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Driverless Mobility: The Impact on Metropolitan Spatial Structures

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Abstract

Diffusion of emerging technologies is following the need of solving particular problems. Each innovation produces also some undesirable consequences. Many examples from the past have shown that along with the spread of each technology their side effects are accumulating until the level they need to be solved. One of the examples is automobile, which advantages and disadvantages were already described including its spatial consequences. Automobile did not change its general way of functioning for over one century, and recent technological advances in automation may revolutionize the way it is used. Nowadays, automotive and IT industries are investing in so called: autonomous automobiles, driverless vehicles and self-driving cars, the meaning of which intertwine. Diffusion of automation in mobility is going to accelerate in the near future. The earliest implementations of new transport technologies appear in metropolises which also have the highest level of general mobility. Due to the possible significant consequences of this innovation's diffusion for metropolitan (urban and suburban) spatial structures it is important to anticipate its potential side effects to avoid negative consequences, and if necessary – to prepare to encounter them. This led to undertake research on the relationship between modern mobility innovations and metropolitan spatial structures. The article presents the assumptions and principles of scenario-based research. The example shows how diffusion of different driverless mobility solutions determine different impacts on spatial structures, and thus possible scenarios for the future.

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Keywords: autonomous automobiles; driverless vehicles; metropolitan spatial structures; scenarios; self-driving cars; urban planning;

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1. Introduction

Examples from the past has shown that new inventions, implemented to solve particular problems, are followed by their unpredicted or underestimated side effects [1]. The problems emerge during diffusion of technologies. Many of negative consequences of new technologies were foreseeable, and thus preventable. The objective of this paper is to emphasize the importance of predicting, and therefore preventing problems that may emerge during diffusion of particular technical and organizational solution. For this purpose, the scenario-based method is used. The paper is discussing the impact of driverless mobility on metropolitan (urban and suburban) spatial structures. Driverless technology is also mentioned in authors' paper discussing the impact of car-sharing on metropolitan spatial structures [2].

Abbreviations of technical and organizational solutions

AA	autonomous automobiles
CS	self-driving car-sharing
DS	driverless shuttles
EV	electric vehicles
RS	self-driving carpooling and ridesharing

2. Literature review

2.1. Nomenclature and definition

There are multiple names and words' combinations used for technical and organizational solutions discussed in this paper e.g.: *autonomous cars* [3], *autonomous (land) vehicles* [4, 5] or *automated vehicles* [6] – AVs, *autos* [7], *driverless cars* [8], *self-driving cars* [7], *pods* [9], *robocars* [10] or *robot cars* [3] and more. The meanings of *autonomous*- (also named *automated*-) and *self-driving cars* are intertwining, depending on the level of automation distinguished by automotive industry organizations [11–13]. For the research purposes this paper discusses exclusively the highest levels of vehicles automation regardless of (differently named) technical and organizational solutions. In this respect automated vehicles *have no steering wheel and no gas and brake pedals* [7], and the automation technology is *seamless* for its users [14].

2.2. Background

Driverless mobility emerges as an effect of evolutionary continuation of traditional modes of transport, as shown on *figure 1*. Since the 20th century two main modes of urban transport may be distinguished: individually owned automobile and mass transit. Automobile had a significant impact on spatial structures [15–22] and its domination may continue due to the total automation street intersections [23]. Along with owning a car, two major organizational solutions emerged: ridesharing and car-sharing [24, 25]. Due to automation new possibilities of application emerged [26, 27] and people are ready to use them [28]. Since there is no need of driving the user can be picked-up by the car, therefore it is easier to maintain virtually on-demand services. User does not need a driving license; thus more people are allowed to ride a car anytime they want. On-demand mobility solves also the first and last mile problem, enabling more people to reach the traditional mass transport, thus complementing it. On the other hand, it competes with insufficient transit as well as with the need of owning a car. The question is what the impact will driverless mobility have on metropolitan (urban and suburban) spatial structures? Many researchers and writers are discussing related problems [3, 6–8, 12, 29–35]. There is lack of distinguishing impacts from different technical and organizational solutions of driverless mobility. Therefore, this paper proposes a typology model used for the discussed later research.

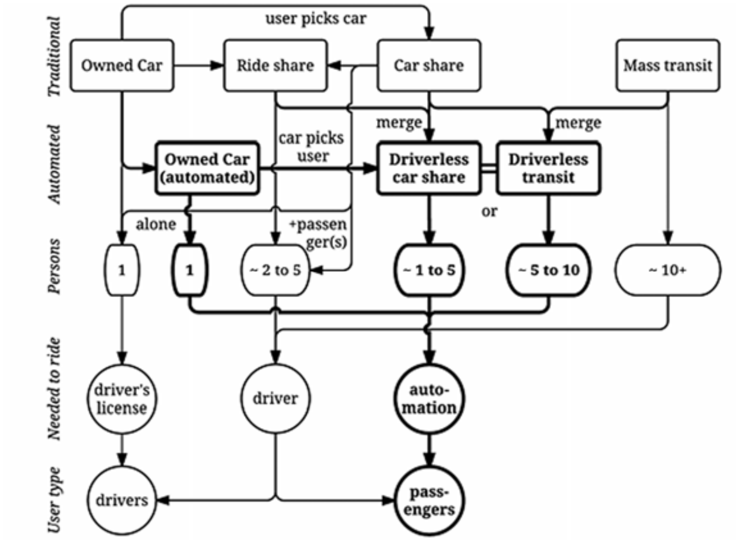

Figure 1. Driverless mobility on the background of urban modes of transport. Author: Piotr M. Smolnicki.

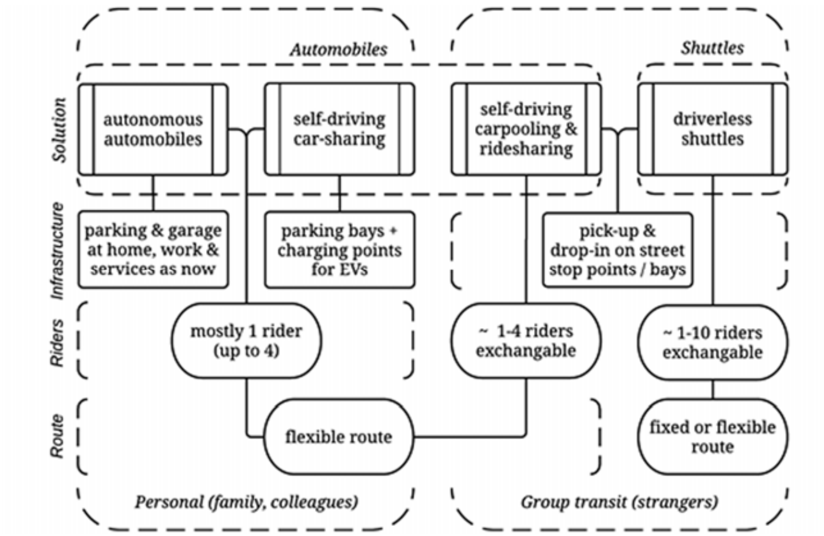

Figure 2. Driverless urban mobility typology. Author: Piotr M. Smolnicki.

2.3. Typology model of driverless urban mobility

There are many combinations in naming driverless mobility due to synonyms for both technology and its platform. For the purpose of this research four technical and organizational solutions are distinguished, according to different naming by e.g. automotive and IT industry and researchers: (1) *autonomous automobiles – AA* (eventually automated automobiles), (2) *self-driving car-sharing – CS*, (3) *self-driving carpooling and ridesharing – RS*, and (4) *driverless shuttles – DS*. The *figure 2* presents the intertwining of their main features.

In general presented driverless solutions may be divided on personal (AA and CS) and group transit (RS and DS) mobility. The first group is used for individual trips, or with family and colleagues, when in the second group mostly strangers ride together. Three first solutions are based on automobile-like platforms, when the last one is based on the mini-bus-like shuttle. Car-based vehicles have the capacity around four riders, but mostly used in RS, rather than in AA and CS. DS can fit around 10 users, therefore it may also need fixed route [36] – in opposition to the rest of discussed solutions. Since the AA is the evolutionary continuation of individually owned car it needs parking space or garages near every travel destination, regardless of their use. Parking lots are not only single function but may also generate additional 30 percent congestion when cruising for free place [37]. CS may need also the parking bays combined with charging stations for electric vehicles (EVs).

3. Methodology

The research study was based on construction of scenarios. Scenario method is one of the most useful prognostic methods, especially in the case when the social and institutional behaviours play a crucial role [38]. For Kahn and Wiener, a scenario is a set of"hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points" [cited in: 39]. *A scenario is not a future reality but rather a means to represent it with the aim of clarifying present action in light of possible and desirable futures* [39]. In presented research the scenario building method came from Godet [40], and then adopted for spatial planning in research projects at the Gdansk University of Technology [41, 42]. The elements of this method are: (1) the structural analysis of a given spatial system and the analysis of actors; (2) making assumptions as the rules of differentiation of scenarios; and (3) scenario construction:

- Construction of so-called main lines of the scenario – recorded in a general, synthetic manner, using a small number of key variables – the most significant, strongly aggregated and synthetic;
- Opinion, evaluation and verification of the main lines based on different criteria, e.g. probability and importance for showing a range of possible development;
- Choice of a few main lines that are quite probable, different from each other, and most characteristic with regard to the range of problems and possible actions;
- Evolvement of full scenarios from the choice of main lines.

In this article each scenario presents diffusion of technical and organizational solutions of driverless mobility and its impact on metropolitan (urban and suburban) spatial structures (related to physical structures – built environment, and spatial socio-economic structures). Two kinds of priority decisions of the metropolitan authority indicated two types of their policy (pedestrian friendly and riders friendly). These were assumed as rules of differentiating two edge scenarios. Figure 3 presented the main lines of these scenarios.

4. Results and discussion

Metropolitan spatial development depends on decisions foreseeing far-reaching consequences. Lack of decision may also have various consequences dependent on (uncontrolled) technological diffusion. Figure 3 presents scheme of two edge-scenario main lines and relations between their variables and four technical-organizational solutions of driverless mobility. There are infinite numbers of scenarios that may appear between the two presented. Main lines follow the authority's priority decisions focusing on pedestrians or riders. Each variable results from the previous one and determines the next one. *Pedestrian friendly* priority results in shaping the more inclusive street, with lower speeds, better transit options. It also results in longer time commutes, therefore shorter distances chosen by users. These variables use existing multifunctional and densely populated spatial structures and promote their further development (urbanization) or city revival (reurbanization). On the other hand, *rider's friendly* decision results on modernist-like separation of the street design allowing bigger speed differences, therefore faster travels linked to personal modes of transport. Since it allows quicker commute the longer distances are chosen, therefore it promotes spatial-functional separation. The result on spatial structures might be migration of citizens from the urban core (deurbanization) to the suburban and rural areas (suburbanization). As a result of uniformly distributed access to transport (automobile-oriented district) it promotes suburban sprawl (homogenous district of detached houses).

There is strong dependency between presented decision-based edge-scenario main lines and diffusion of different technical and organizational solutions of driverless mobility. The analogy is mentioned before in the article widely described impact of the 19th and 20th century transport on spatial structures. First presented in *figure 3* solution is *autonomous automobile* (AA). It is the evolutionary continuation of individual car, therefore it has strong relation with the second scenario and weak relations with the first scenario – if the speed could be reduced locally, the optimal distance of travel could decrease but without impact on spatial structures. Therefore, the domination of AA in general share of mobility can lead to (continuation of) deurbanization and suburbanization, rather than the opposite.

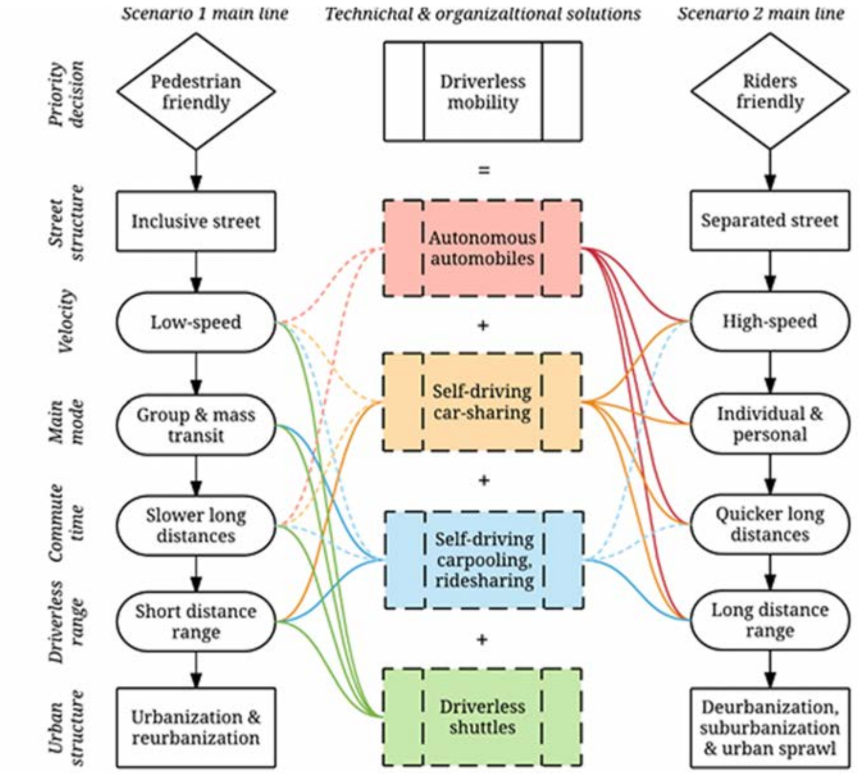

Figure 3. Impact of driverless urban mobility types on spatial structures. Author: Piotr M. Smolnicki.

Self-driving car-sharing (CS) results will be the same to AA, if not one variable giving the potential of changing to the scenario – the limited coverage of the service. It is competitive to individually owned automobiles, therefore in case of public organization of car-sharing it could be managed to support only the places of choice. CS has also potential of reducing Vehicle Kilometres Travelled (VKT) [24]. Since each vehicle is used more efficiently the need of parking places could be reduced, therefore complicating and reducing the sense of using owned car. On the other hand, CS, if not managed publicly, could result in bigger automobile share, giving the possibility of individual car travel for everybody. This may result not only in higher congestion but also in even bigger spatial-functional separation, due to the possibility of easier living in the suburbs without a car. Even MIT City Car is already considered as an obsolete idea and new autonomous electric bike-like vehicle was proposed [43]. Therefore, CS may result in both scenarios, depending on technological diffusion and political decision.

Another technical-organizational solution is *self-driving carpooling and ridesharing* (RS), which mixes features of individual and mass transit. RS may be carried by company and public fleets or individually owned cars. It may work as well in the first and the second scenario on shorter and longer distances. The main difference to individually owned or shared automobile is riding with strangers (higher commute efficiency), therefore the need of stopping-by and changing the route for picking-up and dropping-in co-users (longer commute times). Main difference to traditional mass transit is on-demand (no schedule) on-street stop (no bus stop), and related with it smaller capacity, same as the automobile. RS can be used as a cheaper alternative to individually owned or shared automobile as the door-to-door service. Occasionally it can serve as an alternative for transit, for example to reach not supported location, or alternative for long distance inter-city travels, as carpooling. Thus, it rather complements transit by solving the problem of the first and the last miles. It can be assumed that R-S may serve both: dense urban structures, where it could work cheaper due to efficiency and shorter trips, including switching modes of transit; and suburban structures as an alternative to car ownership, but complementing with e.g. regional transit. Therefore, it rather does not support sprawl but transit oriented neighbourhoods. The last solution may be considered as a group (mass) transit and is based on bus-like on-demand *driverless shuttles* (DS), like Easymile EZ10 shuttle used for CitiMobil2 project [44]. It is designed to serve as a public service, therefore it has full relationship to the first scenario. Its inclusiveness can support whole range of people, from children going to school to improving mobility of elders and handicapped. DS should work even on the no-car zones due to being close to the users, and thus its speed should be reduced. This makes the service efficient on smaller distances promoting inclusive development of urban core and transit oriented neighbourhoods.

5. Conclusions

It can be assumed, that the first scenario could be reached due to diffusion of technical and organizational driverless solutions, such as ridesharing and carpooling applications, and publicly operated limited-range car-sharing and transit shuttles. The second scenario may emerge due to continuation of automobile use in both forms: personally owned autonomous automobiles or individually shared self-driving cars. Real scenario's main line will flow in between of two presented edge scenarios, depending on transport and urban planning policy, existing local conditions, and diffusion of different technological and organizational solutions of driverless mobility. Therefore, the research presented in this paper should be continued considering different diffusion (share) of each solution in different (local) conditions.

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