Augmented Mobility

Reinventing Public Transport

Autonomous Fleets in Place of Public Buses

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From Driving to Being Driven

The transformation of transportation appears irreversible. An important step along the way toward the electrification of drive technology is a vastly more efficient organization of transport resources, with fewer private automobiles, a significant transition toward resource-conserving public transport, and more cycling and walking. Although the transformation of transportation is a global topic, we place our focus on examining the case of Germany, as this country can be seen as one of the biggest automobile strongholds. This article asks whether this supremacy of the automobile industry in Germany can be diminished. We argue that, while we will witness the transition to autonomous driving in the foreseeable future, the German automobile industry as well as the public transport sector are currently failing to recognize the concomitant opportunities. With the question raised of whether autonomous driving is part of the solution or the problem, it becomes evident that political guidance is needed. Required are not just conducive regulations, but also ambitious providers in the public transportation sector and a fundamental reconceptualization of the automobile industry. It is a question not only of radical technical innovation, but also of a paradigm shift in transport policies: a transition from driving to being driven.

The aim is comprehensive mobility with a smaller number of vehicles and a radical reduction in resource use. When it comes to autonomous driving, the current focus of both experts and the media is on the conventional automobile. Since the 1960s images of driverless cars, whose occupants no longer need to steer and can while away the time with board games have dominated the media. But autonomous driving need not necessarily be conceived as a continuation of private automobility. A completely new perspective opens up provided we imagine the development of autonomous vehicles as representing a shift toward a radically modernized, multi-optional, public transport service. Passengers could be driven from door to door in vehicles having a variety of sizes and amenities. This specific way of using the vehicles is generally denoted by the futuristic term *robotaxi*. The word conveys an extreme degree of automation: there would no longer be any human drivers, and passengers would have no influence on the driving process. Vehicles would operate autonomously, their assignments preprogrammed, and would be surveilled remotely within a defined territory. In this case, it is therefore useful to distinguish autonomous driving, which implies a driverless, independent vehicle, distinguished from automated driving, meaning technology that provides a support function for private automobiles that are controlled by human drivers.

In recent years, discussions about automated and autonomous driving have been conditioned by internationally agreed-upon levels of automation; the currently prevailing Level 2 is expected to transition all the way to fully autonomous driving, referred to as Level 5. Implicitly, the dominant model of the private automobile is to be perpetuated, with the successive introduction of additional assistive functions. Foregrounded are concerns about greater comfort, convenience, and safety for private automobiles as we know them today. The race to claim the prerogative to identify the potentials of autonomous driving, beyond safety and function, has only just begun (Canzler et al. 2019).

When it comes to automated driving, announcements about which kinds of vehicles will be traveling our roads and when and how they will revolutionize street traffic are reaching us almost on a daily basis. There is a tendency to use the terms *automated* and *autonomous* interchangeably. As a rule, these terms are used to refer to partially automated vehicles, since we have no actual experience to date with fully autonomous vehicle fleets. In the United States and China, however, test vehicles produced by various digital companies are being operated in real conditions, and are gathering many test kilometers of experience, or stated more precisely: they are collecting data in order to learn. In particular, the Google subsidiary Waymo has accumulated a substantial wealth of experience, establishing a considerable lead over competitors.

In examining these developments and test projects, a fundamental difference between European and US cultures of innovation becomes conspicuous. In Europe, pilot trials are being undertaken in protected laboratory situations, for the most part on hermetically sealed test tracks preceded by strict premonitoring, and only after elaborate approval procedures. In the United States, in contrast, testing is conducted in real street traffic with one or two occupants who can intervene in emergency situations, and of course in compliance with current regulations. Here, in contrast to Germany, the vehicles do travel in real-life conditions and are exposed to erratic street traffic. With the digital enterprises in California, the preparedness to engage with risk and to undertake technical adaptations through trial-and-error procedures is far higher than with European auto manufacturers (Canzler and Knie 2016; Daum 2019).

Alongside technical and legal challenges, however, it still remains an open question which model of use for automated—and later autonomous—vehicles will ultimately prevail. The visions of the traditional automobile manufacturers diverge essentially from the aims of the US tech enterprises.

The large auto manufacturers are working on the stepwise construction of driver assistance systems such as the »Traffic Jam Chauffeur« and the »Highway Chauffeur.« These make it possible for drivers who find themselves stuck in traffic or traveling on freeways to relinquish the steering wheel, at least intermittently, and turn their attention to other activities. These technologies, as expected, are being introduced together with expensive and elaborate technical add-on systems via the luxury segment. In engineering language, this step can be described as the transition from Level 3 to Level 4 of automation logistics.

A major theme throughout this development is »takeover time,« the period of transition from automated steering back to human driving. At this point, no accepted standards exist in this regard. The central problem yet to be resolved is to distinguish at which exact point the responsibility of the human driver stops and that of the machine begins. Clarity about this process is required for accidents to be avoided. User acceptance will only occur if this transition can be achieved in a stress-free manner (Stilgoe 2017). The question is: Which activities, apart from driving, will the person in the vehicle be allowed to do, and how quickly should that person have to change from a passenger—who is likely in a relaxed state, or even a state of semi-sleep—to an active driver (Wolf 2015)?

In general, it is important to ensure that during disturbances or in emergency situations, the passenger in a partially automated vehicle can intervene. Paradoxically, this becomes more difficult the more rare emergencies are. There is a considerable danger that passengers will »unlearn« driving skills and require too much time to find their way back to the unaccustomed role of the driver. Difficulties involving this so-called handover to a human driver have plagued pilot projects with partially automated vehicles for years now, and the problem remains unresolved (Morgan et al. 2017).

A series of research projects has tested rules and technical warning signals designed to facilitate takeover by passengers. Looking at the focus of the current research projects and questions involved makes clear that vehicle manufactureres still adhere to the classical model of the private automobile. Automobility is becoming simpler and more comfortable, while the actual business model is to change as little as possible. As of summer 2021, German manufacturers, for example, had not yet succeeded in offering a technically reliable solution that could actually enter production. In this regard, the design decision to continue to center the human as the driver of the car even when it comes to automated driving has resulted in a technological dead end.

An entirely different vision is being pursued by US digital enterprises. With every test mile driven, Google (Alphabet), with its subsidiary Waymo, optimizes its algorithms for genuinely autonomous driving with the assistance of artificial intelligence. In selected areas, the test vehicles, as robotaxis, offer comprehensive point-to-point services without any driver intervention, relying on a combination of radar, camera, and lidar (light detection and ranging).

Before a Waymo vehicle rolls onto the street, it is equipped with a detailed data map of the driving environment, with information about streets, crossings, and fixed objects lining the roadway. Such prior knowledge concerning permanent features of the operational terrain allows the sensors to focus on moving objects and other road users.

When it comes to weighing their technical options, Waymo and other digital companies such as Cruise and Uber remain »open.« They are confident that products and services that have demonstrated their large-scale practical value will find a suitable commercial model, even where current operations have failed to show positive quarterly results. This means that neither strictly commercial key figures nor ecological indicators count as benchmarks for the strategic success of these companies; what counts instead is a larger vision. Nonetheless, they do rely—and it is here that the European enterprises regularly underestimate the American competition—on functional blueprints. After all, the imagination of capital providers is only genuinely inspired when evidence of success can be demonstrated, at least in principle, in well-defined subareas.

Neither the consistent automation of private automobiles nor the vision of truly autonomous robotaxis is being pursued in earnest by the traditional automobile manufacturers. In particular, the idea of autonomous fleets seems to be seen more as a variety of public transport. And neither vehicle manufacturers nor platform operators have sufficient experience with managing vehicle fleets in public space. It is also questionable whether they bring the necessary empathy to the task. After all, transport is necessarily public in character, as it serves collective transport objectives and always involves a mixture of political and entrepreneurial interests. For this reason, a municipality or region that commissions public transport services may compel operators to provide service in areas and on routes where demand is weak, even far below the threshold of financial viability. In order to resolve this contradiction, German cities and municipalities often operate transport services themselves, covering deficits with their own budgetary resources, or advertising bids for such services and paying private operators with public funds. It is not uncommon for a certain type of service to be considered in the public interest, even though it would not be regarded as viable from the perspective of a for-profit enterprise.

Neither in Europe nor in North America would the established operators of public transport services—largely rail or bus companies—be able to generate the requisite investment or to marshal the required competencies to embark upon the development of robotaxis. When it comes to the technological development of automated driving, the real impulse comes from the digital enterprises. In contrast, public transport companies—including Deutsche Bahn—have not played a major role to date in the race to develop this technology. Repeatedly, these enterprises are instead relegated to their core priority, namely rail transport, a sector that has fallen behind when it comes to the necessary modernization measures.

The current intermediate stage of semi-automated vehicles—whether in the form of partially automated private automobiles from the major manufacturers or robotaxi prototypes by Waymo and others—raises the question of which technological developments are deemed beneficial when it comes to climate-protection goals, an envisaged redistribution of public transportation areas, and the general improvement of quality of life, and which ones conflict with these political objectives (Dangschat 2017; Fleischer and Schippl 2018).

Up to this point, we lack suitable protagonists when it comes to developing autonomous vehicles as integrated elements of an attractive public transport system. Neither platform operators nor automobile manufacturers have sustainable or socially equitable public transport in mind—their aim is simply to market their services or vehicles profitably. The development of autonomous vehicle systems for the sake of modernizing public transport is therefore ultimately a political question as well. The design task consists of using autonomous driving as a component of a multioptional and environmentally friendly mobility, or, in other words, part of a transformation of the transport system. It is a question of shaping the framing conditions of transport, or of modifying existing regulations in such a way, that automated vehicles are integrated into a multioptional transport structure (Knie and Ruhrort 2019). This means exploring the potential for the development of automated vehicles to play a key role in a transport system that is both ecologically efficient and compatible with urban life, and that could improve transport connections in rural regions. Possible are hitherto unconventional forms of cooperation, such as that between the South Korean automobile manufacturer Hyundai and the US ride-hailing business Lyft, which could provide public transport services.[01]

In addition to cost savings, one advantage of (partially) automated shuttles over conventional buses is that they can be deployed far more flexibly and are far more adaptable to changing topographical and infrastructural conditions. The range of application includes connections to stops and stations (»hubs«), serving residential areas, and also operating in industrial parks, hospitals, schools and institutions of higher learning, in an on-demand mode in the form of shuttle services (»spokes«). While transport volumes are reduced due to limited capacity, flexibility is increased when it comes to types of service and schedules is substantially larger than with conventional buses. Even conventional bus route operations can be covered using shuttle systems during off-peak hours (Hunsicker et al. 2017).

At the moment, (partially) automated shuttles are still far from ordinary operational capacity. Regarding both technical and legal standards, many technical and operational questions have yet to be resolved. Currently, there exists a substantial gap between the technical standard attained and robust serial operation, while economies of scale cannot be achieved as yet.

When attempts are made to introduce such a system, a basic problem in the public transport sector becomes clearly evident. In comparison to other industries, it is not just financial clout that is absent; it is the lack of a culture of innovation that prevents the operators of regional and local transport systems from catching up. In their legal constitutions, public transport operators, as well as networked municipal transport authorities and special purpose associations, are not geared toward addressing open, future-oriented topics. The transport operators are operative providers, while the commissioning organizations were set up for the purpose of the legally tendering of standardized transport services. Competitive bidding proceeds exclusively at the level of costs. The logic of the public transport system hinders innovation because it is not represented in the system, much less rewarded (Canzler and Knie 2016: 39ff.).

Reinventing Transportation in Germany, the Land of the Automobile

A genuine alternative to the private automobile will emerge only if new forms of modernized public transport are convenient, reliable, and flexible. Under the conditions of the Personenbeförderungsgesetz (German Passenger Transportation Act; PBefG), which was modified in August 2021, on-demand transportation on the basis of digital platforms can contribute to achieving the target vision of sustainable, efficient mobility. Interlinked with classical bus lines to form an overarching service, on-demand offerings could provide an alternative to the private automobile. The larger question is: How can a reorientation of transport policies avoid having flexible mobility offerings—and potentially fleets of automated vehicles—simply generate a rising flood of barely used private automobiles in cities? How can it lead instead toward reducing the number of vehicles by providing highly efficient public fleets and door-to-door services?

In essence, the use of (partially) automated vehicles opens up additional public transport options, and can therefore enhance its attractiveness. Rural regions already have great potential when it comes to implementing (partially) automated shuttles. Gaps in a hub-and-spoke concept can be filled in, and the preconditions for such transport models are easier to establish in rural areas. From a fiscal point of view, shuttle systems not only offer greater flexibility, but also promise distinct advantages in comparison to buses in the mid- to long-term by virtue, for instance, of their substantially lower operating costs.

To summarize, if the necessary political framework were in place, automated vehicles in the form of autonomous fleets would make a considerable reduction of vehicle numbers possible. Whether autonomous fleets actually arrive, and whether they turn out to be a blessing or curse is less dependent upon technological developments than on the political will of the regulators. If climate targets are to be taken seriously, and if the transformation of the transportation system and the objective set of targets outlined here are to be pursued in earnest, then automated vehicle systems will have to play a strategic role.

An additional requirement for achieving this target vision, and for making possible on-demand offerings in public transport with potentially autonomous vehicle fleets, is to ensure that the collective use of vehicles is not only authorized, but that adequate space is also provided for their use. The objective must be to ensure that a steadily growing share of public space is reserved for the most efficient modes of transport. Exclusive—which is to say private—vehicles must be charged a substantially higher fee for the use of public space, and public parking spaces for private vehicles should be strictly limited. The car-sharing law adopted by the Bundestag in 2017 made it possible in principle for the municipalities to privilege shared autos in this way. It is left to the local authorities to actually exploit this legal basis by reserving public space for car-sharing vehicles.

Currently, the parking of all types of motor vehicles is allowed by German road laws as an aspect of »general use« vis-à-vis traffic. This is understood to mean that the parking of private vehicles has become established as a quasi-natural and unalterable »transport need.« Transportation planning has had to take this into account. In view of the goals of climate protection, this logic now appears obsolete, especially in light of the current potential of new intelligent mobility offerings. Reformed traffic regulations could exclude private vehicles from using public space in accordance with the Swiss model (Notz 2017; Agora Verkehrswende 2018; Ruhrort 2019). This would mean that non-transient parking in public space would only be possible where explicitly permitted. On this basis, communities could decide at which locations and to what extent, if at all, valuable public space could be made available for the parking of private automobiles.

An altered legal framework, however, is only one aspect of the needed reforms. What is also missing is a culture of experimentation. In Germany, providers of public transport are fixated on managing the operation of buses and rail vehicles, and are disinclined to test out new ideas (Canzler and Knie 2016). In order to enhance the preparedness of public transport operators to seize upon innovative approaches, the Federal Ministry of Digital and Transport, together with the Federal Ministry of Education and Research, could organize a number of real-life tests. Such a framework would make it possible for manufacturers of rail vehicles and buses, in collaboration with operators, subcontractors, and research institutes, to develop and test such systems outside of normal operations.

It will be important that there is a low threshold access for operators, and in particular that application scenarios are tested in public space in collaboration with municipalities and other regional authorities. Beyond this, the central question is whether and to what extent the largely municipal public transport companies succeed in developing the necessary trial-and-error culture.

New Options in Germany: An Invitation to Autonomous Driving

Concerning the question of whether autonomous vehicles are a blessing or curse, far more is at stake than simply a new means of transport. Ultimately, it is a question of the modernization capacity of the mobility sector. At the center stands the German automobile sector, which has long profited from the continuing fixation on private vehicles. However, generally changing attitudes toward the automobile, the pressure to electrify the powertrain, and of course the diverse, widely circulating visions, are having an impact on the industry.

On-demand transport operations, automated shuttles, and the prospect of autonomous vehicle fleets could become a game changer: they have the potential to fundamentally change the transport landscape. But such fleets are not going to simply

01 Ioniq 5 Robotaxi: »Elektro-Hyundai zum Mitfahren,« in: *Autohaus* (August 31, 2021), https://www.autohaus.de/nachrichten/autohersteller/ioniq-5-robotaxi-elektro-hyundai-zum-mitfahren-2929687.

drop from the (Californian) sky to become accessible on German roads overnight. Instead, they need to be made possible on a political level, and we will need to shape their interface with existing public transport resources. Surprisingly, creative freedom has already been created through the Gesetz zum autonomen Fahren (German Act on Autonomous Driving), which was adopted by the German Bundestag and the Bundesrat in spring 2021. More precisely, it is an »Act that changes regulations governing road traffic … to allow it autonomous driving, as well as on an ordinance on the approval and operations of motor vehicles with autonomous driving functions within delimited areas of operation« (Autonome-Fahrzeuge-Genehmigungs-und-Betriebs-Verordnung; Autonomous Vehicle Approval and Operation Ordinance—AFGBV).

Regarding their purpose and application, these regulations are unique worldwide because they expressly permit autonomous fleets to operate on public roads. Accordingly, it now becomes possible—within a specified area of operations—for a vehicle to be controlled not by a human driver, but instead by a »technical supervisor« that is not stationed in the vehicle. This establishes the legal preconditions for the envisioned paradigm change in the direction of partially automated driving. Through proactive regulations, and in light of the progress currently being made by digital enterprises, a practical opportunity exists for making autonomous fleets of vehicles a component of an up-to-date, flexible public transport system.[02]

A much-noted simulation study carried out by the International Transport Forum outlines a scenario within which autonomous shuttles serve the general public, and could already be implemented today if used in order to supplement a functioning public transport infrastructure, and provided that efforts are made to radically reduce the number of private automobiles (ITF 2017).

Driverless vehicles would then emerge as a new public transport option and would achieve a high degree of individual serviceability in combination with larger high-performance vehicles. Based on empirical studies, it becomes possible to estimate that a system of fully automated shuttles—one that is embedded in a hub-and-spoke system—would make it possible to reduce the number of vehicles in cities to around fifty vehicles per 1,000 inhabitants. This would mean an inventory of automobiles that would be just one-tenth of the present number (ITF 2015, 2017, 2018). Of course, these calculations are context-dependent, and are valid for European cities only. Studies from other parts of the world, such as the United States, cannot be extrapolated elsewhere given the utterly different settlement and transport structures present there (Canzler et al. 2019).

Concerning the implementation of (partially) automated shuttles as a component of the public transport infrastructure, further action is needed. The current design of vehicles, along with the media needed to employ them, and especially the intermodal connection points of a hub-and-spoke system still require considerable adaptation when it comes to interface layout. People can only be persuaded to use an intermodal option provided they are able to negotiate the system and have trust in it. This is not at all the case for currently available options, which were developed and optimized in complete isolation from one another. In the automobile industry, an awareness of the relevance of design and professional symbolic user elements is nothing new. But for the public transport sector and the authorities responsible for commissioning it, these aspects have played almost no role up to now.

Emerging—although much remains to be done, and a number of questions still need to be resolved through real operations—is a situation that is atypical for Germany, one in which the legal preconditions for the reconfiguration of the transport system are present, but the entrepreneurial capacity that would allow these options to be exploited is lacking: the automobile manufacturers do not want to do it; the public transport authorities cannot.

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