New Mobility Concepts and Autonomous Driving: The Potential for Change

9

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9.1 Introduction

Transport is an expression for the satisfaction of mobility needs with different means of transportation—for everyday travel, people walk, cycle, drive or take public transport. There are two main groups here: people with a distinct preference for using private vehicles, and people who prefer so-called "ecomobility"—the combination of public transport with walking and cycling [1]. In addition, a group has been emerging for some years of "multimodal" users, who no longer restrict themselves to a particular mode or mix of modes, but rather exhibit a wide range of modal use in their personal repertoire [1, 2]. This gradual transformation in behavior has coincided with the development of new mobility concepts that, firstly, involve a further development of conventional carsharing [3], but also supplement established ridesharing with new forms. New concepts already in operation include flexible carsharing fleets, such as those of Car2Go, DriveNow and Multicity, that are available as mobility services in cities in Germany, and across Europe and the USA. In parallel to this has been the emergence of so-called peer-to-peer services, where private owners make their vehicle available to a community of members via an internet platform. On online platforms such as Mitfahrzentrale and Zimride, private individuals offer rides on routes and at times when they themselves will travel in any case. Additionally, more and more services such as Uber and Lyft are currently starting up, where the distinction between (semi-)professional individual transportation, comparable to taxi services, and "standard" ridesharing is not always so clear-cut. The new forms of car

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and ridesharing services have primarily arisen in the major cities and metropolitan areas of industrialized countries.

What is new, and also special, about these mobility concepts is the high degree of flexibility they offer users. Flexible carsharing vehicles are available at any time and for any duration, with no pre-planning. The new ridesharing services are similarly flexible, although in this respect they resemble conventional taxis. One essential prerequisite for the emergence of all new mobility concepts is the possibilities that information and communications technology now offer for networking vehicles, users, and operators. This is what makes fundamentally fast and easy access to vehicles or services via the internet or smartphone apps possible in the first place. Access, in the sense of the physical distance between the user's location and the vehicle, is still a hurdle, however, particularly in areas where vehicle density is not very high.

With the introduction of autonomous vehicles, it seems possible to appreciably extend and diversify existing mobility concepts. Accessing and egressing a vehicle is changing, in that the user no longer goes to the vehicle, but the vehicle comes to the user. Vehicles themselves are becoming usable for a wider section of the population, e.g. those with impaired mobility. New forms of public transport are possible, also in the sense of further blurring the boundaries between private and public transport.

This article aims to introduce these options and the expectations accompanying them, concentrating on carsharing. First, we shall outline the current state of provision and usage of so-called "new mobility concepts," at the heart of which is carsharing. The main section discusses the opportunities and challenges resulting from the introduction of autonomously driving vehicles into carsharing fleets. There are currently a series of indications that spontaneity and flexibility could be particularly significant factors in the use of new mobility concepts (see [11, 13]). Precisely this increased spontaneity could be the starting point for new mobility concepts with autonomous vehicles. The operators of flexible carsharing fleets are already thinking on such lines [4].

9.2 Carsharing: "Core Application" of New Mobility Concepts

There has been carsharing in Germany and numerous other countries since about the 1980s. Carsharing is here understood as the operation of a fleet of cars that is available either in station-based or point-to-point systems. Every holder of a valid driver's license can register as a member of a carsharing organization—usually upon payment of a registration fee—and thus acquire access to the vehicles. The basic variations in carsharing result from the spatial and temporal conditions for vehicle access, and also from the business models; Fig. 9.1 summarizes the various concepts' main features.

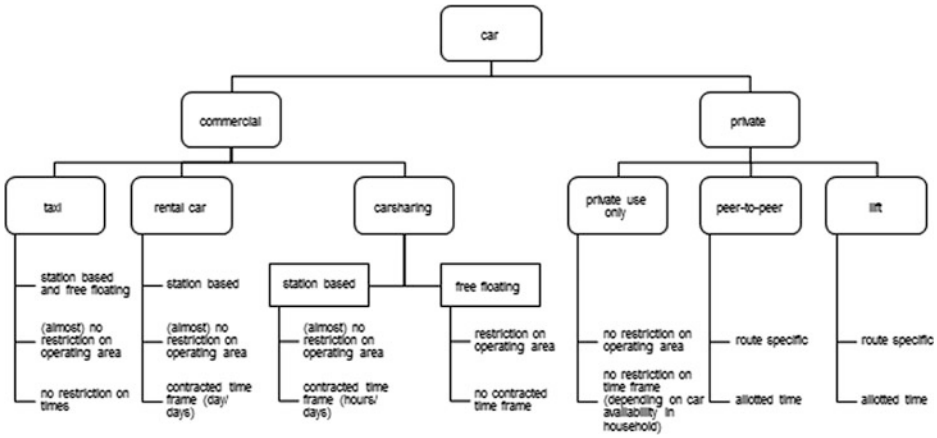

Fig. 9.1 Scheme for car use in the tension between private and commercial use

9.2.1 Station-Based Carsharing

The standard form of carsharing is station-based carsharing, where vehicles are furnished at "collection points." The user must pick up the vehicle there and bring it back to it. The length of use is agreed in advance. In contrast to traditional rental cars, station-based carsharing vehicles may be rented by the hour, as well as by the day, although hourly rental is now also increasingly available among rental companies. Users pay a basic annual fee and vehicle use is charged according to duration and mileage. This varies according to organization or provider, and can also be adjusted according to demand, depending on time of day and day of the week. There is no restricted area of operation. When these services began, reserving vehicles largely took place over the phone; bookings are now also made on provider websites or mobile device applications.

At the time of writing (2014), station-based carsharing is available at approximately 3900 stations in 380 cities and municipalities in Germany [5, 6]. This also includes a whole series of medium and small towns. There is already very good coverage in German cities of over 100,000 inhabitants, while only 5 % of municipalities with less than 50,000 population have carsharing services available [7]. The 3900 stations are served by a fleet of 7700 vehicles from some 150 carsharing providers. The German market leader is Deutsche Bahn (Flinkster), which owns around 55 % of the station-based fleet [8, 9]. The worldwide leader in standard carsharing, with a fleet of about 10,000 vehicles in the USA, Canada, the UK, Spain, and Austria, is the American company Zipcar, founded in 2000 and currently owned by the Avis Budget Group (as of August 2014).

9.2.2 Flexible (One-Way) Carsharing

New forms of carsharing have emerged in recent years. Especially in Germany, but also in the UK and USA, a new type of commercial carsharing, known as "flexible," has appeared. Its flexibility mainly consists in not needing to previously arrange the time and duration of use with the provider, and not having to pick the vehicle up, or bring it back, to a specified location. Instead, the user collects the vehicle from wherever he comes across it, and leaves it at any random position within an operating area defined by the provider. The user acquires information on what vehicles are available at a particular location on the internet or via a smartphone app. In principle, a vehicle can also be rented "in passing," i.e. a user rents a parked, non-reserved vehicle on the street. It is also necessary to be registered with the fleet operator to use a vehicle, which is initiated via a chip card or, most recently, directly via the user's smartphone.

The worldwide leading corporation in flexible carsharing is Car2Go, with more than 10,000 vehicles in 27 cities in Europe and North America (as of August 2014). In Germany, flexible carsharing providers have a combined fleet of around 6250 vehicles [5]. These, however, are in service almost exclusively in large cities of more than 500,000 inhabitants such as Berlin, Hamburg or Munich. Furthermore, the operating areas do not cover the entire territories of these cities, but are limited to a part of them, mainly the city center, its bordering neighborhoods and "island zones" with high usage frequency. Apart from a one-time registration fee, there are no further regular charges. Vehicle usage is charged on a time-dependent scale, mostly per minute. As with station-based carsharing, fuel costs are included in the fare. Moreover, parking fees are also included, which are normally agreed on a flat-rate basis between the provider and the municipality.

Flexible carsharing started as a pilot project of Car2Go, a Daimler Group company, in 2009 in Ulm (Baden-Württemberg, Germany). Other relevant operators by now include DriveNow, active since 2011 and a venture by BMW and Sixt Autovermietung; and also Multicity, a joint venture between Citroen and Deutsche Bahn that operates vehicles powered purely by batteries. At the same time, new operators are increasingly attempting to break into the market: Quicar, for example, which belongs to the Volkswagen group, or Spotcar, which launched in Berlin in June 2014.

9.2.3 Peer-to-Peer Carsharing

Peer-to-peer carsharing—hiring out private cars between private individuals—is only in the first stages of evolving into the third form of carsharing systems using online communication platforms. Precise user numbers are not yet available. In this system, bookings are processed via an online platform. There are no picked up and dropped off stations. Vehicles are instead picked up and drop off at specially agreed locations. A glance at a web platform such as www.autonetzer.de is enough to show that this form of carsharing is in no way limited to large cities, but can also be found in smaller cities and municipalities.

This would appear to confirm Hampshire and Gaites' assumption [10, p. 14] that peer-to-peer carsharing is scalable in form—in contrast, for now at least, to commercial carsharing. The fleet composition is also markedly dynamic, as persons who are prepared to offer their car do not appear to do so constantly, as a basic mode of behavior. The findings of a study in Berlin instead suggest that car owners only make their vehicles available at certain times, for example when they themselves use them at low levels due to personal circumstances [11].

9.3 Users and Use of the New Mobility Concepts

The objectives associated with carsharing vary depending on the perspective of the parties involved. The political context in Germany largely involves setting up the necessary framework conditions to implement carsharing on the local level. The essential motives here are to reduce private car traffic volumes (as carsharing users also increase the share of public transport in their modal split over the duration of their carsharing use), to concomitantly lower CO_2 and air pollution emissions, and to shrinking the amount of land used by non-moving car traffic (see Chap. 19). Commercial operators, such as car manufacturers (generally in cooperation with car rental companies) or transport service providers such as Deutsche Bahn, use carsharing to pursue product-related strategies. Extending their provision with an (additional) mobility service, or offering their own brand's attractive vehicles, thus generating brand allegiance, are two examples. Other motives for operating a carsharing fleet include decidedly ecological aims, which have essentially driven carsharing's emergence, and which are adhered to by interest groups and associations [12].

9.3.1 Users and Usage Conditions

Carsharing users in 2014 form a specific group in view of both composition and mobility behavior. They are clearly above the population average in various respects: proportion of under-40s, proportion of men, proportion of people with high levels of formal education (high-school diploma, higher education graduate) and household income. This deviation from the population mean is more highly pronounced for flexible carsharing than station-based [3]. Both types of carsharing are combined with a highly above-average use of public transportation. Studies on carsharing use from 2014 show, for example, that 52 % of Flinkster customers in Berlin and 44 % of Munich Flinkster customers have a public transport season ticket. A high proportion of DriveNow and Car2Go users are likewise season-ticket holders: 43 and 38 % of DriveNow customers in Berlin and Munich respectively [13, p. 12]; for Car2Go this figure stands at 40 % in Stuttgart and 50 % in Cologne [15, p. 13]. Nationally, the average for core-city dwellers is 33 % ([1],

authors' own analysis; in Germany, official figures count all urban municipalities with more than 100,000 inhabitants in the category of "core city").

Good public transport or the possession of an own car currently appear to be essential preconditions for carsharing use. Only in this way is one-way usage possible in the flexible carsharing variant. If the user had to organize those trips that are complementary to his carsharing trip by himself, this would most likely be highly inconvenient. The attractiveness of a system that allows for individual routes would clearly fall. In the case of station-based carsharing, public transport is also often the main form of transport for users. In many cases, carsharing vehicles represent a second, supplementary car, used as needed, in car-owning households [16]. In order to meet this need, and in the sense of creating a symbiosis, there has been long-standing cooperation between station-based carsharing and public transport providers, now being replicated with the new flexible carsharing services [17].

9.3.2 The Carsharer—the "New Citizen" in a Sharing Economy?

Under the slogan "using not owning," carsharing is frequently called on as an example for the transformation from an ownership economy to a "sharing economy" [18, 19]. This perhaps results from carsharing's particular visibility, as an act that takes place in public view. Behind this, however, possibly lies some astonishment at objects that are still seen as status symbols being used by several random people in a rental system.

In fact, carsharing is one in a long line of trends where "goods" that were never previously rentable are "shared" on a hire basis: owner occupied apartments, allotment gardens, cars. Economists account for whether a good can be loaned (or not) by the difference between the transaction costs accrued and the revenue that can be generated by the rental. If there is a positive difference, the rental is justified, and the greater the difference, the greater the interest in renting it out [20]. Renting something out only makes sense for individuals, however, when they have a product they do not use to full capacity —hence the renting out of cars when not in use, apartments when the owner or main tenant is on holiday, and parking spaces in front of the house during the day, when the owner is at work.

Looking at the effects of shared use essentially stems—at least in Germany—from the debate surrounding the sustainable use of resources [21–23]. At aggregate level—regional, national or even supra-national—sharing thus appears to be a possibility for saving resources. On the individual level, in contrast, sharing does not mean consuming less, but rather the opportunity of maintaining or even increasing consumption levels. Carsharing, where members have at their disposal a wide choice of vehicles, even a selection of vehicle types, can in fact be viewed as an example of this. It offers a range of consumer goods, in this case in the form of vehicles, that outstrips what the majority of private households could own themselves. On the aggregate level, less vehicles are needed (the German Bundesverband Carsharing (BCS) quotes figures of 42 people sharing one

station-based vehicle and 70 persons sharing a flexible one; [5]); on the individual level, high mobility levels are nevertheless assured.

In its first years, carsharing was often associated with attitudes where car driving is not something done purely for its own sake. Car users with this attitude thus took no pleasure in driving (see [21, p. 92]). Carsharing usage was instead motivated by a desire to counter the environmental degradation for which users held the growing motorization of private households responsible [12]. It is possible that this has fundamentally changed. For instance, carsharing, in both station-based and flexible forms, has evolved into a commercial product. Moreover, studies on the use of flexible carsharing have found that aspects such as "attention received, appreciation experienced, fun and enthusiasm" are absolutely essential motivations (see [24, p. 21]: approval ratings of the corresponding statements between 38 and 86 %). Carsharing vehicles and their use here take on the emotional and psychosocial functions that were previously ascribed to cars only in the form of ownership [22]. Bardhi and Eckhardt view "sharing" (termed by the authors more accurately as "access-based consumption") as a defining characteristic of a "liquid society," in which fixed reference systems, such as those arising from property, increasingly begin to crumble [24].

9.4 Digitalization of the Everyday World as a Basic Precondition for New Mobility Concepts

The development and extension of carsharing via new concepts such as flexible and peer-to-peer carsharing is inconceivable without the availability of devices with mobile internet access and communications applications. Every provider does indeed also present their carsharing product extensively on the (stationary) internet, but this is more about giving information to (potential) customers than immediate use of the service. To access the vehicles, mobile applications in particular play an essential role. In the first place, they enable the user and vehicle to be located in real time. This allows users to see what vehicles are available, and to decide whether they are willing, and able, to make the trip to the vehicle (for which, depending on the provider, they currently are given between 15 and 30 min). As a second step, the mobile application allows the selected vehicle to be reserved and offers navigation to it. With some operators, even opening the vehicle can already today be done via the app.

The potential use of such technologies thus depends largely on users being technically equipped to access the online choice of available vehicles via mobile. Rates of private smartphone ownership have in fact considerably risen in recent years. While only around 6.5 million Germans owned a smartphone in 2009, this figure stands at over 40 million today, almost every second person. For 2014, it is expected that 97 % of all mobile phone sales will be smartphones; sales of almost 30 million devices are forecast [25, 26].

At the same time, it may be assumed that hardware and software skills are increasing in all population groups. In 2013, for example, a study found that the number of internet

users continues to expand [27]: in 2013, 54.2 million people in Germany were online at least occasionally. That is 77.2 % of the population, and an increase of 800,000 people on the previous year. The driver of this growth is exclusively the over-50s. Time spent online is rising concurrently: the average German internet user was online for an average of 169 min a day in 2013, 36 min more than the previous year. A considerable proportion of this was mobile internet use, practiced by only 23 % of users in 2012, but already by 41 % in 2013. Apps are used by almost half of online users (44 %) on various end devices [28].

In the transport context, what particularly stands out is the ever greater possibility of reducing planning horizons arising from digital applications and mobile devices. Spontaneity in organizing individual mobility is thus a particularly important connotation of "flexibility," the most common among the specific qualities of the new mobility concepts. Correspondingly, the statement with the highest approval rating in a 2014 survey of Car2Go users was: "What I find attractive about Car2Go is that I can use a car spontaneously, even when I am out and about without one"—98 % of respondents agreed with this statement (for 72 % it was "highly accurate", for 26 % it was "quite accurate") (see [15, p. 20]). This also goes to explaining the quick success of flexible carsharing, which is released from the (long) pre-planning required for conventional station-based carsharing. At least in the medium term, it could also take on the advantage that private cars have enjoyed until now of being permanently available (on this, see also [22, p. 64]).

Overall, this means that almost no barriers to access on the part of the (potential) users should be expected, provided that future mobility concepts tie in with what is already currently practiced ("practiced" in the true sense of the word; for an analogous comparison, see the acquisition by repeated practice in the interaction between humans and computers in vehicle navigation systems in Chap. 3). Less likely, even if repeatedly cited by the scientific community, is the conversion of the entire vehicle fleet into vehicles that are on the road on a sharing basis or operated by public transport providers. There are currently no indications that private cars are losing any of their attraction. According to the Federal Motor Transport Authority (Kraftfahrtbundesamt, or KBA), vehicle stocks in Germany reached record levels on 1 January 2014, rising by around 500,000 vehicles between 2013 and 2014. This accords with long-term trends [29].

9.5 Can New Mobility Concepts Be Further Developed via Carsharing's Automation?

There are a series of variants for the further development of existing carsharing concepts using autonomous vehicles, which run in parallel to the use cases outlined in Chap. 2. These variants are aimed at different user needs which are already being addressed, albeit via a human driver. In the following, we shall discuss the "Full Automation Using Driver for Extended Availability," "Autonomous Valet Parking," and "Vehicle on Demand" use cases, and also ask: What changes would carsharing experience with an influx of

autonomous vehicles? What effects can be expected for the user? Competition with currently existing transport provision will also be addressed.

In all use cases, the highest degree of automation is assumed—"fully automated," according to the nomenclature of the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen, or BASt) [30]. The difference in the cases lies in the uses encompassed in their definition. Autonomous Valet Parking, for instance, exclusively involves picking up and parking vehicles. Full Automation Using Driver for Extended Availability, on the other hand, covers every conceivable use in road traffic, even if the emphasis is on situations with comparatively simple traffic mixes, such as freeway traffic, where high speeds also prevail. In this use case, the driver must take over the driving task at certain times and on certain route sections where clearance for autonomous driving has been temporarily or permanently withheld. A Vehicle on Demand is likewise in a position to deal with any potential usage scenario, including those with mixed traffic. By renouncing the so-called driver's workplace—the seat from which the driver performs the driving task—the potential uses of the vehicle interior increase greatly in comparison to Valet Parking or Full Automation.

9.5.1 Autonomous Valet Parking in Carsharing

The Autonomous Valet Parking use case starts from the assumption that the vehicle will be able to independently move from parking space to user and vice versa, even on public roads.

The use of Autonomous Valet Parking in carsharing would initially mean that the effort required for the user to procure the vehicle and park it after use would fall considerably. Instead, from the user's point of view, there would be a door-to-door service—comparable to taking a taxi, although one in which the user takes over the driving task for the actual journey. The overall travelling time would in any case be reduced with the shortened time and distance for accessing and egressing the vehicle.

In order to make the service more attractive, various enhancements would be possible, regardless of automation. These could be options in vehicle features: number of seats, carrying capacity, internet access, and multi-media provision. How greatly the options differ would depend—as with today's carsharing—on the fleet size, the number of (potential) customers per vehicle and the size of the operating area, and also on the readiness of customers to pay for various optional features. In a large fleet, it would also be possible to have a differentiated price scale for different vehicles, comparable to that currently found in station-based carsharing and traditional car rental. This is in contrast to current flexible carsharing business models, which possibly have the added attraction for users that they can use a large range of vehicles from the current fleets for the same price.

With Autonomous Valet Parking, providing vehicles at a station becomes essentially superfluous. Carsharing provision as a whole could thus be made flexible—at least in that fetching and returning the vehicle would be unnecessary. The operators, of course, would

still need their stations or vehicle depots to keep things centralized to a certain extent, which is more efficient for vehicle maintenance. These stations, though, would no longer need to be built in the greatest possible proximity to customers, but could instead use low-cost land. The distance to the journey/start end points is not arbitrary here, however, as there may be a relatively small time window for getting to the customer. Moreover, the journey to the customer also uses resources and is also "dead" time if no other use is possible for the vehicle on the way.

As an alternative, or supplement, to this, numerous smaller collection points with a few vehicles could be spread relatively densely across the operating area. This would keep the time between ordering and picking up a vehicle down. A mixed form of vehicle ordering with optional autonomous collection or picking up in person would also be possible. This would significantly even out access times, which currently still differ widely, depending on the density of available vehicles. At present, access times, calculated on the difference between the measured values of "time of booking/reservation" and "journey duration," are between 1 and 16 min (e.g. DriveNow with a maximum reservation time of 15 min; source: WiMobil project, supported by the German Federal Environment Ministry (BMUB)). The differences in average access times are closely linked to the various trip purposes.

9.5.2 Carsharing Used as "Full Automation Using Driver for Extended Availability"

The use case of Full Automation Using Driver for Extended Availability assumes that vehicles will basically be able to move autonomously on public roads, but that the driving task can be taken over by the driver independently from time to time.

From a carsharing perspective, the potential changes and extensions involving "Full Automation" are far smaller than those of Autonomous Valet Parking, at least when drivers are required for on-hand availability in the vehicle. The only difference to today's carsharing that would result from this use case would be the possibility of letting the vehicle drive during the trip, should the driver wish. Autonomous driving may also be permanently proscribed on some route sections, however, "e.g. roads with a high frequency of pedestrians crossing" (see Chap. 2). This would primarily be areas in urban districts which—at least for now—form flexible carsharing's main usage areas.

Accordingly, upgrading carsharing with fully automated vehicles, with the driver available for extended range, would be more likely to find use on routes at the edge of or outside settlements. But this is hardly the basis for a business model for "carsharing in rural areas," however. The necessity of having a driver available would prevent serving operating areas with a vehicle that drives to and from the customer autonomously.

Overall, the use of Full Automation Using Driver for Extended Availability offers far less potential than that resulting from Autonomous Valet Parking.

9.5.3 Carsharing as Vehicle on Demand

The Vehicle on Demand use case assumes an autonomously moving vehicle on all public roads. A driver is—even as a fall-back option—not necessary. A driver workstation is thus no longer required, which opens up new design possibilities for the vehicle interior.

A carsharing vehicle on demand starts with the same advantages as a carsharing vehicle with a valet parking function, but in addition the vehicle can become a kind of "compartment on the road." As a result, very diverse activities are possible in these vehicles, such as reading, playing, telephoning, working or taking a nap, and the user can sit anywhere they choose. If we assume usage durations similar to those generally found in today's flexible carsharing, however, it remains open to question whether these additional uses would in fact be highly valued—the average usage duration of a vehicle in a fleet such as that of DriveNow, for instance, was roughly only half an hour in 2014 [31]. If we assume that autonomously driving vehicles will be used for all work journeys in the course of a day, this time span would come to an average of 54 min in large cities at today's rates. For those living in surrounding areas of large cities or in rural areas, the total time spent on travelling to work on a weekday is currently 49–50 min (data source: MiD 2008 [1]). There is, then, almost no difference in the time spent making work journeys with cars in various types of geographical areas (Fig. 9.2).

Carsharing in a Vehicle on Demand would be similar to a taxi ride, and because the vehicle would be available to a wide circle of users, it would most probably replace taking taxis. But the costs of taking an autonomous carsharing vehicle should be compared to those of taking a taxi.

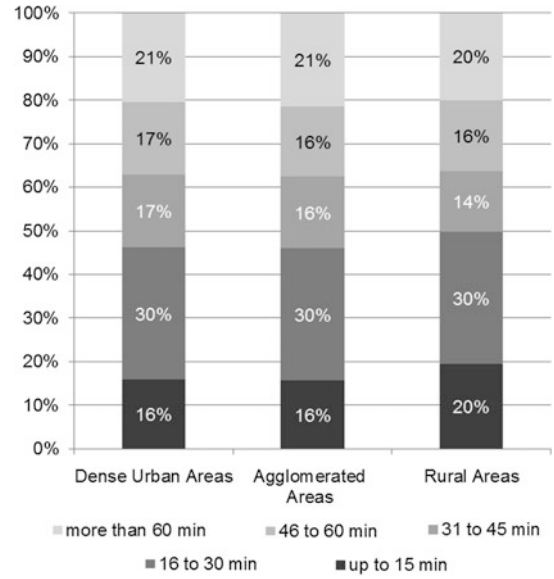

Fig. 9.2 Commute time for commuting by county types (data source: [1])

9.5.4 Interim Summary

If we compare the various possible uses of autonomous vehicles in carsharing, the vehicle user gains in comfort from automating the driving task, in a way that is not essentially any different from private vehicles. In carsharing, the travelling time is also free for any other activities that can be carried out in the vehicle during the journey. The decisively novel type of use likely to emerge for carsharing would be delivering the vehicle to the user and disposing of it after use.

The user's prospects are different to those of the operators, who, with the automation of pick up and drop off, will achieve increased usage frequency and overall usage duration for a single vehicle, which could increase carsharing's profitability. This would at least even out differences in usage frequency that show up in studies on flexible carsharing. Currently, usage frequency is directly related to the location at which the vehicle is left. Hotspots in inner-city districts stand in contrast to places where most vehicles parked there wait unused for several hours (Fig. 9.3). Operators currently put average usage duration at between 68 and 78 min per vehicle per day [32], which shows that there is still room for these vehicles to be utilized at greater capacities.

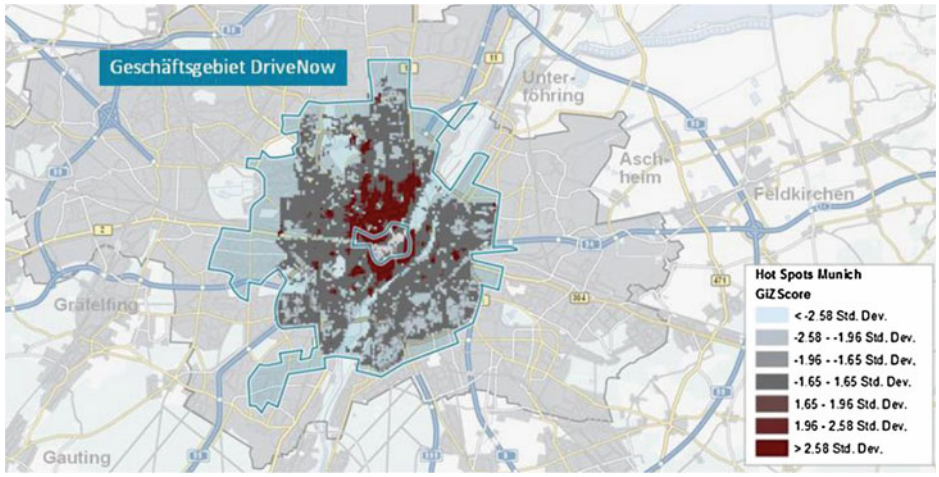

Fig. 9.3 Booking intensity of vehicles in flexible Carsharing—the example DriveNow Munich [14, p. 18]. A high positive value equals a high number of bookings in the respective area (the higher the value the more bookings are made). A low value equals a low number of bookings (the lower the value the lesser bookings are made)

9.6 New Mobility Concepts Beyond Carsharing: Hybridization of Public Transportation?

While carsharing attracts particular attention, especially in its new flexible variant, and also in connection with vehicle automation, it is often overlooked that new options for (further) diversification in current public transport provision could also result, with further new forms of mobility concepts emerging. It also is vital here to take the relevant local conditions into account.

The basic options to be discussed in connection with public transport involve:

- redesigning intermodality and transition to a more flexible form of public transportation
- individualizing public transportation
- expanding public transportation service options

The particular benefit that would arise from the use of autonomous vehicles here especially concern demand-driven services: Fixed route plans could be supplemented by flexible services. The additional routes could be optimized according to customer requirements. Fixed timetables would be replaced by temporally optimized routings corresponding to customer demands.

This individualization of public transport will, then, amount to "hybridization" at the latest when, beyond the flexibilization of times and routes, options regarding the vehicles available are also on offer. In essence, the idea of diversifying public transport via vehicle-specific provision is not new. Until now, however, it has only been possible to introduce this in very limited, mostly tourist-centered niches, due to the costs of manning the various fleets with the required staff (e.g. Cable Car in San Francisco, the Glacier Express in Switzerland, or the Blue Train in South Africa).

9.6.1 Reshaping Intermodality and Making Public Transport More Flexible

Intermodality is defined as the change between different transport modes in the course of a journey [33]. According to this definition, intermodal behavior exists only to a very limited extent, at least in Germany. According to the study "Mobility in Germany 2008," it only applies to 1.3 % of all day-to-day journeys [1]. What is overlooked here, though, is the considerable amount of intermodality within public transport, particularly in the linking of main routes with access and egress routes. A typical example of this is accessing commuter or regional trains on a bus line, as is often the set-up in suburban and rural areas. In cities, intermodality between the various modes of metro, commuter train, trams, and bus is much more pronounced. The situation in urban peripheral areas and less densely populated (rural) districts is outlined below. Heinrichs discusses comparable scenarios for cities elsewhere in this volume (see Chap. 11).

Reshaping intermodality by using autonomous vehicles could take place along the same lines as the current system, using private cars or public means. In day-to-day transport, getting to and from the main lines would to some extent correspond to what is today known as "kiss and ride": One person drives another to the main route transport mode, bids goodbye and takes the car with them so they can use it (generally in the daytime) for other purposes during the other person's absence. With an autonomous vehicle, the first person would not need to do the driving, as no driver would be needed to be present for the return trip. The kiss-and-ride pattern can also be found in similar form for long-distance transport, where carsharing operators have also begun, incidentally, to introduce special services for getting to and from airports, train and long-distance bus stations. These include reserved parking spaces at airports, and special rates for intermodal use of long-distance buses and carsharing vehicles [34].

If travelling to and from main lines is done on a public system, it will be possible, by means of autonomous driving, to target user requirements far more closely. Fixed routes and timetables could be dropped in favor of individually arranged pick-up times and locations. A larger fleet of small and medium-sized vehicles would probably be used for these journeys; the local public transport system would be one of a multitude of collective taxis with tailored capacities. Despite automation, the logistical challenges would be enormous. There is also the essential precondition for a functioning system that the user sticks to the agreement with the operator very reliably. This is especially true regarding departure times, for instance when fixed schedules on the main line, or at least fixed timetables, are involved.

Such a transformation of the system could also breathe new life into ideas of financing basic public-transportation services—on the one hand in the form of pay-as-you-drive, but also on a flat-rate basis financed via taxes or levied on all citizens, as is often debated for cities. Also, a high service density in suburban and even rural areas would justify a flat-rate levy and could in the process help to reduce private car use.

9.6.2 Individualization of Public Transport

Individualizing public transport via autonomous vehicles could, then, go beyond abolishing fixed routes and timetables if it actually came to reducing vehicle sizes—at least in certain parts of the areas served. This would open up the possibility of offering users different vehicle types and features, which presently only exists in a rather rudimentary form with first and second classes on public transport, and even there only really on medium- and long-distance trains.

One possible first step in individualizing public transport could be company buses, such as the so-called Google Bus, equipped with WiFi access and operating in and around San Francisco, which brings the company's employees to work. In this case, a specific community gets together in a communal shuttle. Comparable concepts, albeit in manifold

varieties, are conceivable and appear particularly attractive when based on autonomously driven vehicles.

Parallel to this—also as a private initiative—the development of new carpooling concepts is also possible, which could mean a mix of common ownership and use of the vehicle, though it may be used individually at times too. Today, carpooling is essentially restricted to ridesharing organizations, where journeys are planned in the medium or short term, and the vehicle is provided and driven by the owner. Even new services such as Uber (www.uber.com) or Lyft (www.lyft.com) do not deviate from this principle. What they offer is taxi-like services, and are thus not comparable with the standard carpooling communities, which predominantly consist of fixed groups of people. It seems reasonable to assume that carpooling services will become obsolete with the rise of autonomous vehicles, and evolve into peer-to-peer carsharing.

9.6.3 Broadening Service Options in Public Transport

Concerning intermodality, possibilities include more public transport services, even in the suburban and rural areas mentioned above (for urban areas, see Chap. 11). The benefits resulting from the use of autonomous vehicles are equally true in spatial and temporal terms, that is both for districts on the outskirts and off-peak hours. An economic lower limit resulting from frequency of use also applies here, however, even in view of the saved labor costs. This also means that a spatially highly dispersed use can only be covered to a limited extent by providing larger fleets. In any case, operating these vehicles would have to pay for itself in terms of initial outlay and operating costs.

9.7 Implementing New Mobility Concepts with Autonomous Vehicles

Carsharing is currently causing quite a stir, in part due to the new forms it is developing, its increasing visibility, and how abruptly its user base has grown in the last two years. But beyond that, carsharing, which in its commercial or group forms is independent of private car ownership, seems well cut-out for introducing new vehicle technologies into the market. Users get to use and try out new technology in providers' vehicle fleets, without the costs of doing so that comes with conventional vehicle ownership. In fact, this is already taking place with electric mobility, where companies such as Car2Go, DriveNow and Citroen's Multicity service are incorporating electric vehicles into their fleets. The user response has been markedly positive. On this point, projects have reported two aspects of electric-mobility carsharing: Firstly, the new technology has been successfully and speedily furnished for a large section of carsharing users; this has stimulated its use. Secondly, many users actively seek out the option that carsharing gives of testing and using new technologies [13, p. 15; 15, p. 19].

The introduction of autonomous vehicles into public transport may be more difficult, even if automated rail and metro lines have so far largely been positively received, e.g. Linie 1 of the Paris Metro, fully automated since 2012 [35], or the metro line to Nuremberg Airport [36]. But the spatial separation of rail tracks provides for different conditions than would most likely be the case on the roads. If autonomous vehicles were also tied to a rigid infrastructure in road transport, then not only would considerable costs result, but the possibility of more flexible navigation would also be lost. Testing the deployment of autonomous vehicles in prescribed, small-scale public or semi-public areas, as described in Chap. 10, thus assumes especial importance. A comparably open "experimental philosophy" is not currently visible in many places.

9.8 Conclusion

Further developing carsharing systems and changing public transportation through the deployment of autonomous vehicles appears in essence possible, and is in many places also linked to clearly defined benefits for road users. In carsharing, the use of fully automated pick-up and drop-off services, in the sense of Valet Parking, seems to almost be a logical and necessary consequence if carsharing's availability and use are to be extended further in the medium-term.

We can already see that numerous new ideas concerning car and ridesharing are cropping up and being tested out, which could have an even greater potential when combined with autonomous vehicles. Carpooling schemes are being developed, for instance, that have an additional "care" aspect, not only for elderly people, but also for children—as "Boost by Mercedes Benz" is demonstrating in Palo Alto, California. We also see here the close interconnection between mobility and information and communications technology when organizing such services [37].

The question of costs and profitability are currently completely open; possibly this question should be linked to that of financing the system. On the user side, it also remains to be seen whether, and to what extent, users come to accept pay-as-you-drive carsharing set ups. Experiments in this area are also only at initial stages. For example, in their current version, Spotcar are positioning a distance-based charging scale against Car2Go and DriveNow's time-dependent pricing, in order to avoid immediate cost penalties for customers stuck and delayed in city traffic. The pay-as-you-drive era is only just beginning in public transport, for instance with systems such as Touch&Travel. It may well be, however, that such payment systems in carsharing, and comparable ones in public transport, are merely forerunners of a highly flexible system.

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