



## The Effects of Autonomous/Driverless Cars in the City - Developing Scenarios and Deriving Causal Relationships - – Summary –



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## 1. Current Developments and Issues

“Anyone who only thinks of technology has not yet recognized that autonomous driving will change our society.” *Dr. Dieter Zetsche, CEO Daimler AG*<sup>1</sup>

It will still be quite some time before we reach the maturity stage in the technological development of fully autonomous (i.e. driverless) vehicles, in which the driver no longer needs to have his or her hands on the steering wheel and instead lets the vehicle do the steering. It will take an even longer time until these vehicles exhibit a considerable level of market penetration. Almost all manufacturers have announced that their highly autonomous vehicles will be ready for series production by the turn of the decade. Yet the development of advanced driver assistance systems has already made it possible for drivers today to experience partially autonomous or highly automated driving, as documented in press releases on test-drives with Google or Tesla vehicles.

In addition to the traditional automobile manufacturers, the market is being opened up to new business models for new vendors as well as joint ventures. The American auto manufacturer GM is cooperating with the rideshare service company Lyft and plans to introduce robot taxis. Uber would like to enter the mobility services market together with Toyota and is deploying the first robot taxis in Pittsburgh. Volkswagen is taking a stake in Gett, a Chinese rival to Uber, so that they too can bring mobility services with autonomous vehicles onto the market in the future. Also, within 5 years, Ford wants to put autonomous vehicles without pedals or steering wheels into serial production and onto the streets, and as a first step, deploy them in fleets for mobility service providers. Even Deutsche Bahn, under the leadership of Rüdiger Grube, wants to expand its range of services and promote the interconnectivity of the systems in the future, stating: “we too (...) will surely operate fleets of driverless cars in the future.”<sup>2</sup> Throughout the world, new companies are being founded that would like to play a role in shaping the future of mobility services in the city.

Regardless of the issues concerning the technological development of autonomous vehicles and the obstacles still to be overcome, there are also questions concerning the implications for mobility, traffic in the city, and settlement patterns. By utilizing fleets of autonomous vehicles for transporting people, there is the potential, with increasing efficiency, to absorb and unite several functions that had previously been distinctly separate realms, such as the private car, taxi, group taxi, car-sharing vehicle, and rental car. This is leading to new mobility concepts and new business models that could bring about a major transformation in urban mobility as we know it today. With the introduction of these vehicle concepts, experts from the automotive industry and public transportation companies expect a disruptive development in the mobility sector and a transformation of the forms of mobility available in the city. With this in mind, it is absolutely necessary for municipal transportation planners as well as public transportation providers to have a discussion about these potential future developments at an early stage, in order to set the course now for the future of sustainable mobility.

The objects of this study are the effects of these developments on the traffic and mobility options in the city, as well as the range of fields that are affected by autonomous/driverless vehicles. Several scenarios are provided to help illustrate and discuss these potential future developments, and the courses of action for city planning and transportation planning are sketched out. Ultimately, there is the question of what short-term and medium-term strategic and regulatory options municipalities have for taking advantage of the full potential of autonomous vehicles and the newly developed mobility concepts, while also minimizing the risks associated with it. From the perspective of the city of Bremen, the sponsor, the goal is to prepare the city for the topic and at the same time to start an initiative to sensitize the municipal committees in a time-

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<sup>1</sup> URL: [www.mercedes-benz.com/en/me/inspiration/me-blog/autonomous-driving-as-future-mobility/](http://www.mercedes-benz.com/en/me/inspiration/me-blog/autonomous-driving-as-future-mobility/), 17 Aug 2016

<sup>2</sup> Der Tagesspiegel, Article: “Bahn und Fiat setzen auf selbstfahrende Autos,” 5 May 2016

ly manner, so that, in cooperation, the interests of the municipalities can be communicated to the industry and to lawmakers.

## 2. Observation of Effects – External Studies

The effects of autonomous vehicles on city traffic can only be estimated today with the help of a few simulations. Several studies based on simulations for the cities of Singapore, Lisbon, and Stuttgart deal with how deploying autonomous vehicles would affect the mobility options and city traffic. In each case, the discussion revolves around the utilization of these vehicles in fleets as car-sharing or ride-sharing options supplementing highly effective public transportation systems, or even as a substitute for public transportation. One thing that all of these studies have in common is that they demonstrate a decrease in the number of vehicles required to meet the mobility demands of the city, due to the more efficient deployment of autonomous vehicles. Car-sharing options have positive effects on the number of vehicles and ride-sharing options demonstrate an even larger effect. However, as public acceptance of these mobility services rises, although fewer cars will be required, at the same time it is becoming clear that there is a potential increase in the total kilometers driven by motorized vehicles and the traffic volume in the city, at the expense of public transportation. The challenge for the city is therefore to organize and manage the options in a way that ensures sustainable mobility.

All of the studies work with numerous assumptions, so the results cannot be extrapolated to this magnitude. However, the results also clearly illustrate the heterogeneity of the potential fields of usage and concepts for autonomous vehicles and the complexity of the potential effects on traffic and the city system. A reduction in the available vehicles and a decrease in the demand for parking spaces, while maintaining the mobility supply and the quality of the services, were demonstrated in all of the studies. Yet the others also continually point out the risks of a potentially significant increase in driving services. Therefore, the challenge is to manage the supply of mobility options in an ideal way, so that the desired effects can be achieved, without also worsening the traffic situation and the quality of urban life.

## 3. Scenario Discussion: "The World of Mobility 2035"

In order to facilitate the approach to estimating the future development of autonomous driving and its effects on the city, a panel of experts convened to discuss potential scenarios. Two workshops were organized to identify the parameters and the potential chain of causal relationships. These included experts from research institutions, public transportation companies, municipal offices, and companies that deal with the development of concepts related to autonomous driving (see list of participants).

In January and February 2016, two single-day workshops with experts were conducted in Bremen. The goal was to illustrate the causal relationships and the future scenarios for mobility in the city, thus laying the foundation for deriving strategic recommendations for municipal action. The first workshop focused on identifying the underlying parameters and factors that influence the future of mobility in the city and autonomous driving. At the end of the workshop, the initial causal relationships were discussed and potential developments were presented. The second workshop began with the description and definition of the scenarios that had been developed by the experts. With two use cases, they delved deeper into the fields of action and the steps to be taken, derived implications for city traffic, and developed potential courses of action to manage the traffic sustainably.

### 3.1 Influential Factors

In order to describe the future mobility worlds, the experts first discussed the relevant influential factors that will substantially determine the future of mobility in the city and, mainly, the usage of autonomous

vehicles. The spectrum of 23 influential factors that were identified consisted of issues such as regulation, politics, city development, technological development, the viability and organization of mobility and transportation options, societal factors, human behavior regarding mobility, as well as acceptance of autonomous systems. Furthermore, factors such as IT security, liability questions, insurance, system interconnectivity, and reliability were also addressed. The latter factors were not delved into further in the process, since they are outside the realm of what municipal legislation can organize and influence. Also, the decision was based on the assumption that the corresponding regulations and parameters for autonomous driving will exist by 2035 or even earlier. The factors with the highest degree of relevance for the future development of autonomous vehicles in the city were selected by experts according to the uncertainty of how they would develop over time and according to how strongly they would influence autonomous driving in the city.



Fig. 1: Influential factors identified and expert evaluations

The influential factors “mobility behavior” and “parameters for sustainable mobility and mobility options with autonomous systems” were rated the highest both in terms of the strength of their influence as well as the uncertainty of their future development. They were selected as the essential factors for describing the scenario framework so that the widest spectrum of potential paths of development could be illustrated.

### 3.2 Overview of Scenarios

The scenarios that were derived from evaluating the factors were essentially differentiated by the prevailing parameters for autonomous services and the mobility behavior of the inhabitants, both in terms of the individual and the collective. The scenarios represent the results of the discussions conducted by the experts at the workshops and they describe the spectrum of potential developments for the world of mobility 2035 given the respective parameters. All of these scenarios were drafted with the premise of anchoring urban mobility developments to the idea of sustainability.

The scenarios demonstrate different paths of development for mobility in the city and the use of autonomous/self-driving vehicles. The arrangement of mobility options and services is a decisive driving force for the speed at which these vehicles will penetrate the market and become commonplace on the roads. This is also true for the resulting effects on the traffic system in the city.



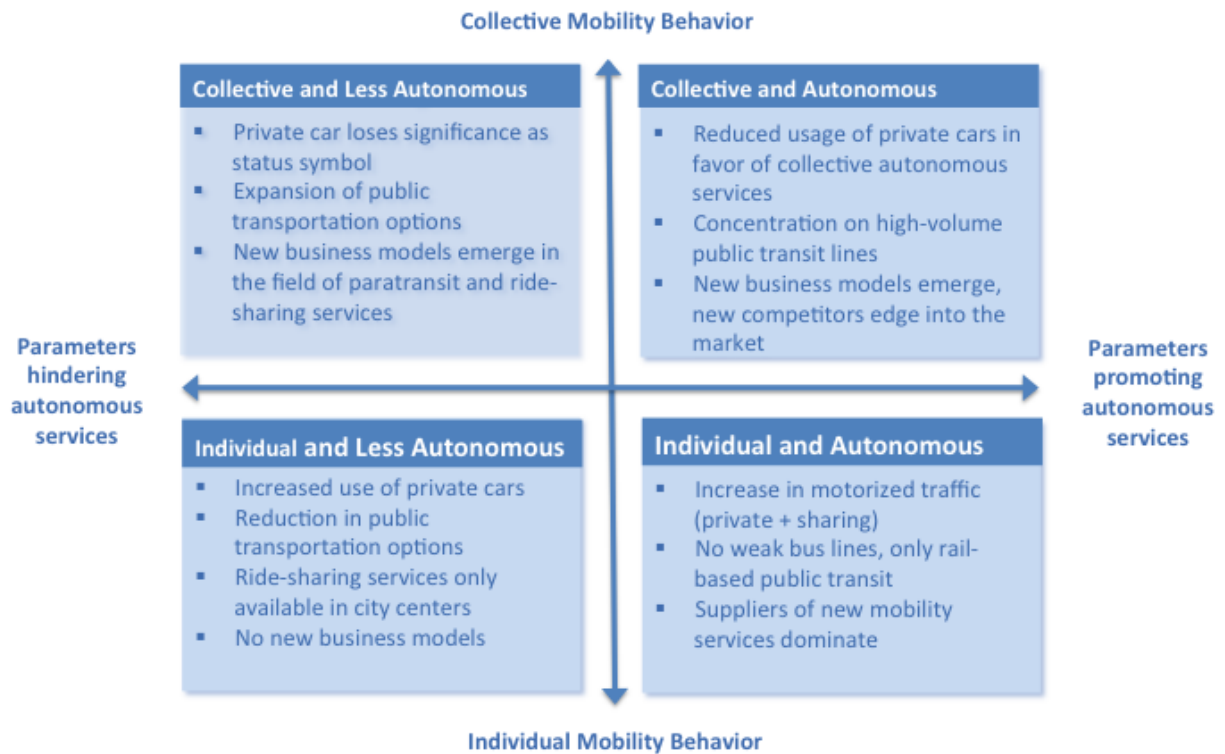


Fig. 2: Results of expert workshops – an overview of scenarios

In all of the scenarios –except the scenario: “collective and less autonomous” –an increase in the usage of motorized modes of transportation and ultimately a rise in the amount of traffic are to be expected, mainly due to the improvement in the range of new mobility service options and the resulting behavioral changes.

	Individual & Less Autonomous	Collective & Less Autonomous	Individual & Autonomous	Collective & Autonomous
Title:	Status quo	Owning car unnecessary	It's cool to be driven	Great new world
Use of motorized transportation	→	→	↑	↑
Range of mobility services	→	→	↑	↑
Public transportation	→	→	→	→
Number of vehicles	→	→	→	↓
Motorized traffic volume	→	→	↑	→
Strain on infrastructure	→	→	↑	→
Parking occupancy rate	→	→	→	↓

Fig. 3: Overview of scenarios, comparing the developments to today

From today’s perspective, all four scenarios are juxtaposed and given equal weight. There were no conclusive results from the discussion about which of the scenarios demonstrates the highest probability of occurrence and most accurately describes the future developments. The highest expectations for reaching the goal of designing a sustainable form of mobility were linked to the scenario “collective and autonomous.” Based on the results, it became clear that introducing autonomous vehicles would not necessarily lead to an improved traffic situation in the city or to sustainable developments in mobility. Instead, further regulations and accompanying measures are needed in order to manage the developments in a way that takes advantage of the opportunities yet minimizes the risks.

## 4. Opportunities and Risks

The discussion of the scenarios has shown that the introduction of autonomous vehicles will completely change mobility and traffic in the city. Self-driving cars can contribute to an increased degree of road safety and to a decrease in fossil-fuel emissions by facilitating the use of electric vehicles. Additionally, these new vehicle concepts bring about numerous opportunities. However, if no associated regulatory action is taken, they could also result in risks to the sustainable development of the city and its transportation system.

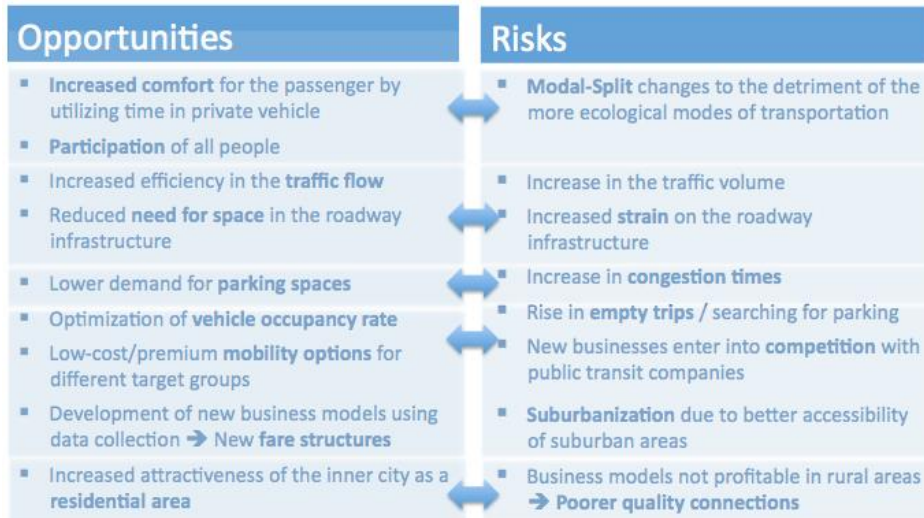


Fig. 4: Comparing the opportunities and risks of autonomous vehicles

## 5. Fields of Action and Options for Design

In the future, the main challenge will be to gain a deeper understanding of the potential paths of development and chains of causality in order to take advantage of the opportunities that autonomous vehicles offer, while at the same time minimizing the risks associated with them. Just when considering how long it takes for decisions to be made concerning investments and expanding infrastructure, or for the procurement processes at public transportation companies, it becomes clear that there is a pressing need today to anticipate the future developments resulting from the usage of autonomous vehicles. Various courses of action for the city could be identified. These must be differentiated between short-term measures, which factor in planning processes today even before the market launch of autonomous vehicles, and medium-term measures, which should be adapted once autonomous vehicles are introduced:

### Short-term measures – before autonomous vehicles are brought onto the market:

- Initiate municipal discussion about the opportunities and risks of autonomous vehicles, e.g. taking space formerly utilized for parking in the streets and repurposing it for non-motorized transportation or other activities.
- Anticipate potential developments and take them into consideration in all long-term planning and investment decisions, with the involvement of all relevant stakeholders.
- Take integrated transportation planning into consideration in order to manage the traffic and the requirements of high-volume public transportation systems.
- Designing future mobility options requires an overarching plan and strategic guidelines. This is where the municipality has the duty to support the transition for public transportation companies, e.g. by initiating pilot projects and test markets, facilitating cooperation and combined fares with ride-sharing suppliers, or announcing concessions for future suppliers.

#### Medium-term – during the initial launch phase of autonomous vehicles:

- Adapt the municipal parking statutes to the changes in demand, especially for high-density, centrally located districts.
- Realign the concepts of parking locations (central/peripheral) and integrate an intelligent system of parking space management with graduated pricing scales.
- Designate boarding and exiting zones for autonomous vehicles on public roads.
- Intelligent traffic management for controlling the road traffic.
- Limit access for single-passenger vehicles and grant privileges to low-emission, collective traffic.
- Manage the quality of the transportation options and the fare structure, especially for peripheral and suburban areas.
- Repurpose and redesign the road infrastructure and parking areas in the urban region for non-motorized transportation and other activities.

## 6. Summary and Outlook

Autonomous vehicles will lead to a disruptive development in urban mobility; all the experts who are involved agree on that. Autonomous vehicles will not only replace the “conventional” private car, but instead they will open up the possibility for new mobility concepts. Individual and public transportation will grow together and options for car-sharing and ride-sharing will arise both as an extension of and in competition with public transportation. The implications of the scenarios that were discussed demonstrate changes for the entire city and its transportation system. They offer a wide spectrum of opportunities and challenges for the cities of the future. The first test tracks on highways and semi-public spaces for autonomous vehicles have already been designated and initial test-drives in urban areas are being conducted. It is only a question of time until the vehicles are ready for mass-production and can be authorized for use in Germany. Therefore, it is important now to deal with the potential developments and their effects on the city, and to develop preparatory measures.

The implications of these new technical developments cannot be clearly predicted today. Mobility is expected to be safer, more comfortable, and in certain aspects more efficient. The transportation options will change and this will lead to changes in behavior regarding mobility. The potential negative effects such as a rise in the amount of motorized vehicle traffic and an increase in traffic congestion cannot be entirely ruled out. On the other hand, by managing the concepts, it may also be possible to reduce the number of motor vehicles in the city, decrease the burden of traffic and fossil-fuel emissions, and bring down the demand for parking spaces. Initial ideas for managing traffic were discussed in the context of the expert workshops. The main focus was placed on the organization of public and shared transportation and the interplay between different options, as well as the organization and management of inactive vehicles. Initial fields of action were identified. Subsequent detailed analyses on the effects and implications of these vehicle concepts will be necessary in order to define the courses of action on an urban level more clearly.

Nowadays, all cities are facing the same situation: dealing with the future developments of autonomous driving is inevitable. New mobility forms will probably first become prevalent in large cities. But smaller and medium-sized cities, as well as rural areas, will be confronted with similar situations in the future. Bremen is the first city in Germany to deal with the questions of these future developments and their implications for the city. Intercity partnerships and cooperatives for pilot projects and research projects could enable shared learning and an exchange of ideas, in order to be prepared for the expected developments and societal changes. It is necessary to facilitate rigorous communication between experts from municipalities, public transportation companies, research institutes, and the industry in order to design sustainable mobility concepts for the future of the city, as well as to take advantage of the opportunities for sustainable city development.



## Participants in the Expert Workshops in Bremen

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