures that will minimise negative impacts and maximise positive impacts.

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