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Defining On-Demand Mobility System Variables through Qualitative Research

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Abstract

New technologies and innovative mobility services have a fundamental effect on future urban mobility. In this respect, digitalization enables providers and users of mobility services to implement and access new solutions and services, such as applications for the simplified use of (multimodal) mobility or general on-demand mobility services. Especially in metropolitan areas, different forms of on-demand mobility like car sharing, ride hailing or ride pooling are being used by larger number of people. Whereas most of the current research concentrates on the optimization of economic on-demand mobility business models or the simulation of selected environmental or social effects, this paper focuses on a holistic perspective, including different influencing factors in the field of on-demand mobility using qualitative expert-interviews from different stakeholder groups. The aim of this explorative approach is to provide further insights of the interaction between the demand and supply of on-demand mobility services and to uncover previously unrecognized influencing factors from technology development, regulatory framework, urban conurbation and demographic conditions. The output of this study is provided in a structured table of influencing factors (variables) and their classification to the corresponding network levels (dimensions). For future research, the structure can be assigned as the basis for qualitative and quantitative system modelling approaches.

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Keywords: On-Demand Mobility, Sustainabile Urban Mobility, Qualitative Research, System Variables

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1. Introduction

Since 2008, for the first time in human history, more people live in an urban environment than in rural areas (The United Nations 2008). According to studies, the percentage of the world's global population in cities is set to rise above 70% by 2050 (The United Nations 2007, Rode 2013). This strong increase in population in densely populated urban areas brings in addition to positive effects, such as a general increase in productivity also many negative influences (Mertins 1992). Especially for megacities there are major challenges for the environment (Gwilliam et al. 2004). A significant, direct impact on the environment, especially in developing countries, is generated by the transportation system. Due to the rapid urban expansion of cities, more trips take place within the city region and there is an increase in the daily distances of the residents and thus also an increase in (motorized) individual traffic (Gaukenheimer 1999). As a result, urbanization has the potential to shorten trips and provide access close-by to multiple amenities but can also bring problems to the transportation system due to the urban sprawl in conurbations, longer commutes and mostly car-based transportation. In addition to urbanization, other megatrends such as digitization, e-mobility, shared economy or autonomous driving can have a significant impact on the future of urban mobility and shape the way people move around in an urban environment (Greenblatt et al. 2015).

For the last years, there has been a strong growth of new mobility services especially in urban areas. These mostly on-demand offerings are made possible in particular due to new technological opportunities of the underlying trends and have already lead to significant changes in urban mobility behavior in the direction of sharing mobility. This change in mobility behavior is possible, because the mobility preferences of individual people are shifting to a more convenient, flexible and user-oriented mobility system. If one considers these changes in the context of the declining interest of *Generation Y* for vehicle ownership (Tully et al. 2017), one can speak of a shift in urban mobility cultures (Kuhnimhof et al. 2013).

Due to the strong development of those new on-demand mobility services, the exact definition and wording of the specific service types diverge in the literature as well as in the general understanding of the people. In this research on-demand mobility is defined as the usage of motorized shared vehicles in its different states of expression. This specific practice can be divided into driving the vehicle and been driven by a driver. In the case of driving, the vehicles can be accessed and booked via a smartphone application. For this case, the vehicle can be located free-floating or at set stations in an urban environment. Examples of those services would be free-floating or station based car sharing as well as short time car renting. In the other cases of on-demand mobility the passenger is been driven in a ride hailing, ride pooling (ride sourcing/e-hailing) or car pooling service. The major difference between these services is, that ride hailing and ride pooling is generally been operated by a service provider, whereas car pooling is usually a platform business using peer-to-peer transport options to bring together travelers with similar itineraries and time schedules. Furthermore the occupancy rate of the vehicle and the level of service is a differentiator. Whereas in a ride hailing vehicle, there is always only one passenger request at one time, in a ride pooling service more passengers could pool together. For a better understanding of the different service types of on-demand mobility see table 1. The table differentiates the different services by type, level of individuality and price, and gives examples.

Table 1. Service Types On-Demand Mobility (own figure)

On-Demand Mobility Service	Ride Hailing	Ride Pooling	Car Pooling	Car Sharing	Car Renting
Service Type	Be driven	Be driven	Be driven	Drive yourself	Drive yourself
Level of Individuality	High	Low	Middle	High	High
Price	Middle – High	Low	Low	Low	Low – Middle
Service Examples	Uber, DiDi, Taxi	UberPOOL, MOIA, Clevershuttle	BlaBlaCar BlaBlaLines	DriveNow, Car2go, Flinkster	Sixt, Europcar, Hertz

Nowadays governments and private operators are experiencing problems in incorporating these new service categories into the existing transportation network, particularly within larger cities (Haucap et al. 2015, Martin et al. 2011). Additionally, in some cases the market of new mobility services is moving faster than cities can adopt guidelines and regulations to manage those (Haucap et al. 2015). The city of London for example has attracted attention when the city council decided to suspend the popular ride hailing provider Uber (TfL 2017).

However, there are clear opportunities predicted to integrate these new mobility services into existing urban transportation systems resulting in more affordable, flexible, convenient and environmentally friendly transport for all (Fagnant 2015, Brownell 2013). Nevertheless, one challenge for city planners and policy makers is the possibility of people choosing to use these new services instead of existing transportation systems (Tirachini 2018, Henao 2016, Rayle et al. 2014), potentially leading to more traffic congestion, less livable public space, more vehicle accidents and additional air pollution.

As mentioned, there is an immense range of possible impacts of on-demand mobility services on sustainable urban mobility. As so far most of the current research in the field of on-demand mobility services concentrates on business model innovations or selected effects using quantitative data and agent-based or micro-simulation modelling methods, there is a need for further research on a holistic system perspective including general influencing factors as well as individual mobility preferences and mobility behavior and their impact on an on-demand mobility system. However, the scientific link between those individual mobility preferences, general influencing factors and the demand of new innovative mobility services still raises questions in the research field. Furthermore, there is no research combining the effects of on-demand mobility services, sustainable urban mobility and the individual mobility preferences in one holistic approach. The goal of this explorative, holistic approach used in this study is to focus on all potential influencing factors of the demand and supply of on-demand mobility services. Therefore this qualitative study discovers relevant variables and concentrates more concretely on the interactions of on-demand mobility services with individual mobility preferences as well as the impact on sustainable urban mobility. Questions that should be answered using this holistic approach are: What are the main influencing factors in the interaction of supply and demand of an on-demand mobility service? How can those influencing factors be structured and categorized? Which individual mobility preferences play an important role in the selection of an on-demand mobility service? In order to answer those questions and to derive the variables, explorative expert interviews with different stakeholder groups are conducted and analyzed using content analysis.

2. State of the Art

2.1. The impact of on-demand mobility on sustainable urban mobility

Although sustainable urban mobility is a broad and subjective term, multiple different approaches in the literature can be investigated, that describe and measure sustainable urban mobility in a quantitative and comparable method (WBCSD 2015, Wefering et al. 2014, Campos et al. 2008). In the context of on-demand mobility in the existing literature there are a number of studies using stated preferences surveys or simulation modelling techniques to describe the influences of innovative on-demand mobility services on different factors, which can be related to the dimensions of sustainable urban mobility (economically, ecological or social). Atasoy et al. (2015) for example model new mobility concepts and innovative mobility services and their impact on different indicators of the urban environment (Atasoy et al. 2015, Agua 2016).

Most of the current research in the context of sustainable urban mobility and innovative on-demand mobility services concentrates on car sharing and show positive results on vehicle ownership, total miles travelled and emissions. In this context Firnkorn and Müller (2015) describe different scenarios of an all-electric, free-floating car sharing fleet and give an overview of possible effects on the urban environment. Rydén et al. (2005) analyzed the positive influence of car sharing on a decrease of individual vehicle ownership (see also: Baptista et al. 2013; Martin et al. 2011; Millard-Ball et al. 2005; Elliot et al. 2016). Further research has been undertaken to explain if car sharing can decrease the total driven vehicle mileage (Rydén et al. 2005; Martin et al. 2011; Millard-Ball et al. 2005), or based on that findings even decrease the total vehicles emissions in a city (Rydén et al. 2005; Baptista et al. 2013). In that respect Nijland (2016) focuses on the impacts of car sharing on CO_2 emissions.

Fagnant and Kockelman (2014) generated a model claiming that the interplay of autonomous driving and on-demand mobility could significantly mitigate the environmental impact of individual motorized transport in the future. However, ´shared autonomous vehicles` (Bunghez 2015) could offer in combination with innovative ride pooling concepts the possibility of affordable on-demand mobility on a socially acceptable level (Krüger et al. 2016). Kang et al. (2015) investigated the interaction of e-mobility and autonomous driving and addressed possible problems of an autonomous, electric sharing fleet. Geldmacher (2016) supposes, that on-demand services could fill the gap between individual motorized mobility and the public transport system (Geldmacher et al. 2016) and Greenblatt (2015) and Chong et al. (2013), explored the synergies between autonomous vehicles and on-demand mobility.

Further research has been done to concentrate on simulating the influence of autonomous, dynamic on-demand pooling services in urban environments (specific use cases like Lisbon, Stuttgart and Munich) and give perceptions of the possible effect of those services in the future on sustainable urban mobility. An overview of relevant studies in the field is provided in table 2.

Table 2. (Autonomous) dynamic On-Demand Mobility Studies (own figure)

Author	City	Selected Study Indicators	Simulation Method	Software
OECD 2015	Lisbon	Number of cars, kilometers travelled, impacts on congestion, impacts on parking space	Agent-based modelling	/
Rigole 2014	Stockholm	Kilometers travelled, number of private cars, parking space, congestion, waiting / travel time, road traffic	Analytical Model	MATLAB
VDV 2016	Stuttgart	Potential replacement of private cars, kilometers travelled, parking space, energy consumption	Agent-based	mobiTopp, VISUM
Fagnant et al. 2015	Austin	Potential replacement of private cars, kilometers travelled, emissions	Agent-based	MATSim
Agua 2016	Munich	Vehicle fleet, road traffic, waiting / travel time, kilometers travelled, energy consumption	Agent based	JADE
Dia et al. 2017	Melbourne	Potential replacement of private cars, fleet size, waiting time, kilometers travelled, empty rides, congestion, emissions	Agent-based	/
Shen et al. 2015	New York	Waiting time, Success Rate, Number of customers served	Agent-based	Mobility Testbed
Bischoff et al. 2016	Berlin	Fleet size, waiting time, kilometers travelled, empty rides, impacts on parking space	Agent based	MATSim
Spieser et al. 2014	Singapore	Financial benefits, Fleet size, Potential replacement of private cars	Analytical Model	/
Marczuk et al. 2015	Singapore	Fleet size, waiting time, Number of customers served, station locations, Potential replacement of private cars	Agent-based	SimMobility

2.2. On-demand mobility and individual mobility preferences

There are numerous approaches to improve the understanding of mobility preferences and the underlying mobility culture in urban metropolitan areas. For example, Kuhnimhof and Wulfhorst (2013) describe a theoretical orientation framework for a change in society towards a sustainable mobility culture (see also: Wulfhorst et al. 2013; Klinger et al. 2010; Deffner et al. 2006). Bartz (2015) focuses especially on individual mobility preferences that should be satisfied with the use of different transportation modes. Therefore Bartz (2015) uses a cluster analyses to describe different types of mobility, based on their mobility behavior and mobility preferences (see also: Zukunftsinstitut 2017, Kuisma 2017). For a better understanding of different individual mobility preferences see table 3.

Table 3. Individual Mobility Preferences (based on Bartz 2015)

Mobility Preferences	Manifestations	Mobility Preferences	Manifestations
Independence	Accessibility, flexibility, spontaneity	Entertainment	Observation of other passengers
Reliability	Punctuality, condition of transport mode	Sustainability	Environmental protection
Economics	Cost, time	Convenience	Availability of transportation, comfort of transport, no effort
Safety	Health, protection from external influences	Aesthetics	Form of appearance, order, self-image when using the means of transport
Membership	Identification with transport users	Orientation	Information
Well-being	Stress-free, relaxation	Privacy	Protected space
Social contact	Shared experience, conversation with driver or passengers	Social recognition	Demonstration of one's own status, stay with like-minded people

3. Methodological Approach

The qualitative study used in this paper focuses on a holistic on-demand mobility service perspective. It concentrates on the potential interactions of on-demand mobility services with general influencing factors, individual mobility perspectives and the impact of a sustainable urban mobility.

Using a qualitative expert-study as a knowledge-based approach, a method is used that focuses on individual subjective expert opinions as opposed to analysis of a representative sample. In this way, this qualitative approach makes it possible to understand underlying reasons and provides insights into the research problem and helps to develop ideas or hypotheses for potential future research. The qualitative research approach can be divided into a planning-, sample-, implementation-, transcription- and analyzing- process.

3.1. Planning

For this study a semi-structured interview guide is chosen (Bortz et al. 2016). For the interview guide, the research problem was operationalized in the form of open, understandable questions in three thematic dimensions. The first dimension covers the general understanding of on-demand mobility. This first step is necessary, as the definition of on-demand mobility varies in literature and in the understanding from different stakeholder perspectives. In the second dimension, potential influencing factors and general conditions are investigated and the third dimension focuses of the understanding of sustainable urban mobility and explores the impacts of on-demand mobility on sustainable urban mobility. As a result, the interview guideline ensures with 12 open sub-questions, that all relevant topics are addressed in a comparable way.

3.2. Sample

When selecting the sample for this holistic approach, it is important to make sure to consult experts from different perspectives to include different standpoints and perspectives to the research question. In this case, experts from automotive Original Equipment Manufacturer (OEM´s), on-demand mobility Start-Ups, Public Transport provider, Academia, the City Council and Non-Governmental Organizations (NGO´s) have been selected, because they all participate in the development and integration of future mobility services in a city. Furthermore, this wide sample makes it possible to compare the understanding of different stakeholder groups in regard to the research question.

3.3. Implementation and Transcription

Once the appointments for the interviews had been scheduled, the interviews could be implemented using the interview guide. Hereby, the duration of the interviews varied between 30 – 90 minutes, depending on the elaborateness of the answers of the experts. An audio record of all the interviews was used, to make sure that all information provided by the experts could be collected. Furthermore, notes had been taken to cover further information about the interview and abnormalities during the interview process.

Once all interviews had been conducted, the audio interview-record was used for the transcription of the interviews. The transcription process was based on the transcription-guidelines from Dresing et al. (2015).

3.4. Analysis

The analyzing-process of the study is based on the qualitative content analysis according to Mayring (2010). This qualitative analysis approach is particularly suitable for the evaluation of interview-guided based studies and provides a clear structure of the collected data. In this respect, the goal in this knowledge-based approach is to gain deeper understanding of potential influencing factors and their interconnections with on-demand mobility and to create a clear structure of the provided data for further processes. Therefore, according to Bengtsson (2016) the analysis process can be subdivided in four main stages: the decontextualisation, the recontextualisation, the categorisation, and the compilation of the results.

In the decontextualisation process, the existing interview-transcripts are worked through and each identified meaning unit that somehow refers to the research problem is labeled with a code. In this analysis all transcribed interviews had been coded and different meaning unites were identified, in total 1002. Bengtsson (2016) describes a meaning unit, as “the smallest unit that contains some of the insights the researcher needs, and it is the constellation of sentences or paragraphs containing aspects related to each other” (Bengtsson 2016). Furthermore, it is important, that the code is understandable in relation to the context. Bortz (2016) also describes this procedure as the “open coding process” (See also: Berg 2001). In the following recontextualisation process, it is checked, whether all aspects of the content have been covered in relation to the aim (Burnard 1991). Once all meaning units are identified and all existing interview-transcripts had been coded, the categorization process starts. In this process, according to extended meaning units must be condensed and the number of words should be reduced without losing content of the unit. Additionally, meaning units with a similar content are combined together in one variable. In the literature this variable is usually described as an overarching category, but for this study the categories can be understood as the identified variables. In the last step of the categorization process, the identified variables had been assigned to different network levels. Those network level cluster all analyzed variables belonging to each other in one group and stand for an overall dimension that suits all meaning units and variables from the categorization. As discussed in literature, the categorization process is finished, once a clear, reasonable explanation and structure of the provided data is reached (Bengtsson 2016). An example of the categorization process is shown in table 4.

Table 4. Example of categorization process (own figure)

Meaning Unit	Variable (Category)	Network Level (Dimension)
Waiting Time		
Time for waiting	Estimated Time of Arrival	
Time periode		Supply On-Demand Service Variables
Fleet of vehicles		
Number of fleet	Vehicle fleet	
Provided vehicles		

This example sows, how different meaning units are combined together in one variable and content related variables are united to one network level. In the compilation process, the results of the study are put together in one clear structure. This structure consists of all variables and network levels and offers the basis for the interaction model introduced later in this paper.

3.5. Results

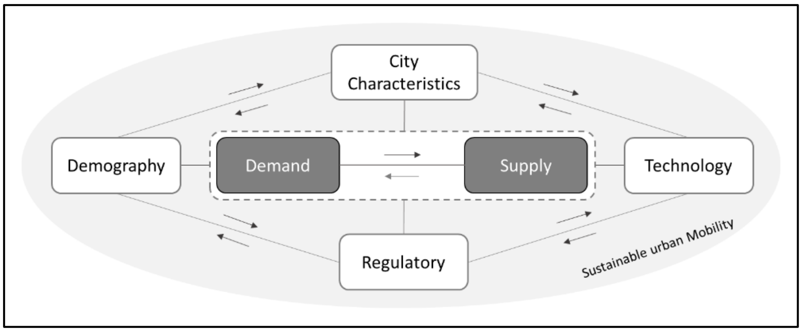
The result of the structure created in the categorization process is displayed in Table 5. The *supply* network level consists of all relevant variables that should be considered by describing an on-demand mobility service. The *demand* variables contain different individual mobility preferences that are important, when calling for on-demand mobility services. The *City Characteristics-*, *Regulatory-*, *Technology-* and *Demography* network level describe all potential, relevant influencing factors that could have an impact on the supply- or demand network level and the *Sustainable urban Mobility* network level includes all variables that had been formed from related meaning units in the categorization process.

Table 5. List of variables divided in network level (own figure)

Supply	Demand	City Characteristics	Regulatory	Technology	Demography	Sustainable Urban Mobility
• Service price • Vehicle fleet • Operating area • Vehicle size • Estimated Time of Arrival • Capital intensity • Operating costs	• Modal split • Mobility demand • Mobility preferences (Reliability, Costs, Comfort, Availability, Time, Flexibility, Reachability, Convenience, Privacy level, Experience, Sustainability) • Attractiveness of the service • Occupancy level	• Car ownership • Public transport offer • Total miles driven • Infrastructure • Population • Population density • Urban structure • Charging infrastructure	• Pricing Instruments • Costs for Parking • City tolls • Driving bans • Laws for person transport	• E-Mobility • Autonomous Driving • Connectivity • Fleet-management • Repair control • Damage handling	• Income structure • Level of Education • Age distribution	• Traffic flow • Emissions • Space • Traffic for Parking • Land Use • Noise • Use of Resources • Social Justice • Traffic safety • Consumption of resources

Build on the structure shown in table 5, the holistic interaction model was developed (Figure 1). The model has the objective to sum up the complexity of the holistic approach by focusing on the network level and its interaction. Furthermore it organizes and divides the network level in supply and demand, influencing factors that relate to Demography, City Characteristics, Technology and Regulatory and the evaluation criterion Sustainable urban Mobility.

Figure 1. Network level based Interaction Model



Using this qualitative expert study and the main influencing factors in the interaction of supply and demand of on-demand mobility services could be analyzed using the categorization process of the qualitative content analysis. It is recognizable, that especially regulatory impact factors have been mentioned and described across all relevant stakeholder groups. Furthermore different individual mobility preferences have been investigated, that have an impact on the usage of an on-demand mobility service. In this respect it is surprisingly, that the experts see the mobility preference reliability besides costs and comfort as the main trigger point for the usage.

4. Conclusion and Discussion

This qualitative research approach aims to explore the holistic system of supply, demand and potential, relevant influencing factors of new on-demand mobility services. A sample of experts from different stakeholder groups had been interviewed to capture different understandings and meanings related to the research problem. The results of the study are shown in a structure of variables and network levels (Table 5) and concluded in a holistic interaction model (Figure 1) that simplifies the complexity by concentrating only on the identified network level.

The provided structure of network levels and the related variables does not provide any information about the significance of influencing factors and their interactions. Furthermore, there are still open research questions regarding the prediction and modelling of the demand of new on-demand mobility services and their impact on changes in mobility behavior and modes in the introduced business area. In this respect future research should focus on system modelling using a *System Thinking* (See: Vester 2002) or *System Dynamics* (See: Forrester 1961) approach. Such research approaches have the possibility to model and simulate the variation of variables on the system and give the chance to identify, describe, and in the case of System Dynamics also measure their impact. As more data will be needed to set up the model, the results from this explorative, qualitative approach show directions of interactions and provide a sound starting point for system modelling.

The provided study is limited to the number of experts participating in the study (N=15) and their professional background. A greater sample with a higher variety of stakeholders could have increased the total number of variables. Besides the size of the sample, the spatial distribution of the interviewed persons is limited in most cases to the greater Munich area. In order to compare the results to another city or location it would be necessary to investigate another urban conurbation in order to be able to work out similarities and differences.

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