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Chapter 4

Implications of vehicle automation for accessibility and social inclusion of people on low income, people with physical and sensory disabilities, and older people

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Chapter outline

1. Introduction

Transport can have significant effects on a critical aspect of social sustainability: social inclusion (Lucas, 2012). Limited accessibility to economic, social, cultural, and political opportunities by lack of adequate transport can affect both the quality of life of individuals and the equity and cohesion of society as a whole (Levitas et al., 2007).

Depending on the level of automation (Society of Automobile Engineers-SAE levels 1−5; SAE International, 2016), the introduction of automated vehicles could influence accessibility levels of certain social groups who

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currently do not have access to cars, such as people on low income, people with physical and sensory disabilities, and older people facing accessibility constraints, and consequently levels of social exclusion (Shaheen et al., 2017). Below we will address the importance of SAE levels where needed. For example, people not owning a car or not being able to drive (younger, older, and people with disabilities) could reach activities via shared on-demand automated vehicles overcoming current accessibility limitations. (Shared) on-demand mobility services for older people, children, and people with disabilities are already in place both in the United States (see e.g., UberWAV, UberASSIST, Lift Hero, HopSkipDrive) and Europe (see e.g., Taxistop, Wheeliz).

Thus far, research on possible long-term implications of automated vehicles for social inclusion is scarce (see Milakis et al., 2017). Few studies have focused on possible positive effects of in-vehicle technologies on driving conditions of older people (see Eby et al., 2016) and on potential travel demand changes of social groups such as nondriving, older people, and people with travel-restrictive medical conditions (see Harper et al., 2016). Cohn et al. (2019) explored potential transport-related changes (e.g., job accessibility) in the case of the introduction of automated vehicles in low-income areas and in areas with higher levels of minority populations in Washington DC. Milakis et al. (2018) identified differences in distribution of automated vehicles–related benefits between social groups, while Mladenovic and McPherson (2016) analyzed traffic control systems in an automated vehicles context focusing on social justice design principles.

Both policy and research interests in possible implications of vehicle automation for social inclusion has increased lately. This chapter aims to contribute to this topic by analyzing the implications of vehicle automation for the accessibility of vulnerable social groups (i.e., people on low income, people with physical and sensory disabilities, older people) and consequently for their transport-related social exclusion.

Our chapter is structured as follows. Section 2 describes the conceptual model on long-term implications of automated vehicles for social inclusion that our analysis is based on. The implications of automated vehicles for the accessibility and transport-related social exclusion of people on low income, people with physical and sensory disabilities, and older people are analyzed in Sections 2.1–2.3, respectively. Section 3 provides the conclusions of this chapter.

2. Implications of vehicle automation for social inclusion

Automated vehicles could influence accessibility of vulnerable social groups in urban and rural areas and consequently have implications for transport-related social exclusion. The magnitude and direction of such implications for different social groups is a function of the accessibility component affected by automated vehicles, the level of vehicle automation as well as the mobility service model (i.e., private or shared vehicles). In this chapter, we focus on the implications of vehicle automation for the accessibility and transport-related social exclusion of people on low income, people with physical and sensory disabilities, and older people.

Our analysis departs from the conceptual model of Milakis (2019) on long-term implication of automated vehicles for social inclusion and public health (Fig. 4.1) The conceptual model builds on Geurs and van Wee's (2004) conceptual framework for accessibility which identify four accessibility components (i.e., land use system, temporal constraints, individuals' abilities and opportunities, and the transport system). In the conceptual model, the impact paths through which automated vehicles could influence various accessibility components and finally accessibility of certain social groups are presented. In the following subsections, we analyze these paths for people on low income, people with physical and sensory disabilities and older people. We first describe which component of accessibility is relevant for each social group, to what extent this component can be influenced by vehicle automation and at

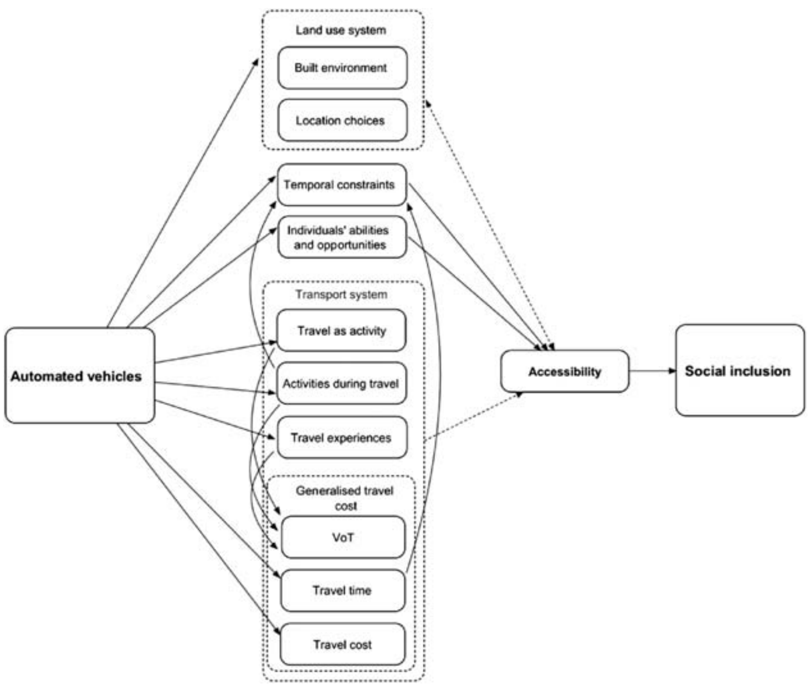

FIGURE 4.1 The conceptual model of the long-term implications of automated vehicles for social inclusion. *Source: Adapted from Milakis, D., 2019. The societal dimension of the emerging mobility technologies transition: towards a research agenda. The Case of Automated Vehicles (Working paper).*

which level of automation. We also explore whether having shared instead of private automated vehicles could enhance or reduce this impact. We summarize the accessibility changes for each group in Table 4.1.

2.1 People on low income

People on low income experience constraints in accessing opportunities because of the fixed (capital) cost of owning a vehicle (Fig. 4.1: individuals' abilities and opportunities), the financial cost of travel (Fig. 4.1: travel cost), as well as the spatial allocation of activities (Fig. 4.1: land use system).

The first generation of SAE level 4 and 5 automated vehicles is expected to be much more expensive than comparable conventional vehicles because of the advanced hardware and software technologies involved. Mass deployment of automated vehicles could reduce the cost of owning such a vehicle, but in any case this will not be as low as the cost of a conventional vehicle (Fagnant and Kockelman, 2015). The financial cost of travel could be reduced through lower fuel consumption. Studies report fuels savings for automated vehicles up to 31%, with higher savings found in simulations involving increased penetration rates of automated and connected vehicles (Milakis et al., 2017). Regarding long-term changes in the land use system, automated vehicles are expected to trigger a dual urban process involving both further dispersion and concentration of activities in urban centers (see Gelauff et al., 2017; Milakis et al., 2018; Zakharenko, 2016; Zhang and Guhathakurta, 2018). Further suburbanization of urban activities would lead to higher travel time and cost and therefore reduced accessibility for poorer social groups. On the other hand, concentration of urban activities in urban areas could enhance accessibility to those areas. Yet, increased demand for land in central areas (e.g., substituting former parking garages with commercial or residential uses) might drive land prices higher reducing housing affordability and thus displacing people on low income from those areas (see Hochstenbach and Musterd, 2018) (Table 4.1).

For shared (electric) automated vehicles, the fixed (capital) cost of owning a car will not exist. The financial travel cost is expected to be significantly lower than the current cost of accessing taxi services, mainly because of lower operating costs. For example, in Zurich the cost of a taxi driver represents 88% of the taxi operating costs (Bösch et al., 2018). Yet, access to shared automated vehicle services would require owning a smartphone, internet connectivity and/or mobile data package as well as a banking account and a credit card, which could constitute an important barrier for people on low income. In Western Europe and the United States that represent two of the largest smartphone markets, about 30% of the population do not own a smartphone (Statista, 2018, 2017). Moreover, 37% of the adults (mainly women, poorer, and lower educated) in developing economies (mainly Bangladesh, China, India, Indonesia, Mexico, Nigeria, and Pakistan) still are unbanked

TABLE 4.1 **Overview of possible accessibility changes for vulnerable social groups because of automated vehicles (↔: no change, ↑: increase, ↓: decrease).**

	Changes in accessibility because of automated vehicles			
	Accessibility component affected	**Private automated vehicles (up to SAE level 3)**	**Private automated vehicles (SAE level 4–5)**	**Shared automated vehicles (SAE level 4–5)**
People on low income		↔	↔/↓	↔/↓
	Individuals' abilities and opportunities	Capital cost will be higher than conventional vehicles.	Capital cost will be higher than conventional vehicles.	The increased cost (e.g., owning a smartphone) for digitally accessing shared automated vehicles services can limit access to such services.
	Travel cost	Fuel consumption could be reduced.	Fuel consumption could be reduced.	Lower operating costs, will reduce the cost of hailing a shared automated vehicle, but could compromise conventional public transport services.
	Land use system		Suburbanization or concentration of activities triggered by private automated vehicles in the city center would negatively impact poorer social groups	Suburbanization or concentration of activities triggered by shared automated vehicles in the city center would negatively impact poorer social groups by reducing accessibility and housing affordability respectively.

Continued

TABLE 4.1 Overview of possible accessibility changes for vulnerable social groups because of automated vehicles (↔: no change, ↑: increase, ↓: decrease).—cont'd

	Changes in accessibility because of automated vehicles			
	Accessibility component affected	**Private automated vehicles (up to SAE level 3)**	**Private automated vehicles (SAE level 4 –5)**	**Shared automated vehicles (SAE level 4–5)**
			by reducing accessibility and housing affordability respectively.	
People with physical and sensory disabilities		↔	↑/↔	↑/↔
	Individuals' abilities and opportunities	A fully capable driver will still be needed to take over control of the vehicle.	Accessibility to opportunities can increase through use of private automated vehicles. Custom-designed vehicles will be needed. Purchase price will be higher.	Accessibility to opportunities can increase through use of shared automated vehicles. Custom-designed vehicles and operating complexities can lead to higher cost for using such services.
Older people		↑/↔	↑/↔	↑/↔
	Individuals' abilities and opportunities	Private automated vehicles could be used for more years by older people. Operation and learning difficulties, uncertainty, insecurity, and distrust	Private automated vehicles could be used for more years by older people.	Accessibility to opportunities can increase through use of shared automated vehicles. Uncomfortability with digital access

		might prevent adoption of such new vehicle technologies.	Operation and learning difficulties, uncertainty, insecurity, distrust, and higher price due to custom-design might prevent adoption of such new vehicle technologies.	and anxiety with online payment could prevent older people from using such services.
	Travel cost			Lower operating costs, will reduce the cost of hailing a shared automated vehicle.
	Land use system		Urban dispersion because of private automated vehicles would reduce accessibility of older people because of increased travel cost, time, and effort to reach opportunities.	Urban dispersion because of shared automated vehicles would reduce accessibility of older people because of increased travel cost, time, and effort to reach opportunities.

(Demirgüç-Kunt et al., 2018) (Table 4.1). However, we need to consider that these figures might be different when full vehicle automation becomes available in the future.

For automated public transport, a reduction in financial travel cost is also expected given that the cost of bus drivers represents a significant part of the operating costs (e.g., 55% of bus operating costs in Zurich). If automated public transport offers access by physical means (e.g., waiting at the station instead of digitally calling public transport service, payment in cash), then no additional financial costs will occur for public transport users. On the other hand, a modal shift from conventional public transport to shared automated vehicles is possible (Clewlow and Mishra, 2017). Such modal shift could be gradually enhanced if public transport services would be cut due to limited viability in a more suburbanized urban context after introduction of automated vehicles unless those two systems are complementary (Ohnemus and Perl, 2016). Reduction of conventional public transport services could lead to further increase of travel cost and time for public transport users and subsequently a reduction in their public transport−based accessibility levels and it is not clear if this reduction in accessibility will be compensated by the increase accessibility due to the availability of shared automated vehicles.

2.2 People with physical and sensory disabilities

People with physical and sensory disabilities experience constraints in accessing opportunities because they are typically not able to drive or having difficulties to access other travel modes (e.g., public transport, bicycle) (see Fig. 4.1: individuals' abilities and opportunities).

Lower levels of vehicle automation (up to SAE level 3) are not expected to remove the constraints related to driving. A fully capable driver will still be needed to take over control of the vehicle whenever is required by the automated system. People with physical and sensory disabilities are expected to be able to use a private automated vehicle of SAE level 4 or 5 and therefore significantly improve accessibility to opportunities. Yet, custom-design of those vehicles, complying with specific needs of people with different types of disabilities will be necessary which would result in higher purchase price. For example, for people with physical disabilities, vehicles would need to be wheelchair accessible (e.g., having a ramp), while for people with sensory disabilities in-vehicle audible and braille information systems about refueling and maintenance would be necessary (Table 4.1).

Shared automated vehicles, could also increase accessibility levels for people with physical and sensory disabilities. Yet, several technical issues need to be solved (e.g., identification of appropriate boarding spot avoiding access obstacles), while the price of such services is expected to be higher than the typical for-hire services cost because of the custom-designed vehicles needed (i.e., wheelchair accessible; multiple wheelchair seating arrangements)

(Table 4.1). Complementary public transport services (i.e., paratransit) for people with disabilities have been proven to be both expensive and difficult to coordinate and operate (Fei and Chen, 2015). For people with sensory disabilities, vehicle sharing software/apps need to be custom-designed (building on existing smartphones' accessibility features like on-screen magnifier, large text option, VoiceOver) offering seamless access to ride-hailing/sharing services.

2.3 Older people

Older people combine characteristics and thus constraints facing both people on low income and people with physical and sensory disabilities (see Sections 2.1 and 2.2, respectively). For example, older people experience constraints in accessing opportunities because of reduced ability (or even inability) to drive due to health reasons (e.g., reduced vision and reflexes, fatigue) and to own a car or afford travel costs after retirement due to less income (see Fig. 4.1: individuals' abilities and opportunities). In addition, older people could experience constraints because of reduced (perception of) safety (Adler and Rottunda, 2006). Below, we focus on constraints and subsequently accessibility implications specific for older people.

Both lower levels (up to SAE level 3, e.g., lane departure warning, forward collision warning, blindspot warning, parking assistance, adaptive cruise control) and especially higher levels of vehicle automation (i.e., SAE levels 4 and 5) could enhance the ability of older people to drive or use a vehicle for more years despite possible problems with their health (Eby et al., 2016). Vehicle automation might also improve their perception of safety that constitutes another barrier for this social group in using a vehicle. Hartwich et al. (2018) reported that older drivers in a driving simulation experiment of automated driving preferred driving styles unfamiliar to them (e.g., higher speed). Moreover, automated vehicles could be used by older people to accomplish shopping activities (e.g., grocery shopping) and deliver them to their home without the need to move. The price of private automated vehicles will be higher than conventional vehicles. Moreover, several adaptations to automated vehicles design will likely be needed to serve particular needs of this social group (e.g., panic button, medication box, small kitchen, large windows, seats facing each other, table for lunch or playing card games: see Obst et al., 2017) that will probably result in even higher purchase price. Thus, older people facing also income constraints would probably be difficult to acquire vehicles equipped with automated driving features. Possible further dispersion of urban activities because of automated vehicles would also cause a reduction in accessibility levels of older people both for financial reasons (i.e., increased travel cost) but also because of the extra effort and time needed to reach activities.

The extent to which older people will adopt such advanced technologies in their daily mobility routines is still an open question. Several studies have shown that technology acceptance by older people is influenced by the ease of use and learning the new system, trust, social norms, earlier experience with technology and perceived behavioral control (i.e., self-efficacy and capacity to use the new technology) (Morris and Venkatesh, 2000; Reimer, 2014; Renaud and van Biljon, 2008). For acceptance of (owned) automated vehicles by older people, initial studies confirm that effort and especially operation and learning difficulties (Ingeveld, 2017) as well as uncertainty, insecurity and distrust (Obst et al., 2017) have a strong negative effect (Table 4.1). Such constraints might change over time as new technologies are introduced into daily life and new generations of older people become more familiar with them. For example, the results of a focus group with older drivers aged between 70 and 81 years, most of them owning a navigation aid system in the car, showed that this group was on average very positive regarding advanced navigation aid systems (e.g., based on augmented reality) (Bellet et al., 2018).

Shared automated vehicles, could enhance accessibility of older people by removing constraints related to driving as well as by reducing the cost of such services. Yet, older people might face constraints accessing those services because of the requirements for owning and using a smartphone or other internet access devices as well as to perform online transactions. Shirgaokar (2018) reported that senior citizens in Edmonton, Canada stated that they feel anxious with online transactions because of possible fraud and uncomfortable with using taxi-hailing smartphone apps. Moreover, part of the sample in this survey reported that they only had basic cell phones for cost reasons. Ingeveld (2017) found that the intention of older people to use shared automated vehicles in the Netherlands is mainly influenced by the operation and learning difficulty of the system and to a lesser extent by social and peer pressure (Table 4.1). Also, custom-designed apps for older people might be necessary to overcome health-related constraints in using those apps such as reduced visibility and hearing acuity. Finally, possible cuts of conventional or automated public transport services because of competition with shared automated vehicles and suburbanization of urban activities could also negatively influence accessibility levels of older people.

3. Conclusions

Automated vehicles could influence long-term social sustainability by affecting levels of social inclusion. Such effect has attracted little attention in the literature, thus far. In this chapter, we contribute to this topic by analyzing the implications of vehicle automation for the accessibility of vulnerable social groups (i.e., people on low income, people with physical and sensory disabilities, older people) and consequently for their transport-related social exclusion. Below we present our conclusions.

The conceptual model that we based our analysis on shows that changes in accessibility because of automated vehicles constitute a key path through which certain social groups (e.g., people on low income, people with physical and sensory disabilities, older people) could possibly experience changes in levels of social inclusion. The component of accessibility affected by automated vehicles, the vehicle automation level, and the mobility service model (i.e., private or shared vehicles) are expected to define the magnitude and direction of implications for different social groups.

According to our analysis, accessibility to opportunities for people on low income could either remain unchanged (lower levels of vehicle automation) or negatively influenced (higher levels of vehicle automation) in a context of private automated vehicles, despite the fact that such vehicles can be more fuel efficient already from lower levels of automation (Table 4.1). Shared automated vehicles could lead to lower financial travel cost but increased cost for digitally accessing those services could compromise possible gains. Moreover, further suburbanization or concentration of activities in the city center would negatively impacts poorer social groups by reducing accessibility and housing affordability respectively. Finally, automated public transport will likely enhance accessibility of low-income group through reduced financial travel cost. Competition between shared automated vehicles and automated public transport might compromise accessibility benefits for public transport users.

Accessibility to opportunities for people with physical and sensory disabilities is not expected to change in lower levels of vehicle automation (up to SAE level 3) (Table 4.1). Both private and shared automated vehicles of SAE level 4 and 5 could enhance accessibility for this social group. Yet, custom-design of the vehicle as well as operating complexities could result in higher prices for owning or hailing such vehicles compared to conventional automated vehicles. Thus, for people facing both income constraints as well as physical or sensory disabilities the introduction of automated vehicles is not expected to alter the level of their accessibility to opportunities.

Accessibility to opportunities for older people could be increased by both lower and higher levels of (private) automated vehicles because they could enhance the ability of this social group to use a vehicle for more years (Table 4.1). Yet, it is unclear to what extent older people would overcome operation and learning difficulties, uncertainty, insecurity, and distrust to adopt such new vehicle technologies. Moreover, adaptation of automated vehicle design to older people's needs would drive purchase price even higher, making difficult for this social group to own such a vehicle. Further urban dispersion because of automated vehicles could compromise accessibility to opportunities for older people. Shared automated vehicles could enhance accessibility of older people but the requirement of digital access and online payment for this service could prevent them from using such services both for psychological and financial reasons.

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