D3.3 Social Impact Assessment of Autonomous Vehicles

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1. Introduction

Electric shared autonomous vehicles can provide our society multiple opportunities. To take fully advantage of these opportunities, local and transport authorities have the important task to integrate autonomous vehicles (AVs) in their transport and spatial plans. An impact assessment can help authorities in their decision-making process. There are different types of impact assessments. Here, we will focus on a Social Impact Assessment (SIA) for AVs.

A SIA has attention for the influence of a measure on different social groups. This social aspect appears to be neglected in transport research, policy, and practice. This may be partially attributed to the lack of social concepts and transport frameworks. Based on a couple social transport frameworks including some key concepts, a methodology to assess the social impacts of AVs is proposed. This methodology will allow guidance for the implementation of various types of AVs, across different locations and time scales. Furthermore, the most important social impacts were identified and will be discussed. This is complemented by some of the findings of COVID-19. The implications will be mentioned in the conclusion.

2. Social impact assessment (SIA) of autonomous vehicles

2.1 Guiding transport frameworks

The introduction of autonomous vehicles (AVs) will have an impact on our society as a whole and will influence the way we live. We can estimate the impact of AVs with an impact assessment. Traditionally, there are different types of impact assessments. The most common are environmental, economic, and social impact assessments. Here, we will focus on the latter.

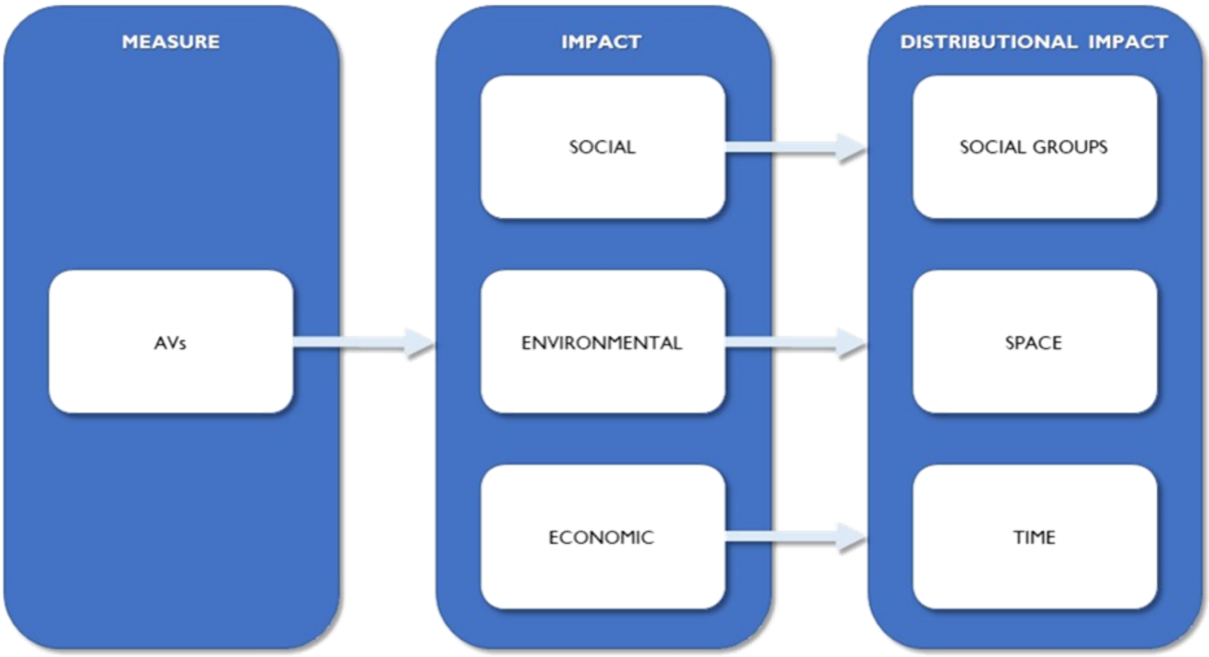

Figure 1: Conceptual model of transport impacts of AVs (based on Jones and Lucas, 2012)

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A social impact assessment (SIA) can be defined as the process of identifying the future social consequences of a current action (Becker, 1997). A thorough assessment also entails an evaluation of the consequences of past actions (Blaikie, 2010). Social impacts, specifically of transport, can be defined as changes in transport sources (travel, traffic, and infrastructure) that might positively or negatively influence the attitudes, behaviour, or well-being of individuals, social groups, and society in general in the future (Geurs et al., 2009). The conceptual model of Jones and Lucas (2012) is adapted for AVs and shown in Figure 1. Social impacts also comprise economic and environmental elements but the focus is different. Impacts will also have a different distributional impact in space (e.g. varying locational distribution of air pollution), time (e.g. varying noise levels by time of day), and across different social groups (e.g. differential impacts by age, gender, income group) (Jones & Lucas, 2012).

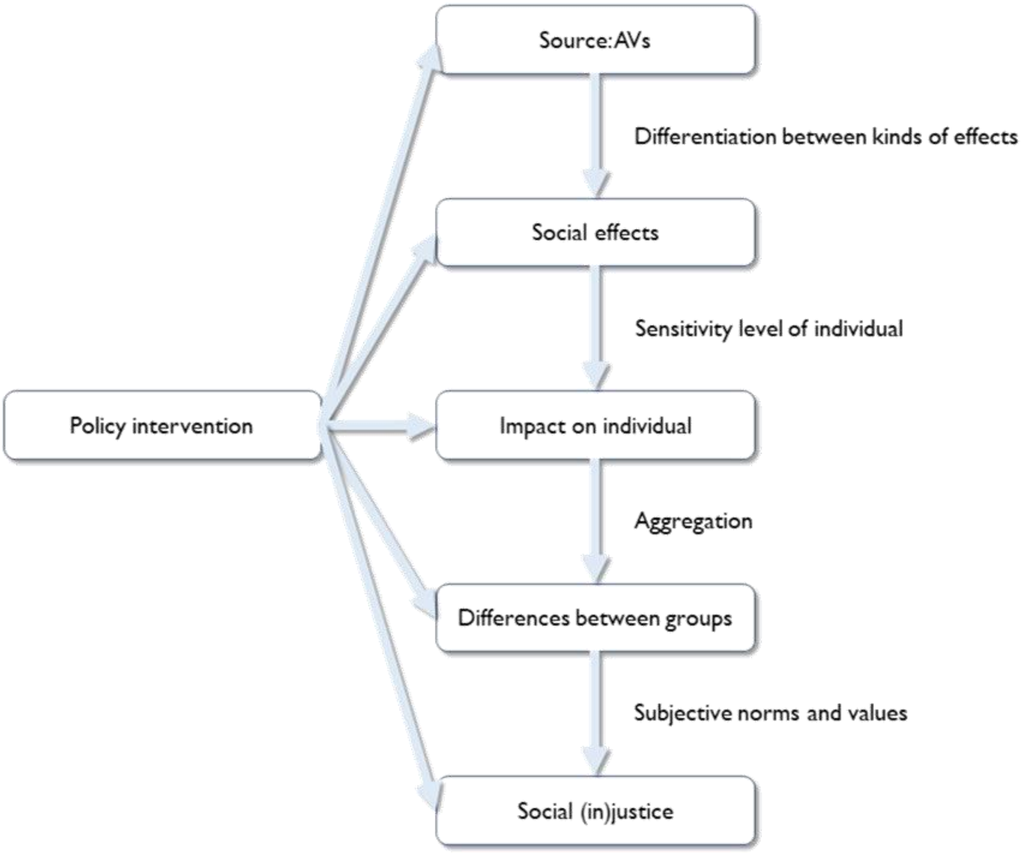

Figure 2: Source-effect-impact-receptor framework for social impacts of AVs (based on Geurs et al., 2009)

The broader framework of transport impacts by Jones and Lucas (2012) is narrowed down by Geurs et al. (2009) who focus on social transport impacts. The conceptual model of Geurs et al. (2009) is adapted for AVs and shown in Figure 2. They suggest analysing this through the source-effect-impact-receptor chain. Three different types of effects can be distinguished: direct, indirect, and external effects (Eijgenraam et al., 2000; Ministry of Transport, Public Works and Water Management, 2004). There is a distinction between a social effect and social impact. If the effect is higher or lower than an individual's sensitivity level, it has an impact on individuals (Lichfield, 1996). If there is a sensitive response (this can be objective or subjective), an effect can thus turn into an impact. The receptor consists of the individual, social groups, and social (in)justice. Social injustice occurs if the subjective norms and values are violated. If this is the case, policy makers and politicians need to intervene with mitigating measures, especially if the benefits exceed the costs (Geurs et al., 2009).

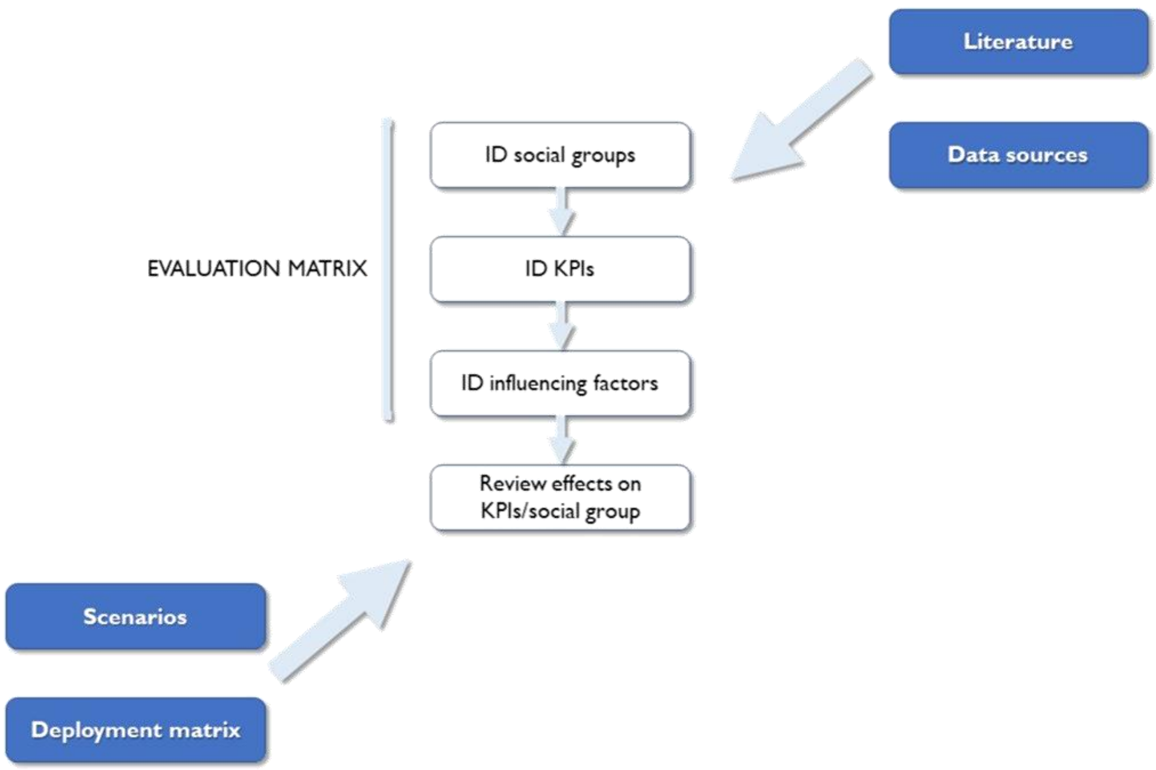

Figure 3. Conceptual evaluation framework of AVs (based on Alonso Raposo et al., 2018)

Alonso Raposo et al. (2018) developed a conceptual framework to define the socio-economic impact of AVs on our society in terms of transport and daily activities with special attention for the impacted economic sectors. The conceptual model of Alonso Raposo et al. (2018) is adapted for AVs and shown in Figure 3. Scenarios and a deployment matrix serve as input for the estimation of the effects for each social group. The evaluation matrix consists of the identification of social groups (instead of economic sectors), Key Performance Indicators (KPIs), and influencing factors (e.g. impact of AVs on traffic safety). The KPIs can be defined by their measuring unit(s) according to different literature and data sources. The effects can be reviewed by their expected direction of change, i.e. increasing or decreasing (Alonso Raposo et al., 2018).

2.2 SIA methodology for AVs

Based on the guiding transport frameworks, a social impact assessment methodology was established. A research methodology can be described by a theorisation of different systematic processes to generate, gather, verify, and validate knowledge and reflects the research strategy (Ramirez et al., 2015). This methodology distinguishes the measure, scenarios, groups, Key Performance Indicators (KPIs), effects, impacts, and distribution (Figure 4).

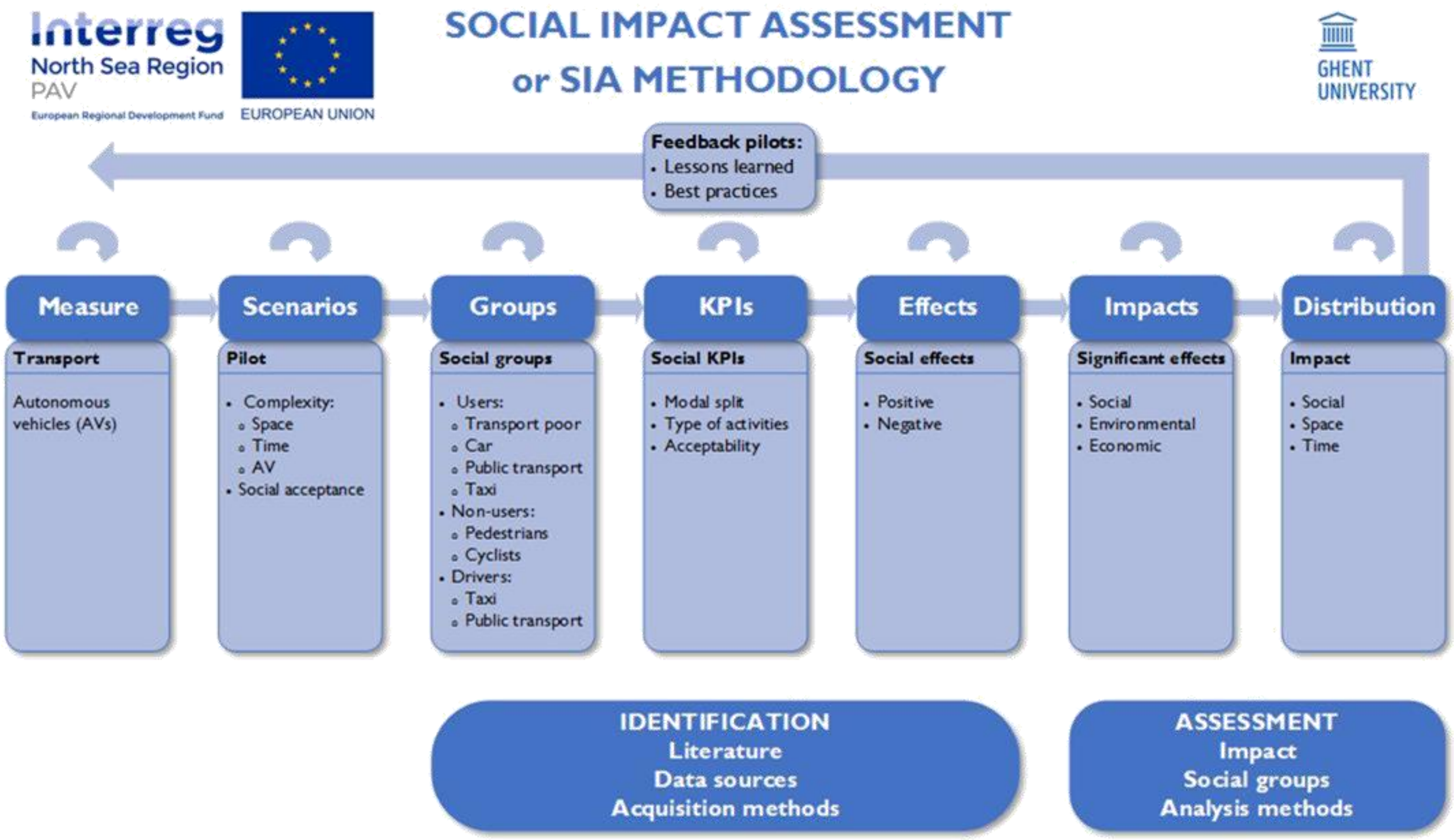

Figure 4: Social Impact Assessment methodology for AVs

The measure is the implementation of autonomous vehicles (AVs). The scenarios are based on the social scenarios that were defined earlier in the project. Two social key factors were identified: ‘complexity’ and ‘social acceptance’. Complexity constitutes of the factors: space, time, and AVs (type and service), with their own criteria and levels.

An identification phase follows, in which groups, KPIs and effects are being identified. Individuals can be aggregated in a social group. A social group is a more convenient unit to analyse than the whole population. The population can be split into users and non-users. Concerning the users, special attention should be given to vulnerable and disadvantaged groups (i.e. 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) that might be transport poor and people who are currently using motorised vehicles (i.e. cars, taxis, buses). Non-users include other road users, i.e. pedestrians and cyclists. People working in transport and especially drivers are another group to take into consideration. Next, the social KPIs need to be identified using literature and secondary data (e.g. current modal split, types of activities) provided by the local authorities. This will provide input for the reference situation. Secondary data will be supplemented by primary data (e.g. acceptability) which can be gathered through different acquisition methods, e.g. fieldwork, observations, interviews, focus groups, surveys, etc. It would be interesting to analyse if the social groups are connected to specific groups with similar attitudes (e.g. innovators, early adopters, early majority, late majority, and laggards according to Rogers in 1962, enthusiasts, pragmatists, conservatives, and rejecters according to Zmud and Sener in 2017). The social effects will be reviewed and categorised as positive or negative for the specific social groups.

If the social effects are significantly positive or negative, they will be perceived as social impacts and can be reviewed for each social group. From here onwards the social impact assessment starts. Environmental and economic elements will also influence the social impacts. Attention will also be given to the distribution of the impacts across the different social groups, space, and time. The social impacts can be assessed in a qualitative or quantitative way by classifying the impacts. At the end, it is important to provide feedback for the authorities and summarize the lessons learned and possible best practices. The authorities have the power to anticipate and monitor the social impacts by mitigating the negative social impacts and maximising the positive social impacts.

3. Potential social impacts of autonomous vehicles

The social impacts of autonomous vehicles (AVs) will depend among others on how AVs will be used, which business models will become popular, and which complementary information and communication technologies will be deployed. The first pilots will use only a limited number of AVs but it is expected that in the future fleets of electric shared AVs will be used, similar to current ride-sharing services (International Transport Forum, 2015a). Currently, it also seems that consumers are rather in favour of AVs (Winkler et al., 2019). However, there are also several studies that claim the opposite (Haboucha et al., 2017; Hudson et al., 2019).

Several authors and organisations already tried to predict the possible impacts of AVs at different timescales. What follows are some of the impacts that are considered as social impacts on the short term that will need to be covered by the social impact assessment methodology. The following social impacts are being discussed: accessibility, environment and health, safety, liveability, and employment[1]. Since there are a lot of uncertainties involved, the impacts will be described briefly and in a critical way.

3.1 Accessibility

In its broadest interpretation, accessibility is the degree to which people can reach goods and services that are deemed necessary by society for our daily life, but with an emphasis on potential or capability rather than actual behaviour (Jones & Lucas, 2012). Jones and Lucas (2012) put emphasis on the physical aspect of accessibility.

According to Jones and Lucas (2012), three levels of accessibility can be distinguished:

- Micro level (vehicle - location): Providing space to get to a vehicle, to board a vehicle, and inside the vehicle for people with physical disabilities.
- Meso level (network - neighbourhood): Movement with various transport modes at the neighbourhood level. This includes connectivity and permeability of the local street network and accessibility by people with different disabilities.
- Strategic level (networks - town-region): The combination of land use and the transport network across a town to a region to travel to participate in different activities.

One of the most described positive social impacts of AVs is accessibility for all. If you do not need a driver license to use AVs, these vehicles become a transport option for current non-users. This is perceived broader than people with physical disabilities. Disadvantaged and vulnerable groups like elderly, children, low-income groups, etc. will be able to travel independently (Cavoli et al., 2017; Papa & Ferreira, 2018; Litman, 2020).

AVs will probably facilitate a smaller fleet size joined by an increased travel demand (Kellett et al., 2019). According to Fagnant and Kockelman (2014), AVs can replace about 11 conventional vehicles. It is estimated that road occupancy can increase by 40% to 50% for all road classes, with the strongest growth on local road networks. Some neighbourhoods might experience more traffic than before (International Transport Forum, 2015b). Due to this, earlier made improvements in accessibility will diminish and might even have a detrimental impact on a neighbourhood.

3.2 Environment and health

According to the British Medical Association (2009) and World Health Organisation (2011a, 2011b), current vehicle emissions and noise have a significant negative impact on human health, e.g. asthma, cardiovascular diseases, respiratory diseases, reduced life expectancy. If urban mobility was based on electric shared vehicles, CO_2 emissions from traffic could fall by 60% (International Transport Forum, 2018). AVs are believed to drive more efficiently and

[1] This list is not exhaustive.

operate in platoons which could reduce energy consumption and emissions (Department of Infrastructure and Regional Development, 2017). Eco-driving and platooning might contribute the most to the decrease of GHG emissions (Massar et al., 2021). Electric AVs will lower emissions and prove to be less noisy which will have a positive impact on the environment and our health. However, if people tend to change their travel behaviour by making more and longer trips (longer travel time and according to Fagnant and Kockelman, 2014, approximately 10% longer in travel distance compared to conventional vehicles), using less public transport options may be accompanied with AVs that drive empty and urban sprawl, these positive impacts might decrease (Department of Infrastructure and Regional Development, 2017). An estimation of the level of greenhouse gas emissions reveals that the emissions probably will be as high on the short- and mid-term. In an optimistic scenario, a reduction in emissions is feasible but this has to be confirmed by other simulations (Liu et al., 2019).

3.3 Safety

It is expected that AVs will eliminate human errors which will improve traffic safety (e.g. less traffic crashes, less traffic deaths, less speeding) (Fagnant & Kockelman, 2015; POLIS, 2018). Safety will not only improve for vehicle occupants but also for other road users (including pedestrians and cyclists) and people near the road environment. An important constraint is that people also have to be convinced about the safety of AVs. A lack of trust in the safety record of AVs will limit the uptake. However, it should be noted that the safety of AVs remains untested at a large scale and may not be immediate or linear (International Transport Forum, 2015a). Furthermore, the expectation of near zero fatalities with AVs may not be realistic (Sivak & Schoettle, 2015). It is also important to have attention for the transition phase with mixed use of vehicles towards a fully autonomous fleet (Sivak & Schoettle, 2015). Related to trust, it is also important to consider subjective stress (Funke et al., 2007).

3.4 Liveability

Cleaner and safer AVs are expected to improve the liveability of neighbourhoods and cities. Liveable neighbourhoods can lead to increased social connectedness and societal wellbeing (Department of Infrastructure and Regional Development, 2017). AVs also have the ability to cruise around and search for inexpensive parking spaces or to keep driving (Millard-Ball, 2019). They can also park more efficiently requiring less parking space (62-87%) (Nourinejad et al., 2018). A reduced number of parking spaces could create more space for different functions and can improve the value of real estate. It should be noted that the liveability will be negatively impacted if AVs generate increased or induced travel due to the ease of travel to the level of congestion (Department of Infrastructure and Regional Development, 2017; Raj et al., 2020). Furthermore, in combination with conventional vehicles or without public transport some neighbourhoods might require more parking spaces and consequently reduce the space for other land use alternatives (International Transport Forum, 2015b). AVs can thus blur the difference between travel and parking (Millard-Ball, 2019). Local authorities have the important task to ensure the previous mentioned social and structural benefits by proactive management and monitoring of land use planning through policy and regulations (Department of Infrastructure and Regional Development, 2017), e.g. congestion pricing based on time and distance or energy (Millard-Ball, 2019).

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3.5 Employment

AVs will have an impact on employment in the transport sector and associated sectors. Some jobs such as driving a taxi or bus will not be necessary with full automation. As mentioned before, there will still be a transition phase where drivers will be needed. Some parts of the transport sector will still be necessary in the future but the delivered service might change. It is expected that the fleet size of AVs will be smaller (Fagnant and Kockelman, 2014; Kellett et al., 2019). But this fleet will be used more intensively than conventional vehicles. AVs will still need to be designed and manufactured and will also need regular technical maintenance and repair. Furthermore, they need to be cleaned and it is expected that these costs will be quite substantial (Bösch et al., 2018). The current services of associated jobs such as car dealerships, insurances, road police, parking officers, road emergency workers might change (Department of Infrastructure and Regional Development, 2017). There will also arise new jobs (Manyika et al., 2017). These new jobs can be less monotonous and more people oriented (POLIS, 2018). Assistants might be available in AVs for those who need assistance. It is again important for authorities to anticipate the job changes and work together with the people who are employed in the transport sector (POLIS, 2018). There has to be an open discussion with people in transport to protect them and facilitate a gradual transition towards AVs that is supported by society.

4. Influence of COVID-19

COVID-19 will have an effect that might have a social, environmental, or economic impact but many of the impacts are still unclear. The short-term impacts are not investigated thoroughly enough and the long-term impacts are very uncertain. The overall influence of COVID-19 on mobility and autonomous vehicles (AVs) is still being analysed. This influence will depend on various factors such as measures taken by authorities, affected social groups, attitudes and behaviours, social norms, values, etc. Accessibility is or was highly restricted by authorities. Because of the travel restrictions in some areas, there was a substantial increase in walking, cycling, and other forms of micro-mobility (McKinsey, 2020). There were also environmental and health implications. Early results show that people living in areas with more air pollution are more prone to die from COVID-19 (Pozzer et al., 2020). This important finding supports a transition towards electric shared AVs. Air pollution also decreased because of the travel restrictions (Lamprecht et al., 2021). In many European countries, i.e. Germany, traffic fatalities dropped due to the travel restrictions (International Transport Forum, 2021). However, the United States saw a rise in traffic deaths (National Safety Council, 2021). The limited accessibility and improved air quality improved liveability for some but not for everyone due to the impact on mental health (Veer et al., 2021). The influence on employment varied, certain transport services closed (e.g. factories) while others provided a minimal but continuous service (e.g. public transport), worked from home (e.g. administration), and some even saw a rise in demand (e.g. delivery services). The earliest impacts showed a decrease in the number of sold conventional vehicles due to the closing of various transport associated companies and financial concerns of the consumers (McKinsey, 2020; Sjoberg, 2020). While the sales of electric bicycles peaked with often even more demand than supply (Butler, 2020; McCann, 2020; The Economist, 2020). However, many (young) consumers still seem to be convinced of the benefits of private conventional vehicles (McKinsey, 2020). What we do know from previous research is that lifestyles and travel behaviour tend to be hard to change and changes are more likely to occur on the long term by changes in attitudes, values, and preferences or by important life events (Kitamura, 1988; Scheiner & Holz-Rau, 2013). The question remains if these changes in lifestyles and travel behaviour due to COVID-19 will perpetuate. This could imply a decrease in the use of motorized vehicles but it is also possible that motorized vehicles become the norm again in the future supplemented by walking and cycling as a leisure activity.

5. Conclusion

Based on different transport frameworks, a social impact assessment (SIA) methodology for autonomous vehicles (AVs) was developed. Some of the most important social impacts can be analysed within this methodology: accessibility, environment and health, safety, liveability, and employment. Additional impacts need to be identified by local stakeholders during stakeholder engagement meetings. A future with AVs might also be impacted by COVID-19 but the expected influence remains unclear. It is crucial to validate and implement the suggested methodology. This will be done by monitoring 4 pilots that will use AVs in Varberg (Sweden), Inverness (Scotland), Hanover (Germany), and Almere (the Netherlands). If necessary, the SIA methodology will be adapted. The reference situation will have an influence on the social effects and impacts. This will be different if a conventional vehicle is being replaced by an AV or if the AV is being deployed in a new setting where no current motorized options are available. People tend to evaluate travel modes better if they have some experience with them, this is something we hope to see during the pilot tests. The outcome of the SIA will provide useful input for all the pilots and future pilots that are being and going to be implemented by local and transport authorities. The SIA will allow to anticipate or mitigate undesirable consequences connected to the implementation of AVs. This makes the social impact assessment a useful tool before, during, and after the implementation phase. In the end, this will contribute to more social transport and spatial planning.

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Appendix

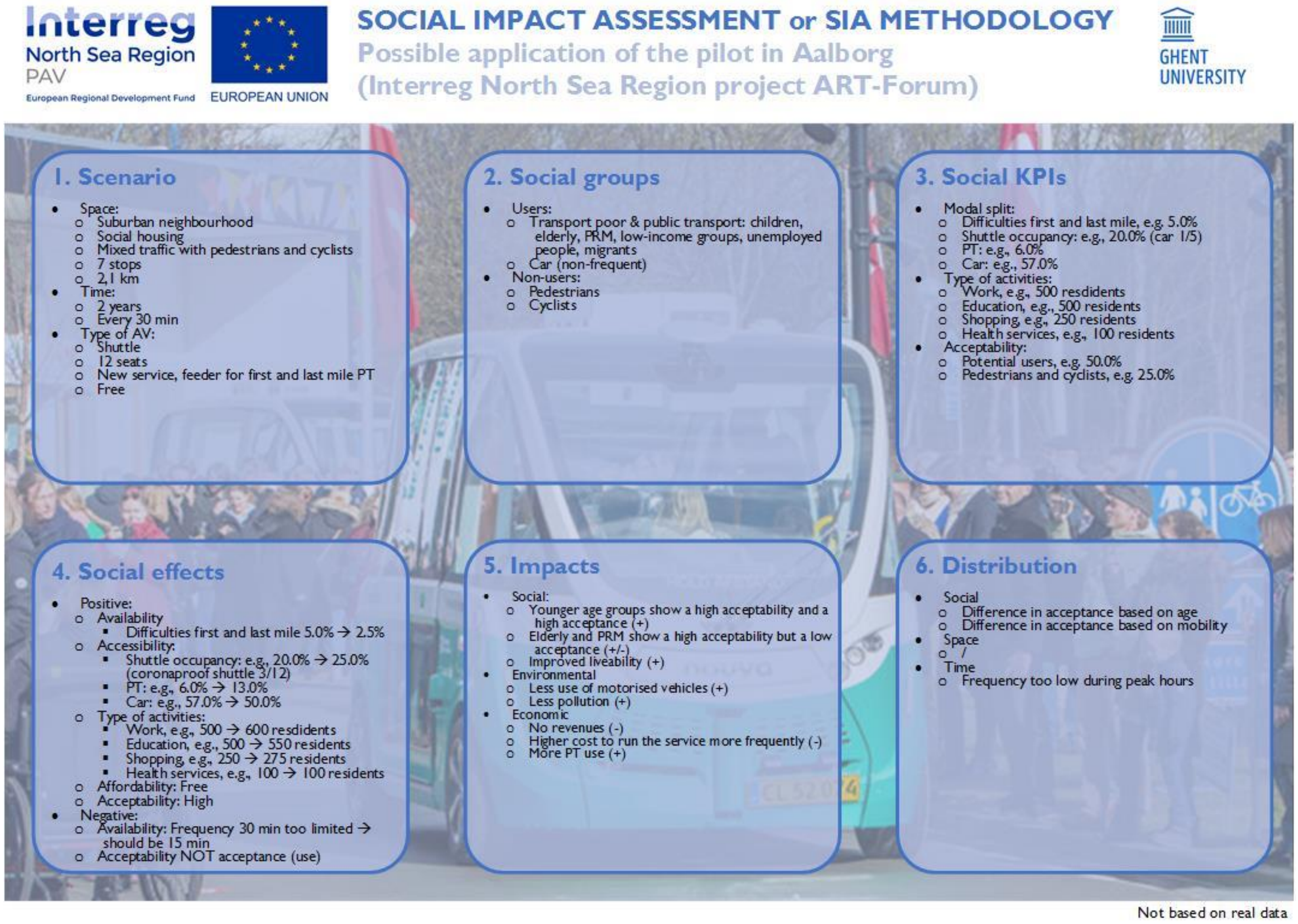

Figure 5: Example of a possible application of the Social Impact Assessment methodology for AVs