From public mobility on demand to autonomous public mobility on demand – Learning from dial-a-ride services in Germany

Alexandra König

Research Assistant at Institute of Transportation Systems at German Aerospace Center (DLR), Lilienthalplatz 7, 38108 Braunschweig, alexandra.koenig@dlr.de

Jan Grippenkoven

Research Assistant at Institute of Transportation Systems at German Aerospace Center (DLR), Lilienthalplatz 7, 38108 Braunschweig, jan.grippenkoven@dlr.de

The question arises how to satisfy different needs for mobility while at the same time containing traffic, given that future demand for mobility will keep increasing due to urbanization and economic growth. Cities like Oslo, Helsinki, and Madrid have announced their plans to reduce motorized traffic in the next years. Electrification, connectivity and automation, as central trends in the upcoming generation of vehicles may not lead to a reduction of traffic but rather increase it. Future mobility is challenged to bundle up traffic demands to handle an increasing mobility demand caused by spatial sprawl, economic growth and flexibilization of working hours. Looking at mobility from a psychological perspective another challenge arises – people strive for a more flexible form of mobility than public mass transport offers. They rather want schedules to adapt to their needs than to plan their mobility regarding to the fixed times of public transport. Demand responsive transport systems offer an opportunity to overcome these challenges for future mobility – both, bundling of demand and flexibility of service. In Germany those dial-a-ride services, called "Anrufbusse" or "Rufbusse", could serve as a possible guarantor for the preservation of personal mobility, especially in sparsely populated rural areas. Those systems offer public mobility on demand within given temporal and spatial restrictions. Currently, the annual number of passengers of those public on- demand busses is relatively small, especially the amount of deliberate passengers, who decide to use dial-a-ride services despite of other individual mobility options like an own car. Given the hypotheses that dial-a-ride systems are a promising way to handle the challenges of bundling of demand on the one hand and individual flexibility on the other hand also for urban areas, those systems need to be examined more closely. Existing dial-a-ride systems in Germany were analyzed with the aim of identifying factors that influence the use and the success of such systems. Factors were identified by means of an extensive investigation of secondary data as well as interviews with system operators and users. Given the assumption that actual dial-a-ride systems are the antecedents of autonomous public mobility-on-demand systems, like "Robo-Cabs", this study takes a first step to analyze the predictors of a future efficient and sustainable mobility.

JEL Classification: R40 (Transportation Economics)

Keywords: Demand-responsive transport, Dial-a-ride services, Market Research, Automation

1 Mobility trends and challenges

Future mobility is affected by technology-driven as well as user-driven trends. Digitalization and automatization are two important technology-driven trends that will affect our future mobility. Technological progress in vehicle development, vehicle-infrastructure connectivity and telematics will provide to a new quality of individual mobility. Furthermore technology-driven trends may contribute to an increase of user groups of motorizied individual mobility as it facilitates the accessability and comfort for disabled, elderly and possibly even very young persons. On the other hand, the user-driven trend of flexibilization of life- and workstyles has and will have a profound impact on mobility needs. In accordance to their life planning people strive for a more flexible form of mobility than public mass transport. As pointed up by the emergence of new mobility services as for example Car2Go (carsharing), Uber (private taxi service) or BlaBlaCar (carpooling), there is a need for flexible and demand driven mobility.

The question arises how to satisfy different needs for mobility while at the same time bundle up traffic demands, given that future demand for mobility will keep increasing due to spatial sprawl and economic growth. Demand-responsive transport systems offer an opportunity to overcome these challenges for future mobility – bundling of individual traffic demands and flexibility of service. Those demand responsive mobility services could also been called *public* mobility on demand systems. They differ from *individual* mobility on demand systems (MoD) as the latter are based on small-sized one-way vehicles, like Car2Go (Mitchell, Borroni-Bird, & Burns, 2010; Pavone, 2015), while public MoDs are based the concept of shared rides. Giving attention to the fact that we need to bundle demand to keep traffic volume in urban agglomerations under control, future mobility systems should emphasize a public shared ride concept like one known for example from the the shuttle service *Navia* instead of a solely shared vehicle concept (Beiker, 2015).

This article focuses on the analysis of actual public mobility on demand systems in the form of dial-a-ride systems. Dial-a-ride services are a form of public mobility on demand in which passengers express their mobility demand by calling a service center that subsequently organizes the operational service. Furthermore, the progress in vehicle automation will contribute to an increase in efficiency of public on demand systems as the autonomous vehicles will be able to optimize their routes and rebalance themselves (Pavone, 2015). With this perspective, the research addresses the question which insights can be transferred from current demand-responsive transport systems to future autonomous public mobility on demand systems. The study takes a first step to analyze the predictors of a future efficient and sustainable mobility by analyzing existing dial-a-ride systems as the most flexible form of demand-responsive transport services in Germany.

2 Demand-responsive transport

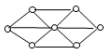
The main reasons of residents of rural areas for using their personal car are a perceived and / or actual lack of service availability as well as the inconvenience of public transport (Velaga, Nelson, Wright & Farrington, 2012). Inconveniences like a long way to the next bus stops, unpunctuality or confusing ticketing systems are examples of annoyances that can prevent potential passengers from using public transport. In order to reach the goal to reduce the amount of individual car use, the most important precondition is to provide alternative public mobility services that meet people's real needs at a high level. If the requirements of potential users are regarded in the service design of demand-responsive transport concepts, they can be promising in terms of improving rural mobility in an efficient and climate friendly manner to adapt the service to specific needs.

Classification

There are many forms of demand-responsive transport (DRT). Each of these forms can be seen as a particular approach of traffic planning that takes specific requirements into account that reflect for example structural and sociodemografical conditions of a region. DRT typically either replaces or supports conventional public transport in rural areas with low and irregular demand (Mulley & Nelson, 2009). In contrast to taxi services, DRT systems usually do not transport individual passengers. DRT systems transport multiple passengers that share a vehicle for their ride. The operation area is usually definded by geographical borders. DRT is characterized by certain degrees of flexiblilty in routing and scheduling according to passenger needs. The demand responsiveness varies between the different types of offered services. DRT systems can be classified into three forms of route flexibilization according to the Federal Ministry of Transport and Digital Infrastructure of Germany (BMVBS, 2009):

- **Fixed on-demand—**vehicle operating in conventional routes and a fixed schedule only if there is demand.
- **Point deviation—**vehicle operating in demand-responsive mode along a corridor with established departure and arrival times at one or more end points.
- **Flexible area based –** vehicle operating time and route are based exclusively on passenger requests

Table 1 compares those three demand-responsive transport systems to conventional fixed route systems.

	Fixed route	Fixed on-demand	Point deviation (corridor)	Flexible area based
Schedule	yes	yes	yes	no
Fixed route	yes	yes	no	no
Pre-booking	no	yes	yes	yes
Schema				

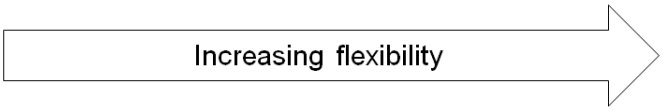


Table 1: Classification of demand-responsive transport based on route flexibilization according to BMVBS (2009, p. 26)

Specification of dial-a-ride systems

The dial-a-ride system is a flexible area-based form of demand-responsive transport wihout schedule. The service provides an on demand service within a defined area and time period and is available to all citizens. An online booking or booking by telephone is necessary for the realization of a ride. In Germany the the dial-ride concept is carried out under the names of *Anrufbus*, *Rufbus* or *T-Bus* and as *PubliCar* in Switzerland. As illustrated in figure 1, dial-a-ride systems are a promising way to connect remote areas to main corridors of public transport by means of a feeder system. In figure 1, the feeder system is exemplified by a small bus that connects passengers from rural areas to the main line that connects them to the next urban centre. Dial-a-ride systems differ in their form of operation concept – the busses either pick up passengers at defined bus stops, so called *RF-Bus* or pick up and drop off each passenger at his front door, so called *F-Bus* (BMVBS, 2009).

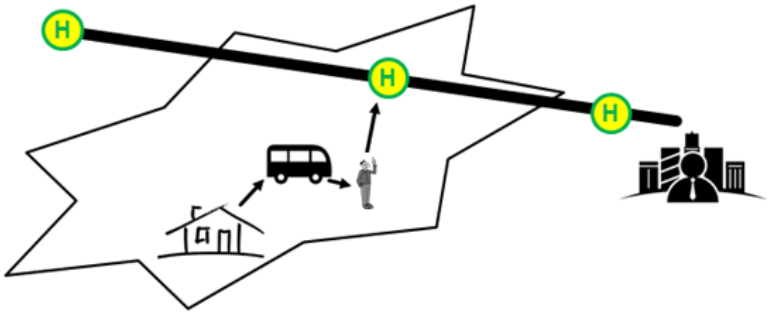
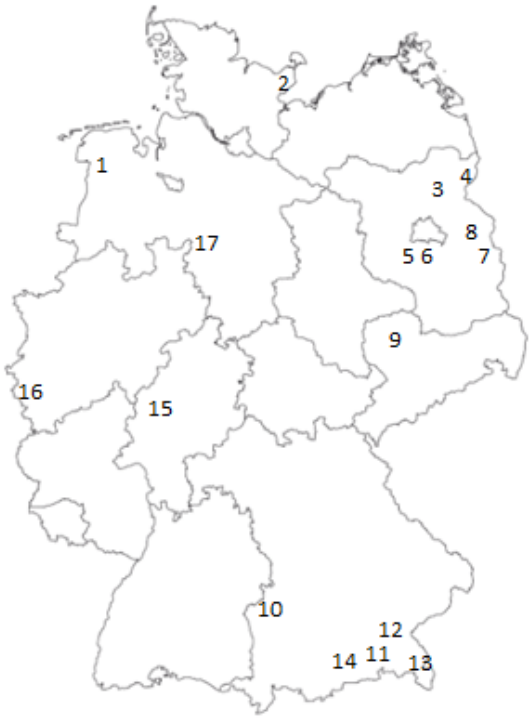


Figure 1: Schematic illustration of dial-a-ride concept

3 Dial-a-ride systems in Germany

Market research

A market research based on an extensive online enquiry, literature review and interviews with transport companies as well as transport authorities was carried out to analyze current and failed dial-a-ride services in Germany. As figure 2 shows, at the current point in time (October 2016) there are 17 dial-a-ride systems according to the definition presented in section 2. The dial-a-ride service in Leer for example is in operation since almost 25 years while the majority of the dial-a-ride systems in Germany started their service within the last decade. With exception of the dial-aride- service in Taunusstein, all of these dial-a-ride systems are located in sparsely populated rural areas with a mean of 243 inhabitants per squarekilometre.



1	Anrufbus Leer
2	Anrufbus Ostholstein
3	Rufbus Uckermark Angermünde
4	Rufbus Uckermark Gartz
5	Anrufbus Nuthe-Urstromtal Beelitz
6	Anrufbus Nuthe-Urstromstal Luckenwalde
7	Rufbus Oderbruch-Süd
8	Rufbus Oderbruch Nord
9	Anrufbus Delitzsch
10	Flexibus Mittelschwaben
11	Vario Bus Traunstein
12	Rufbus Nordwesten Traunstein
13	Rufbus Berchtesgarden
14	Filzen Bus Pfaffing und Albaching
15	Komfortbus Taunusstein
16	Multibus Heinsberg
17	Anruf-Auto Rodenberg

Figure 2: Current inventory of German dial-a-ride systems (10/2016)

Figure 3: Examples of German dial-a-ride buses (from left: RufBus Berchtesgaden, Anrufbus Leer, Vario-Bus Traunstein, source: own images)

Analysis of current dial-a-ride systems in Germany

Dial-a-ride systems are usually operated by local transport companies using small or midi busses (figure 3). In some cases the dial-a-ride service is operated in a shared taxi-based service (e.g. Anruf-Auto Rodenberg). All of the systems can only be booked via telephone within a certain time frame during the day. Some dial-a-ride bus providers consider developing an online booking tool to improve their service quality. While most of the dial-a-ride services are based on a dispatching concept with special software support (e.g. Cover®, figure 4, left), some dial-a-ride busses operate on the basis of *Microsoft Outlook* (Microsoft Corporation, 1997; e.g. Rufbus Berchtesgaden, figure 4, right) or even based on *Microsoft Excel* (Microsoft Corporation, 1985; e.g. Rufbus Oderbruch Nord).

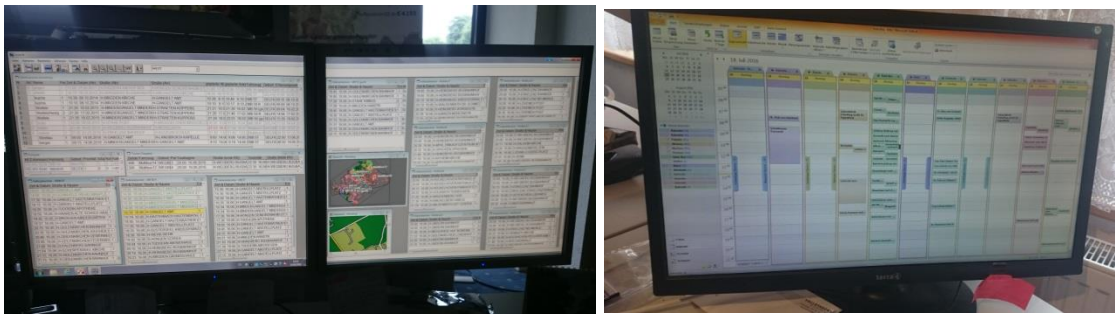


Figure 4: Left: Dispatching software Cover®, Right: Dispatching concept based on Microsoft Outlook (source: own images)

The German dial-a-ride systems can be classified based on the option of access (bus stop vs. front door). As shown in figure 5, most of the dial-a-ride systems are based on a bus stop access due to legislation issues (Mehlert, 2001 for further details). Furthermore the systems can be classified by the area of operation (intercommunal vs. intracommunal).

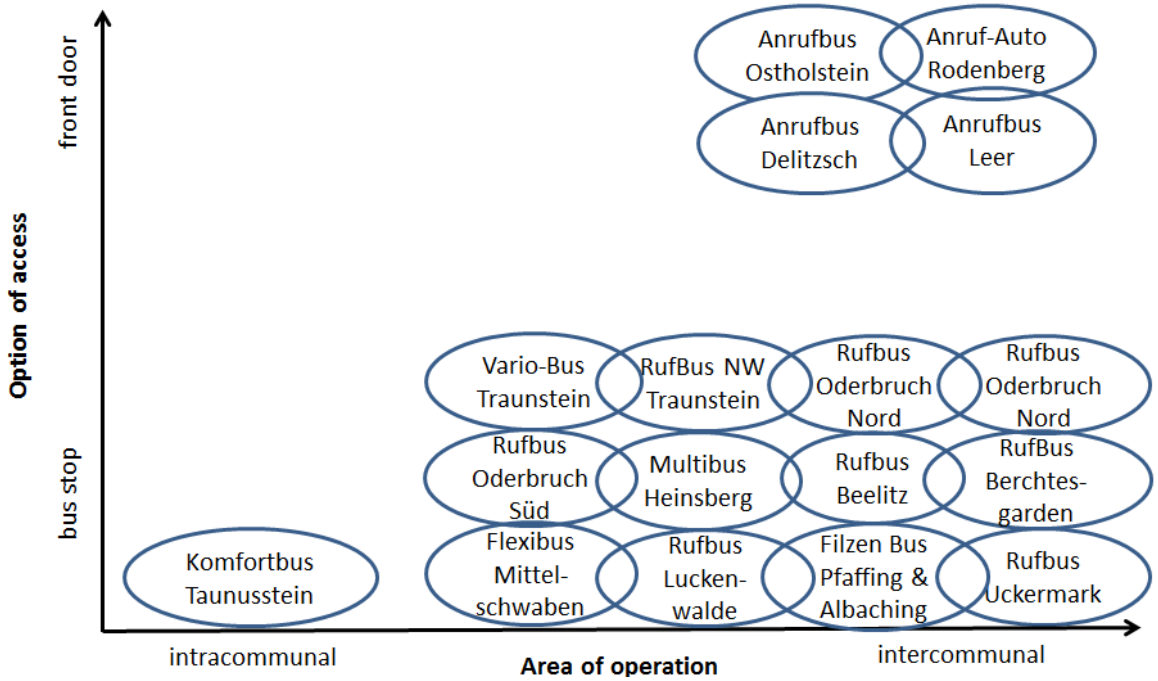


Figure 5: Classification of dial-a-ride systems according to option of access and area of operation

The dial-a-ride-bus systems differ in their underlying concepts. As most of the systems are operated to replace fixed-route bus in a defined area, some of the systems support fixed-route busses during times of poor demand like in the evening or at the weekend. According to their purpose the different systems vary widely in their weekly operation hours (figure 6). For example, the Multibus Heinsberg operates merely from 8 pm to 10 pm on weekdays. On average the dial-a-ride busses in Germany operate for 89.6 hours per week. There are some systems where is it possible to use a dial-a-ride bus more more than 120 hours per week (e.g. Luckenwalde, Pfaffing and Albaching).

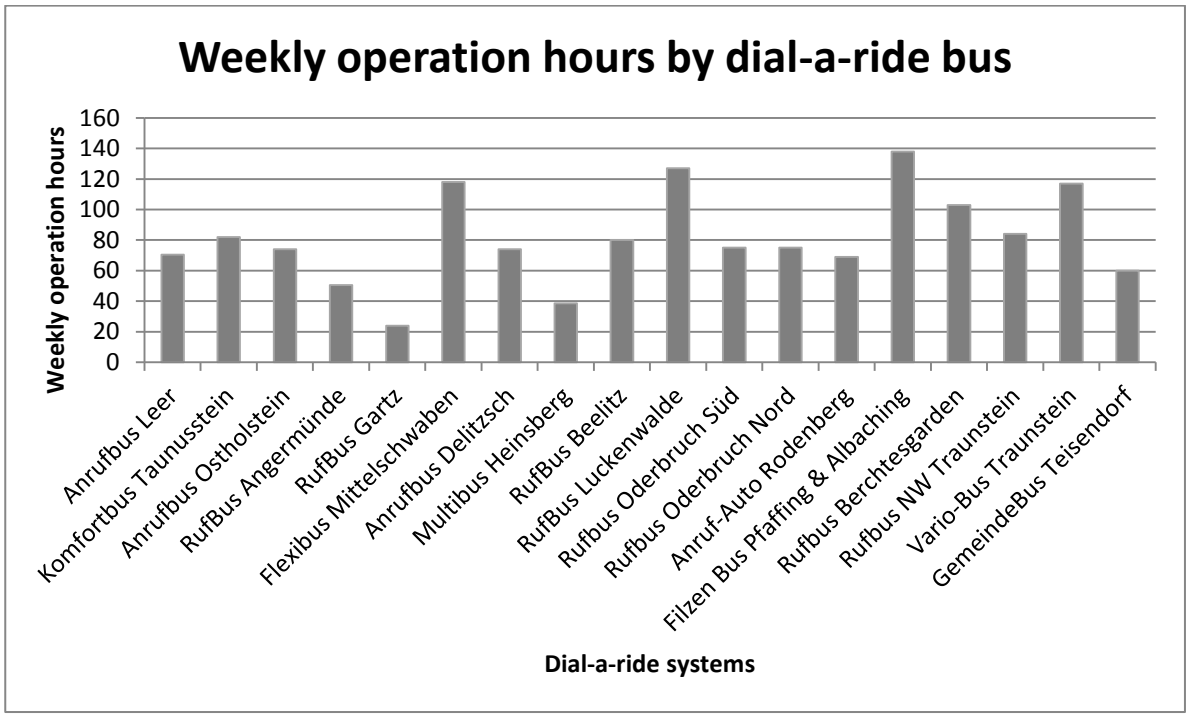


Figure 6: Weekly operation hours of dial-a-ride systems in hours

The number of annual rides of the dial-a-ride busses was analyzed in relation to the number of inhabitants in the operation area, resulating in the measure *number of rides per inhabitant per year*. As shown in figure 7, the number of rides per inhabitant in 2015 varied widely between the dial-a-ride systems. The Flexibus Mittelschwaben was used 1.2 times per per inhabitant in 2015 whereas the Anrufbus Delitzsch, the Rufbus Oderbruch Nord and the RufBus Luckenwalde were used by less than every tenth inhabitant once a year. On average the dial-a-ride buses operated 0.4 rides per inhabitant in 2015.

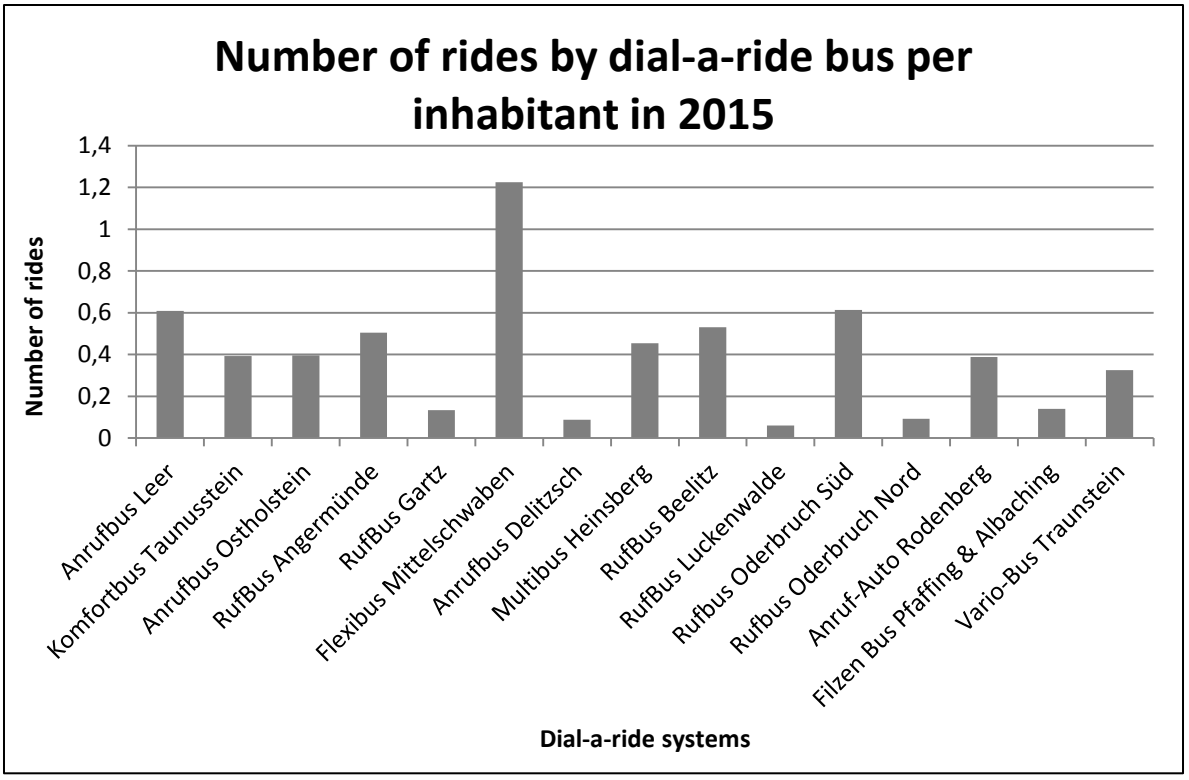


Figure 7: Number of rides by dial-a-ride bus per inhabitant in 2015

A telephone survey was conducted to test the name awareness of the dial-a-ride systems. Fifty persons were interviewed in each of the four analyzed operation areas. The telephone numbers of the interviewed persons were selected randomly from an online phone book. The intervewees were asked if they are familiar with the dial-a-ride bus[1] in their respective regions. The name awareness was high (88 %) for the Rufbus in Berchtesgaden, because it was recently installed and still present in the mind of the inhabitants (n = 44). The name awareness was also high for the Anrufbus Leer (74 %) which is in operation since 1992 (n = 37). The citizens were less familiar with the Rufbus Uckermark (58 %) and the Rufbus Nuthe-Urstromtal (60 %). The telephone survey revealed that even though the name was known by the majority of the local public, the general concept of the dial-a-ride system was not well-known. Some of the interviewees stated that they have heard about the bus but do not know how excactly it works.

4 Implications

Learning from current dial-a-ride systems

The analysis of existing dial-a-ride systems in Germany reveals a high degree of heterogenity. Each operation concept is adapted to the respective structural and socioeconomical conditions. Nethertheless some generic requirements and recommen-

[1] The specific term of the dial-a-ride system was used in the interview, p.e. Anrufbus Leer

dations for a user-centered service could be identified based on a literature review and interviews with dial-a-ride bus operators:

- Integrate the dial-a-ride service into the tariff- and operation system of public transport to provide a higher quality seamless multimodal service
- Prevent the perception of the dial-a-ride service as an exclusive "transport for disabled" or „poor-people-taxi" (Mehlert, 2001), but propagate it as an enhancement of the mobility for everyone
- Provide transparent real time information about departure, route and detours of the dial-a-ride service to increase the perceived controllability for the passenger
- Provide an online booking tool available via a mobile application and homepage to enhance accessibility for the users and to enable algorithm-based routing and scheduling for users and for the traffic provider
- Improve public communication by using advertisement to increase the name awareness and concept knowledge of the dial-a-ride service
- Simplify the dial-a-ride service by the identification and avoidance of restrictions like spefific time windows of operation or an operation area not including main lines of public transport
- Guarantee the accessibility of the system for everyone by means of a barrier-free vehicle concept

Transfer to urban areas

By now, demand-responsive transport systems operate mainly in areas with an insufficient supply of public transport and are therefore seen as niche products. Nevertheless, there is a trend of apllying the DRT concept to areas with a well established public transport system. The emergence of new concepts like *CleverShuttle* or *Allygator shuttle* this year point out the demand for demand responsive transport services, even in urban areas like Berlin or Munich (Frese, 2016; Vogt, 2016). The question arises whether the concept of rural DRT systems is transferable to urban areas? Probably it is not as easy as it seems to be because of fundamentally different structural and socioeconomical conditions in urban areas. Nethertheless, the seven requirements listed above could be applied to concepts in urban areas as well. A central point in implementing an on demand system to a new area is adapting the operation concept to the respective structural and sociooeconomical conditions. This should imply an extensive analysis of the user's requierements.

Transfer to autonomous public on demand systems

The progress in vehicle automation holds a great promise for mobility on demand systems and will entirely change the operation of DRT systems (Pavone, 2015). As driverless vehicles do not underlie regulations of working hours, it will be possible to operate the service around the clock. Operating costs as a decisive factor for the economic inefficiency of dial-a-ride systems today will decrease. The Helsinki Regional Transport Authority (HSL) for example perceives the driverless operation as an opportunity to resume the operation of the *Kutsuplus*, a dial-a-ride bus that was forced to terminate operation in 2015 due to reasons of too high subsidies (Rissanen, 2016).

The emergence of driverless vehicles can be a turning point for public mobility if public transport authorities will offer an autonomous public transport service that is considered as more attractive by the users than individual (shared) vehicles. The *triumph of public transport* as a possible scenario for autonomous vehicles may be based on a pricing system that favours the use of ride sharing or an extensive public transport system that makes private cars superfluous (VDV, 2015b). In parallel with the progress in vehicle automation, research on user's mobility behavior in present multimodal traffic systems should forge ahead, especially in the field of sharing mobility. Pilot projects to develop and test autonomous public on demand systems like *CityMobil2* or *Navia Induct* took a first step to analyze the user`s behavior (Alessandrini, 2013; Beiker, 2015). Research should go one step back for investigating under what circumstances people are willing to share the ride with unknown people and how to improve the user's experience of a shared ride. Furthermore driverless services should been analyzed from the point of view of user acceptance towards using a transport system without driver. Based on the analysis measures to improve trust and perceived safety can be deduced.

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