DEVELOPMENT OF A MODIFIED TECHNOLOGY ACCEPTANCE MODEL FOR AN INNOVATIVE CAR SHARING CONCEPT WITH SELF-DRIVING CARS

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Abstract
Mobility in Germany is changing due to economic, ecological, social and technological trends that lead to a major transformation of the environment in the future. At the present time, it can be assumed that one of the upcoming trends are self-driving cars that hypothetically become part of our daily mobility behavior in the long term. In this regard, the measurement of the factors for acceptance of a car sharing model with self-driving cars shall be analyzed within this paper.
User acceptance is considered as a basic prerequisite for the success of this innovative form of mobility. To develop a viable business model, a corresponding acceptance factor analysis on the customer side is required. Particularly, when innovations are designed for a broad audience, the characteristics of the product shall meet the diversified requirements of this market. The paper examines and compares classic technology acceptance models and defines, based on the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003), a tailored and modified model that incorporates the interaction of internal and external influencing factors, usage phases and time.

Keywords: Technology Acceptance Model, self-driving cars, car sharing, mobility, innovation.

JEL Classification: O33.

Introduction

The urban mobility behavior in Germany will significantly change in the upcoming years per current forecasts and adapt with new technology and digitalization to the changing conditions accordingly. Core developments, such as demographic changes and the accompanying adaptions in lifestyle, technological developments in the mobility sector as well as economic and environmental factors will affect the choice of transport modes. With a high share of individual motorized mobility (52%), followed by foot (22%) and cycling (13%), public transport plays a minor importance (12%) in the modal split in Germany (Karlsruher Institut für Technologie, 2015).

In the same period, an increase of 37% in car sharing can be noted in 2015 compared to the previous year, which highlights the attractiveness of this form of mobility (Bundesverband CarSharing e.V., 2015).
Along with the technological progress in the field of autonomous driving, car sharing with self-driving cars could become a future transport mode - taking a higher priority over the classical car sharing system and thereby even individual motorized as well as public transport.

1. Car sharing with self-driving cars

The idea of self-driving cars in a car sharing model is based both on the classical model of taxi companies in Germany, as well as on the free-floating car sharing model, which is characterized by flexible stations of return. With many of these providers, customers have the opportunity of ordering a vehicle via a smartphone to their location or to locate a vehicle in the vicinity while the whole process from ordering to paying and returning the car can be supported by an app.
Unlike the current car sharing system with the necessity to drive the vehicle, the idea of a model with self-driving cars reveals a much higher flexibility: vehicles are distributed automatically according to the transport flow analysis throughout the city center to reduce the waiting time for customers to a minimum. At the same time, the model may also, upon request of customers, integrate the function of a smart carpooling solution. This would mean that customers will take a small detour to reduce their own travel costs, while automatically being "pooled" through the system with other customers in the vehicle. Furthermore, autonomous vehicles themselves are already advantageous compared to private motorized transport modes:

- Increased transport efficiency by reducing congestion (Bundesministerium für Verkehr und digitale Infrastruktur, 2015),
- Increased road safety (Bundesministerium für Verkehr und digitale Infrastruktur, 2015),
- Reduction of emissions due to carpooling of passengers in a vehicle with the same or similar direction (Greenblatt and Shaheen, 2015) and
- Increased comfort level with respect to the public transport (door-to-door mobility, seats, increased privacy) and the classic private motorized transport (no intervention required, travel time can be used for other purposes).

Summarizing the advantages, the use of self-driving vehicles in a car sharing model, offer an economic, ecologic and personal advantage while ensuring full flexibility on the customer side.
A car sharing model with self-driving cars could hypothetically be considered in the future for not only replacing individual motorized traffic, but also public transport.
Nevertheless, self-driving vehicles in car sharing model simultaneously bear several challenges and obstacles, which could lead to problems or even failure of such a business model. These challenges include technical, operational, political and social aspects. While the social challenge is minimized to the factor of acceptance in this paper, the technical challenge refers to the vehicles themselves and less to the car sharing model. The political challenge is currently strongly determined by the legislation, which requires an adjustment according to the technology and the possibilities of autonomous cars in order to allow a large-scale deployment and expansion. Ultimately, the challenge lies in the operation and maintenance of self-driving vehicles in a car sharing model and the associated services (app).

The acceptance of potential customers of such a car sharing model in German cities is the basis for success. Without the analysis of customer acceptance and the consideration of specific factors, the model cannot be fully elaborated. For a better determination of the acceptability and its influencing factors, a classic technology acceptance analysis is required, which is outlined below.

2. Classic acceptance model frameworks

The literature suggests numerous models for the analysis of acceptance and the consideration of various influencing factors. The models describe the basis for the measurement of acceptance, but can mostly, due to the general and non-specific themes approach not be regarded as an exhaustive list of influencing factors.

In a first step, it is necessary to clarify what the term “acceptance” means and how it is used in this paper. It is already mentioned that acceptance describes a critical success factor for innovations. Furthermore, technology acceptance is understood as a psychological process that starts with pure interest in an innovation and leads toward the (daily) use of this innovation (Kollmann, 1998; Jockisch, 2010). Consequently, acceptance can be defined as a conglomeration of evaluation and affect.

For years, researchers have tried to model and measure technology acceptance. One of the first fundamental models is the "theory of reasoned action" generated by Fishbein and Ajzen (1975) and is used to display influence and trigger factors of a particular behavior. The theory has been altered by the contemplated scientists a few years after the publication and has been published again as the "theory of planned behavior". This theory describes an extension and includes the definition of influencing factors. The theory of planned behavior is considered as one of the most central acceptance models of today’s research (Fishbein and Ajzen, 1975).

The advanced theory by Ajzen and Fishbein (1975) is based on three behavioral factors:

- Attitude,
- Subjective norm and
- Perceived behavioral control.

The rational model is based upon a combination of these factors with maximum expression of a subsequent behavioral intention and the behavior itself.

Besides the classical acceptance model by Ajzen and Fishbein (1975), several other scientists have conducted research in the area of acceptance, while these models have been mostly adjusted to explain specific applications. A selection of commonly accepted models will be introduced in the following to extract key messages and to define a modified, topic-specific acceptance model therefrom.

Another acceptance model in the field of innovation is described by Davis (1989) and known as the “Technology Acceptance Model” (TAM). This model is based on Ajzen’s and Fishbein’s (1975) considerations of the theory of planned behavior. Davis (1989) emphasizes the user in his technology acceptance model to analyze the perceived usefulness and the perceived ease of use of an innovation accordingly. Based on this model, Davis along with Venkatesh (1996) proposed an extended model called TAM 2 that incorporates external influences on the perceived usefulness and the perceived ease of use of the technology. In a further adaptation of the model, the so-called TAM 3, Venkatesh and Bala (2008) focus on the assessment of the perceived ease of use, which is determined by six influencing factors (Jockisch, 2010):

- Confidence,
- Perception of external control,
- System anxiety,
- Playful use of the system,
- Perceived enjoyment and
- Ease of use.

The updated technology acceptance model incorporates again some aspects of Fishbein's and Ajzen's (1975) research and describes one of the most popular models for explaining the personal shaping of acceptance. Yet this model, as it is the case with most other models, needs to be critically considered, as it describes a simplified process of shaping acceptance and can hardly be reduced to the definition of external and influencing factors (Becker, 2016).

The acceptance model by Degenhardt (1986) is a model that was specifically designed to measure the utility of screen texts. The model can nevertheless be applied to other innovations. Degenhardt (1986) explains the formation of acceptance by three key factors: system configuration (form, function and utility of the innovation), task characteristics (importance and frequency in use) and user characteristics (skills or motivation).

In contrast to this model, the acceptance model of Kollmann (1998) focuses on peripheral influences on macroeconomic, socio-cultural, technological and political-legal level. The highly complex model simultaneously considers acceptance as a dynamic process that includes influencing factors in different stages. Kollmann (1998) developed the model for the analysis of acceptance of innovative goods and systems.

One of the most recent technology acceptance models, called the "Unified Theory of Acceptance and Use of Technology" (UTAUT) was developed by Venkatesh et al. (2003) and merges the strengths of different previous models, i.a. TAM, TRA and TPB. The theory is based on four latent key factors: performance expectancy, effort expectancy, social influence and facilitating conditions. Additionally, the model foresees influences by gender, age, experience and voluntariness of use.

Summarized, the following three key model components can be derived from the examined models that determine a person's acceptance towards an innovation: external factors, individual factors and phases or stages of use.

The listed individual model building blocks are composed of external as well as individual influencing factors, which can lead to different behavior and ultimately to acceptance throughout various phases of use. It is striking, however, that all studied models above are two-dimensional and cannot represent the direct relationship between influencing factors, the time, and the respective acceptance phase.

3. Modified acceptance model

The modified acceptance model shall be theme-specific for the purpose of responding to the supposed individuality of the acceptance of self-driving cars in a car sharing model. To this end, the individual as well as the external influences are combined and lead to a different behavior in different stages of use and ultimately to user acceptance.

In order to determine influencing factors of self-driving cars in car sharing model, motives for selecting particular modes of transport are considered. The Traffic Club of Germany (Verkehrsclub Deutschland) identified three top motives for the choice of transport mode through a survey with 2,200 participants in 2014: accessibility of places and locations, costs and reliability or punctuality (VCD, 2014a).

Other reasons for choosing a particular transport mode are the motives of the total driving time, the flexibility and convenience. The environmental performance, privacy and security are less relevant motives according to the survey (VCD, 2014a).
Examining the reasons for the choice of the individual transport modes, the advantages and disadvantages are clear and thus show the differences from a customer perspective between the individual transport modes. Public transport (bus, train, tram, etc.) and motorized individual transport (usually: car) are compared by using the development of a simplified network diagram with the motives for selecting the respective transport mode. The data is based on surveys from Germany and Austria that analyzed the motives for using the train, the public transport in general and cars. The weighting of the individual values is done on a nominal scale (1-6), that is determined by the relation of the respective percentage of value. The number six represents the greatest severity, while number one expresses less motivation of using a specific means of transport. The survey results were summarized by seven core motives for modal choice and illustrated in a network diagram below (figure no. 1): comfort, process of the ride, simplicity, accessibility and availability, travel time, costs and flexibility.

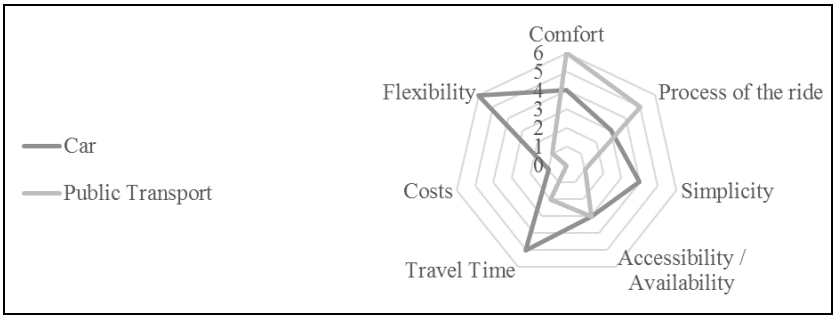

Figure no 1: Motives for the choice of different transport modes
Source: own figure, based on IMAS International, 2015; VCD, 2014a; VCD, 2014b

It should be noted that the statistics shown above describe a summary, but are highly dependent on the travel time and travel purpose (e.g. business travel, vacation, etc.).
The network diagram illustrates the strengths and weaknesses of the respective transport modes (public transport vs. car). It is obvious that different customer groups with different travel purposes influence the decision of transport mode.
Derived from the motives for one or the other transport mode, a model is developed that takes all influencing external and internal factors into account for customers. The modified model shall incorporate different user phases and that could lead to the use an innovative means of transport (acceptance): self-driving cars in a car sharing model.
The three stages that are traversed by a customer that start with attention and end with the use of a new technology are presented in Kollmann's acceptance model (1998). These stages shall be incorporated in the modified acceptance model. In the so-called recruitment stage, the potential customer has not yet tested the product itself, but has drawn attention to self-driving cars through media and society that lead to an attitude towards this innovation. This phase can further be clustered according to the AIDA model: attention, interest and desire (Koschnick, 1983; Walker, 2014).

The penultimate stage of the AIDA model (desire), ultimately leads to the phase of action. If the user is satisfied during the action phase and if all personal motives in regard to personal mobility are met the action phase is followed by the regular usage phase, which implies a repeated use. The extension of the AIDA model corresponds with less itemized steps to the greatest possible extent to the model of Kollmann (1998). It includes, in addition to “attention, interest, desire and action”, also satisfaction and conviction (Fitzgerald and Arnott, 2000).

The modified acceptance model of the authors considers, along with the above described individual phases, also the timeframe. Hence, time is a critical success factor for the creation of acceptance. Furthermore, the modified acceptance model provides a three-dimensional structure, where the (potential) users passes the different phases in order to reach the level of acceptance, while he is simultaneously affected by individual and external influencing factors.

As already mentioned at the outset, the UTAUT model is used as the basis for the determination of influencing variables and the general acceptance level. The "voluntary" factor is not further investigated because, in the implementation of such a car sharing model with self-driving cars, excessive, existing mobility alternatives are assumed. The aspect of "supporting circumstances" is broader defined than the original definition of Venkatesh et al. (2003). The individual factor "experience" is replaced by the term "knowledge/ information", because of the current lack of existence of a car sharing model with self-driving cars. Instead, the hypothesis is made that already information and knowledge about this technological innovation could positively influence the level of acceptance.

If the subdivision of individual and external factors is followed by a subsequent distribution of the influencing factors, the investigation of the above-mentioned surveys reveals that all identified motives for the choice of transport are found in the UTAUT model under other or generic terms. Accordingly, the modified acceptance model provides for a three-dimensional structure, which incorporates the time factor, represents the level of acceptance and, in the third dimension, considers the influence of individual and external factors. In doing so, influencing factors are considered in the setting and action phase before it leads to the final status, the acceptance. The figure no. 2 summarizes the modifications of the UTAUT theory and the influence of further existing acceptance models to a new modified acceptance model:

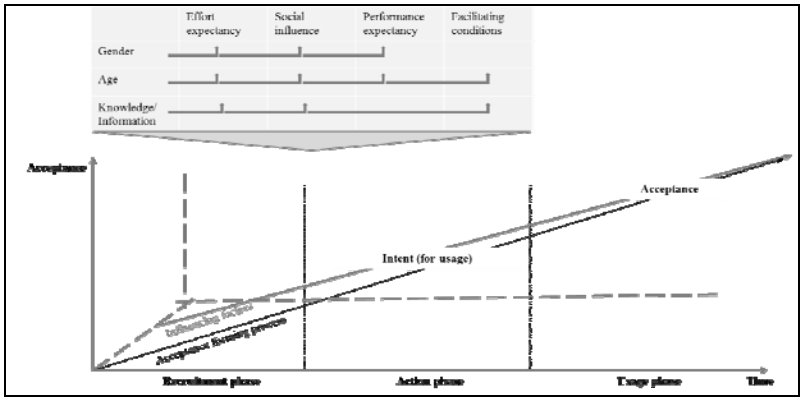

Figure no 2: Modified Acceptance Model
Source: own figure

4. Summary and outlook for the measurement of acceptance of self-driving cars in a car sharing model

Self-driving cars in car sharing model represent a sustainable mobility concept in Germany per the hypothesis of the authors that takes the changing environment into account and implements most motives from a customer perspective regarding transport choice.

Acceptance describes a fundamental criterion, indicating the success of such a model. Since acceptance cannot be easily measured due to the lack of implementation, the authors have developed a modified acceptance model, based on existing models (predominantly the acceptance model by Venkatesh et al. (2003). The time factor is a central criterion in the development of acceptance and is incorporated in the three-dimensionality model that displays a construct of external and internal influencing factors.

This model represents the basis for the measurement of influencing factors of self-driving cars in car sharing model. Based on this model, hypotheses shall be developed that are then in a second step to be operationalized for measurement. The operationalization of the modified acceptance model can be conducted through empirical research. The method of structural equation modeling could be applied to not only measure the latent variables, but also identify their dependencies. In a last step, the superordinate hypothesis of the acceptance of self-driving in a car sharing model in Germany is then to be confirmed or refused, revealing the key factors for acceptance.

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