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Implications of automated vehicles for accessibility and location choices: Evidence from an expert-based experiment

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ABSTRACT

In this paper, possible accessibility impacts of fully automated vehicles (AVs) are explored. A conceptual framework for those impacts is developed based on the model of four accessibility components (i.e. land use, transport, temporal and individual) of Geurs and van Wee (2004). Q-method is applied among a sample of seventeen international accessibility experts to explore heterogeneity among experts with respect to the impacts of AVs on accessibility, and study different views and clusters of experts. Q-method statements are deductively categorized according to four accessibility components of the conceptual framework. Three viewpoints were extracted, indicating that experts expect AVs to influence accessibility through all four accessibility components. Viewpoint A expects that accessibility benefits stemming from AVs will be highly uncertain, mainly because of induced travel demand that will likely cancel out travel time and cost savings of AVs in the long term. Viewpoint B anticipates that accessibility changes because of AVs will have two opposing implications for urban form: densification of city center and further urban sprawl. Finally, viewpoint C expects that those who can afford an AV will mainly enjoy AVs benefits, thus AVs will have more negative than positive implications for social equity.

1. Introduction

Automated vehicles could have significant implications for cities and transport systems. Milakis et al. (2017b) identify three stages of sequential impacts after introduction of AVs: first order (traffic, travel cost and travel choices), second-order (vehicle ownership and sharing, location choices and land use, transport infrastructure) and third-order (energy consumption, air pollution, safety, social equity, economy and public health). This paper focuses on the implications of AVs for accessibility and the location choices.

Thus far, only few studies have explored these impacts using quantitative modeling methods. Childress et al. (2015) used an activity-based model in Seattle, WA to simulate a transport system entirely based on AVs and to explore possible accessibility changes. These researchers concluded that the introduction of AVs could enhance accessibility across the region, particularly in rural areas. A second study explored land use impacts of automated driving from an urban economics perspective (Zakharenko, 2016), concluding that automated driving could induce two divergent land use dynamics in the city. Reduced transport costs could cause cities to further expand, while reduced parking requirements could enhance density of economic activity at the center of the cities. Similarly, Gelauff et al. (2017) using simulations of a spatial general equilibrium model (LUCA) in the Dutch context concluded that automated vehicles could induce both urban dispersion and concentration effects. Dispersion of population in suburban areas resulted when more productive use of car travel time was assumed in the model. Concentration of population resulted when most public transport services (i.e. bus, trams, metro) were replaced by door-to-door shared automated mobility services. Papa and Ferreira (2018) employed Geurs and van Wee's (2004) definition of accessibility to identify critical governance decisions that could steer impacts of AVs on the four accessibility components (i.e. land use, transport, temporal and individual) toward an optimistic or a pessimistic future with respect to the possible benefits for the society. Beyond these studies, some theoretical and empirical work has been done in the related area of Intelligent Transport Systems (ITS) by Argiolu et al. (2008, 2013), showing that these systems have significant impacts on location preferences of office-keeping organisations within urbanised areas. However, literature so far has not provided empirical evidence about potential impacts of AVs on accessibility and the location choices (see e.g. van Wee, 2016; Anonymous, 2017).

Our study aims to fill this knowledge gap by exploring these impacts through an expert-based approach. AVs are a radical and potentially even a disruptive innovation, and it is very difficult to forecast the

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implications of such innovations, as well as the transition path and penetration rates. What is going to happen, depends – among others – on path dependence, (potential) lock-in, coincidence, and many more factors, as explained by evolutionary economics (see Rammel and Van den Bergh, 2003). It is much easier to explain from hindsight what has happened and why, than it is to accurately forecast what is going to happen, especially in case of disruptive innovations. Therefore, we argue it is better to explicitly explore heterogeneity among experts, and study different views and clusters of experts.

To this end, we apply the Q-method among a sample of international accessibility experts to explore possible impacts of AVs on accessibility and the location choices. The Q-method is considered appropriate in this case because it allows capturing heterogeneity in subjective viewpoints regarding a particular topic. Other methods to explore expert opinions generally strive for reducing heterogeneity among experts. The Delphi method, for example, is even designed to reduce heterogeneity among respondents by presenting preliminary results in a second (or even third) round of expert elicitation, aiming to explore reasons for heterogeneity and next reduce it.

In this study, we focus on the impacts of fully automated vehicles (SAE level 5; SAE International, 2016) and we take into account possible synergistic effects of vehicle automation and vehicle sharing. Fully automated vehicles can perform all dynamic tasks of driving (e.g. monitor the driving environment, steering, acceleration/deceleration), in all conditions (e.g. highways, urban streets). They can travel both occupied and unoccupied (e.g. to park or reposition themselves in the case of shared automated vehicles). This study does not distinguish between autonomous and cooperative vehicles (i.e. vehicles that can communicate with each other and/or with the infrastructure). Below, we analyze our conceptual framework on accessibility and location choice impacts of AVs (Section 2), we describe the Q-method and how we applied it in this study (Section 3), and we present the results of our expert-based experiment (Section 4). We close this paper with the conclusions (Section 5).

2. Conceptual framework

Our conceptual framework is based on Geurs and van Wee (2004), who define accessibility as “the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)” (Geurs and van Wee, 2004: 128) and identify four components of accessibility: land use, transport, temporal and individual. The supply and demand for opportunities (e.g. jobs, shops and health) and the competition for those opportunities within a specific area describe the land use system. The transport system expressed as the disutility of travel in terms of travel time, cost and effort describes the transport component. The temporal availability of opportunities (e.g. open and closing times of stores) and the temporal constraints of individuals (e.g. people may have to work a fixed amount of hours at specific working place) describe the temporal component. The personal needs, opportunities (which can vary according to, for example, income or educational level) and abilities (e.g. physical conditions which might constrain access to specific travel modes) describe the individual component. The land use and transport components form the basis, a first layer, for accessibility and are less easy to change in the short term, while the temporal and individual components form a second layer that is more susceptible to change in the short term. The four components of accessibility interact with each other (see Geurs and van Wee, 2004: Fig. 1, p. 129). For example, the land use component determines to a large extent travel patterns and therefore influences the transport component. Also, the individual component determines the availability of time for an individual and therefore her temporal constraints (individual component).

AVs could influence all accessibility components and subsequently the location choices of people and firms while location choice could affect back accessibility (see Fig. 1). First, the transport component could be affected by changes in travel effort, time and the marginal value of travel time savings, and cost associated with vehicle automation. Second, the individual component could be affected because people that are currently unable to drive could reach activities by (shared) AVs. Third, the temporal component could be affected, for example because people might be able to accomplish activities on the move or (fully) AVs might be able to accomplish certain activities themselves, thus overcoming temporal restrictions of opportunities (e.g. closing times) and individuals (e.g. working hours). Finally, the land use component could be affected because people, firms, shops, services might chose to relocate, compensating for example lower travel costs with more distant location or choosing a more central location taking advantage of self-parking capability of AVs.

In addition to the impacts above, AVs may also influence accessibility via developments in shared mobility. Given that (SAE level 5) AVs can pick-up and deliver passengers autonomously, there is, in principle, no longer a need for personal car ownership. Hence, the trend in AVs is intrinsically linked with the trend in shared mobility, which is reflected in the conceptual model. For example, apart from their possible impacts on car ownership levels, shared automated systems may also meet individuals' travel demand needs with higher flexibility and lower costs compared to existing bus or taxi services, thereby affecting the transport and individual components of accessibility.

3. Method

3.1. Q-method procedure

The Q-method can be used to reveal and understand the variety in subjective viewpoints regarding a particular topic. Given that our objective is to explore the heterogeneity (rather than consensus) among experts regarding the impacts of AVs on accessibility, the Q-method was considered an appropriate method. Typically, the Q-method is not used for this type of purpose, but rather to explore heterogeneity in viewpoints on topics on which a more or less mature debate has evolved (Watts and Stenner, 2005), but we think there is not any mathematical or wider methodological objection for its use in this case.

The procedure of the Q-method encompasses four steps. First, the concourse needs to be defined. In typical Q-studies, the concourse reflects all statements of opinion expressed in communications (in text or verbally) regarding a particular topic (Brown, 1980). Often, the concourse contains too many statements and needs to be reduced to a manageable size (for the next step), while keeping (as much as possible) the complete variety of opinions. The resulting selection is called the Q-sample, and typically contains 30–60 statements (Watts and Stenner, 2005).

In the second step, the Q-sample is included in a rank-ordering task, which is administrated among a set of strategically selected participants. The statements do not have to be completely ordered, but a partial ordering, using a forced distribution, suffices (Brown, 1980). With respect to the condition of instruction, participants are usually asked to indicate their level of (dis)agreement with each statement. The resulting rank-orderings are referred to as Q-sorts and reflect the various viewpoints regarding the subject under study.

In the third step, common viewpoints are revealed by subjecting the Q-sorts to a (by-person) factor analysis (Brown, 1980). By applying the factor analysis participants with similar Q-sorts (viewpoints) are clustered together (i.e. they will load on the same factor). Next, a rotation method can be applied to achieve simple structure. Based on the resulting factor loading matrix, common viewpoints can be revealed by computing the (standardized) factor scores.

In the fourth and final step, the factor scores are used to interpret each viewpoint. Ideally, the interpretation of the factors is supported by comments made by participants (in response to open questions) who belong to (i.e. load on) the respective factors.