Driven by Change: Commercial Drivers’ Acceptance and Perceived Efficiency of Using Light-Duty Electric Vehicles in Germany

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Abstract

In this paper, we examine to what extent commercial drivers accept the substitution of conventional cars with light-duty e-vehicles (LDEVs) by conducting a cross-sectional survey at Deutsche Post, a major German postal delivery service provider. Specifically, we explore drivers’ acceptance from two perspectives. First, we investigate whether drivers are more satisfied with the LDEVs than with the conventional vehicles. Second, we question whether the EVs increase drivers’ perceived efficiency. Combining these two perspectives, we show that the greater the drivers’ overall satisfaction with LDEVs, the higher is the drivers’ perceived efficiency. We prove this by means of latent measures, such as perceived usefulness and perceived ease of use, using adaptations of Davis’ Technology Acceptance Model and Rogers’ Diffusion of Innovation Theory to form our Unified Technology Acceptance Model. Findings suggest that, on average, drivers are slightly more satisfied with their assigned LDEVs than with the available conventional cars. If drivers were able to choose their preferred vehicles, the majority of them would favor LDEVs. We detect statistically significant patterns of latent measures affecting perceived usefulness and perceived ease of use of LDEVs. While this paper focuses on German delivery service employees, the methodology presented here could easily be applied to any enterprise in the growing logistics sector electrifying its car fleet. Hence, our contributions are valuable for transportation research, and more specifically, to all potential commercial EV drivers, e.g., our insights might be relevant for approximately 500,400 drivers employed in the German logistics sector alone.

Keywords

Electric vehicles (EVs), Driver acceptance, Commercial EV fleet, Perceived efficiency, Germany, Technology Acceptance Model

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1. Introduction

As a result of tightening urban air quality legislation and escalating amounts of parcel shipments, logistics sector is introducing electric vehicles (EVs) in city operations in Europe. In particular, the accessibility of European inner-city districts for delivery vehicles has been limited by recently established low emission zones (European Union and Sadler Consultants 2015). The European Commission’s (2011) White Paper on European transport demands that city logistics be CO₂-free by 2030. By 2050, conventionally fueled cars (internal combustion engine vehicles, ICEVs), i.e. both passenger as well as commercial vehicles, will have to be banned from city centers (European Commission 2011). In addition to the aim of CO₂-free logistics, the volume of postal shipments is growing due to increasing internet commerce. As a result of these developments, the number of electric vehicles (EVs) used for city logistics is on the rise (Browne et al. 2011; Visser et al. 2014) and with that also the number of employees driving EVs.

The economics, innovation, and social sciences literature is rich in studies dealing with the economic and environmental facets of electrifying commercial light-duty vehicle fleets (Visser et al. 2014). The topics covered range from combining routing constraints, speed profiles, energy consumption, and vehicle ownership costs to examining the competitiveness of electric delivery trucks (Davis and Figliozzi 2013) to procurement intentions (Kaplan et al. 2016). In particular, such electrifying efforts have been made in the German logistics sector, partly due to the sustainable energy transition in Germany. The potential of commercial EVs to reduce pollutant emissions in Germany has been assessed in various studies (Ketelaer et al. 2014; Jochem et al. 2015; Soldado et al. 2015).

Although the EV literature is very diverse, there is one critical gap in the literature concerning the advantages of light-duty electric vehicles (LDEVs)¹ in logistics operations, particularly from the drivers’ perspective. Therefore, we investigate whether and to what extent drivers accept the substitution of ICEVs with LDEVs at the major German postal delivery service company Deutsche Post.² Since 2012, Deutsche Post has gradually been electrifying its vehicle fleet, using various LDEV models with a few ICEVs kept in reserve. The drivers in our study have been using LDEVs on a daily work basis for 3-4 years, which allows us to analyze long-term user acceptance in courier-express-parcel (CEP) operations.

We developed a paper-based questionnaire, connecting the Technology Acceptance Model and its successors (TAM; Venkatesh and Davis 2000), the Diffusion of Innovation Theory (Rogers 2003), and

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¹ This study focuses on the commercial application of EVs. Therefore, in the following, ‘EVs’ are defined as commercially used EVs in the sense of EVs used as work tools for logistics purposes and, if clearly distinguishable, as LDEVs, i.e. non-passenger EVs. Kaplan et al. (2016, p. 12) refer to these LDEVs as “electric commercial vehicles” (ECVs).

² According to its homepage, “Deutsche Post is Europe’s leading postal delivery service provider”; it belongs to the Deutsche Post DHL Group (Deutsche Post 2017).
learning effects from EV field trials in Germany with the electrification of a delivery service fleet in the German currier, express and parcel (CEP) sector. Our adaptation of existing theories, which we name the Unified Technology Acceptance Model (UTAM), captures the context of EV acceptance in the workplace. The research objective is to assess whether the introduction of EVs into the delivery fleet brings benefits from the drivers’ perspective, interpreted as efficiency gains. We hypothesize that the greater the drivers’ overall satisfaction with LDEVs, the higher is the drivers’ perceived efficiency. Thus, the overarching research question is: how does the drivers’ satisfaction with the EVs affect drivers’ efficiency? More precisely, we define efficiency as working more smoothly, not as numbers of parcel and letters delivered. Since we cannot measure real efficiency due to privacy regulations and also because Rogers’ (2003) theories involve perceived measures, we measure drivers’ self-stated perceived satisfaction and perceived efficiency with the EV during a usual workday (lower right corner in Figure 1, blue and green edging). Thus, our two specific research questions are: (1) Are the drivers more satisfied with the EVs than with the ICEVs? (2) Do the EVs increase drivers’ perceived efficiency? Regarding (1), we determine the influential factors driving satisfaction with EVs. We define the drivers’ satisfaction with the EV as perceived ease of use combined with several socio-technical aspects. Next, we split the second research question into two: (2a) What is the drivers’ perceived efficiency when using an EV compared to using a ICEVs? And: (2b) What are the drivers’ perceptions of their efficiency change due to a change in work equipment (i.e. vehicle technology)? Therefore, we define drivers’ perceived efficiency as perceived usefulness, which relates to Rogers’ (2003) relative advantage and to the TAM, in which perceived ease of use has a positive effect on the perceived usefulness. Based on these research questions, we designed the UTAM and a questionnaire.

While this paper focuses on German delivery service employees, the approach presented here could easily be adopted and applied to any enterprise in the growing logistics sector (planning to) electrifying its car fleet. Our three contributions are (1) an exploratory methodological approach that allows us to extend existing theory and to close some of the existing gaps in the literature, (2) EVs lead to perceived efficiency gains for commercial drivers, and (3) perceived satisfaction leads to EV acceptance. Hence, our contributions are valuable for the transportation research area, and more specifically, to all potential commercial EV drivers and relevant stakeholders. The remainder of this paper is structured as follows. The relevant literature is outlined in section 2. Section 3 introduces a new hybrid model of technology acceptance, the constructs of which for conducting a cross-sectional survey are described in section 4. The results of a principal component analysis (PCA) and econometric regression analyses are reported in section 5 and discussed in detail in section 6. Section 7 concludes.

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3 For example, with the EV, I get more done in less time than with the ICEV.
4 Insights from our study can potentially transferred to approximately 500,400 drivers employed in the German logistics sector (Bundesagentur für Arbeit 2014).
2. Literature review

2.1 Diffusion of Innovation Theory and TAM in the organizational context

Employees have long been recognized as instrumental to technology acceptance in an enterprise (Davis 1986, 1989, 1993; Davis et al. 1989; Davis and Venkatesh 1996; Venkatesh and Davis 2000; Venkatesh et al. 2003), using the TAM and its various extensions (TAM1-3; The Unified Theory of Acceptance and Use of Technology, UTAUT). Generally, with the introduction of new technologies in businesses, underuse or reactance such as non-acceptance, and evasions might take place among employees (Holden and Karsh 2010). In order to avoid such issues, studies show which factors influence technology (non-)acceptance. For this purpose, the original TAM has been developed further and extended since its inception (TAM2-3). Rogers’ (2003) Diffusion of Innovation Theory also has an organizational dimension. According to his theory, in an organizational context, technology acceptance by employees is a question of power, materiality, structure, and arrangement (employer-employee relationship). The literature has been applying the TAM and the Diffusion of Innovation Theory separately to investigate the user acceptance of private as well as commercial EVs.

2.2 User acceptance of privately used EVs

The various efforts in the literature to assess user acceptance of private EVs (Rezvani et al. 2015) range from holistic theoretical models based on socio-economic (Sovacool 2017) and socio-technical approaches (Moons and Pelsmacker 2012) to behavioral and experimental economics using discrete choice experiments (Hackbarth and Madlener 2013). In addition, short-term EV field trials have been combined with questionnaires based on TAM (Dudenhöffer 2013a; Fazel 2014), or with the Diffusion of Innovation Theory (Peters et al. 2011), or with psychological evaluations (Cocron et al. 2011). These EV acceptance studies target EV purchase intentions and willingness to pay (Hidrue et al. 2011; Hackbarth and Madlener 2016), psychological barriers of range restrictions (Franke et al. 2012; Franke and Krems 2013), socio-technical barriers of EV deployment (Steinhilber et al. 2013), consumers’ preferences of and interaction with EV charging infrastructure (Hardman et al. 2018), and EV purchasing demand models (Glerum et al. 2013). Some efforts also target EV acceptance directly, e.g., Cocron et al. (2011) using the four pillars acceptance, mobility, human-machine interaction, and traffic

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5 With the implementation of personal computers at the workplace, Davis (1986) developed the TAM considering aspects such as mandatory use. Earlier efforts to explain attitudes and user behavior were made by Fishbein and Ajzen (1975), Ajzen and Fishbein (1980) and later by Fishbein and Ajzen (2010), using the Theory of Reasoned Action (TRA) and the Theory of Planned Behaviour (TPB).

6 The concept of agency, i.e. being able to decide what to do and what not, does not apply in this case. On the contrary, drivers are caught in a particular arrangement, i.e. the adopting employee has no influence on the innovation decision.
and safety implications for a psychological evaluation of the MINI E in private use. Some efforts directly compare EVs with ICEVs. For example, based on Rogers' (2003) *perceived relative advantage*, Peters et al. (2011) asked different consumer groups to answer 16 items representing advantages and disadvantages of EVs and ICEVs separately in order to ensure that both vehicle types are evaluated independently. However, this approach mainly focuses on car characteristics that relate to car ownership (purchase price, maintenance costs, choice of various models) or service and refueling networks. This approach does not represent the multitude of car characteristics that are important to delivery service vehicle drivers. For example, in our case the drivers are faced with the differences in usage of EVs’ automatic gearboxes vs. ICEVs’ manual gearboxes. Such differences may result in time savings, since the changing of gears requires movements of the right hand and thus takes up time, as opposed to automatically changing gears (where pressing down the accelerator or brake pedals with one foot suffices). While many studies address EV acceptance or purchase decisions of private users, there are few investigations of the commercial, operation side of EV acceptance. There are studies that compare EVs in different consumer groups or fields of applications. For example, Gnann et al. (2015), based on German 500 driving profiles, find that EVs are better suited in commercial applications than in private use because of the regularity of their driving patterns. We find that there remain research gaps on the latent process of the eventual (technology) acceptance by employees regarding their new work equipment in the form of EVs. Thus, empirical evidence for commercial EV applications is still scarce to date.

### 2.3 User acceptance of commercially used EVs

For a sustained EV and charging infrastructure diffusion, EV deployment in commercial applications is essential. Thus, it is crucial to assess barriers hindering EV deployment in commercial applications, and specifically in the CEP sector. Therefore, numerous studies deal with investment decision makers or fleet managers and their perception of EVs in their specific application area, however, neglect the end-user, i.e. the EV driver (Steinhilber et al. 2013; Burs and Roemer 2015; Jonuschat et al. 2012; Globisch et al. 2018b; Globisch et al. 2018a). A very detailed model on EV procurement decisions has been developed by Kaplan et al. (2016). However, they measure operational ease of EV use by asking the decision makers, which may or may not coincide with the *drivers’* perceived operational ease of use. Likewise, a review by Jonuschat et al. (2012) of all e-mobility users’ acceptance studies undertaken in Germany before 2012 illustrates the neglect of a crucial part of acceptance, i.e. the acceptance by the end-user, i.e. the driver. This is partly because *EVs as work equipment* have not been in operation long enough in order to measure specific acceptance levels in commercial applications. Therefore, mostly decision makers and fleet managers, who decide whether to electrify the company fleet or not, have been chosen as interview partners or to answer questionnaires (Burs and Roemer 2015; Globisch et al. 2018b). Thus, there is a lack of knowledge on how the non-private end-users, i.e. the drivers of commercial EVs, adapt to a change in driving technology. As Morton et al. (2011) and BMU (2011b) highlight, an EV acceptance study in a commercial context implies a higher degree of complexity than
a study in a private usage context would, i.e. the impact of psychological and sociological influences of the workplace on user acceptance should not to be underestimated. Several qualitative studies investigate user acceptance by commercial EV drivers; whereas only a few studies apply quantitative methods (e.g. Globisch et al. 2018a for passenger EVs in commercial fleets).

Socio-economic research has been conducted using field trials of EVs deployed in goods traffic; one of these field trials took place at a delivery base of Deutsche Post in cooperation with Volkswagen (VW) using the VW E-Caddy (BMU 2011a, 2011b). The research included guided interviews with the drivers, and its qualitative results inform the model developed in our study. Axsen et al. (2013) investigate the role of social influences and drivers’ preferences for EVs in the workplace; however, it remains unclear as to what extent the drivers are dependent on EVs to fulfill their tasks. Similarly, many studies analyze employees’ EV acceptance in the case where EVs are used for business trips (Deffner et al. 2012). However, using an EV for a business trip is quite different from using the EV several hours a day for delivery service purposes. Therefore, previous studies miss covering the context of a real production environment in delivery services. A study close to our context is Peters and Hoffmann (2011) because the authors assessed with focus groups of potential commercial EV users in Germany in 2010 the advantages and disadvantages of EVs as well as concepts and business models of EV fleets. Overall, the respondents evaluated EVs positively. Meanwhile, eight government-funded e-mobility model regions installed between 2009 and 2011 fostered EV efforts in Germany (Hamburg, Bremen-Oldenburg, Berlin-Potsdam, Saxony, Rhine-Ruhr, Rhine-Main, Stuttgart, and Munich). Within these model regions, commercial EV projects enabled Globisch and Dütschke (2013) to clearly differentiate between fleet managers and drivers based on qualitative interviews and standardized short-questionnaires (n < 300 each, data set of n < 900 across all projects). Further, Globisch et al. (2013) evaluate perceived usefulness of EVs and vehicle characteristics and differentiate between 50 private and 50 commercial users across the model regions. A comparison of 145 EV users in the model regions (22% predominantly commercial use, 40% predominantly private use) with 969 online survey respondents indicates that the higher the users’ experience level is, the more positively EVs are being evaluated (Schneider et al. 2014 using Rogers’ Diffusion of Innovation Theory). Mean values of acceptance among 302 pure drivers (i.e. not decision makers regarding vehicle adoption) within these model regions were calculated by Plötz et al. (2014). A more general overview of EV user acceptance in the model regions is given by Dütschke et al. (2012). A recent picture of EV perceptions in the whole of Germany is provided by Hacker et al. (2015). Wikström et al. (2014) provide a socio-technical approach on EV utilization in commercial fleets in Sweden, a country with substantial commercial EV deployment; unfortunately, the study does not show measurement items used for analyzing users’ perspectives. Thus, we rely on studies undertaken in Germany, such as Ehrler and Hebes (2012), which is closely related to our study. The authors scrutinize the acceptance of EVs by drivers in the CEP sector with some of the drivers working for Deutsche Post in Berlin in 2010-2011. Even though they applied empirical interview methods for finding user acceptance, the limited sample size (n = 10 in t0 and n = 9 in t1) restricts a generalization of results. Yet,
their study serves as a reference for drivers’ first impressions and future expectations on EVs in the CEP sector and especially at Deutsche Post. Empirical results from guided interviews alongside the aforementioned VW E-Caddy field trial at a Deutsche Post delivery base in 2011 show a positive reaction of delivery personnel (BMU 2011a). After initial wariness, drivers reacted positively towards the loss of changing gears, noiseless driving (even though, after some time in operation, drivers asked for a horn with a friendly sound, since pedestrians do not hear the almost noiseless EV, something the European Union has made obligatory after 2019; European Parliament and the Council of the European Union 2014), and a pleasurable driving experience. Furthermore, the field trial showed that for ready-to-order, EVs’ maintenance and service are crucial for flawless operations in the CEP sector. Another report on the same field trial highlights how technical issues are perceived by drivers, using guided interviews (BMU 2011b). These technical issues, which are perceived as important by drivers, enter our model. Overall, drivers perceived the EV as an improvement of operations as well as of general working conditions. To sum up, none of these studies in the commercial sector has regarded drivers’ acceptance in the long term. Our study addresses this gap by measuring quantitatively the end-users’ long-term acceptance with respect to commercial EVs 3-4 years after EV implementation.

3. Methodology

3.1 Four core constructs of the TAM

We base the core of the UTAM on the original TAM (Davis 1986, 1989; Davis et al. 1989), i.e. a positive attitude toward using leads to actual usage, and thus to an acceptance of the technology (right hand side in Figure 1). In turn, attitude toward using is directly determined by the influences of perceived usefulness (PU) and perceived ease of use (PEOU) (Wissmann 2013; Davis et al. 1989). In addition, PEOU also impacts PU. Therefore, PEOU directly and indirectly impacts the attitude towards using. A meta-analysis of 60 TAM studies shows that a positive PEOU tends to positively influence PU (Schepers and Wetzels 2007).

3.2 Research Design: Modifications to existing constructs resulting in UTAM

Even though the TAM and its extensions – combined with field trials attempting to mimic daily usages for private users – have been applied to private use of passenger EVs (Dudenhöffer 2013a) or in the context of EV car sharing (Fazel 2014), methodologically, the TAM and its successors do not capture the entire context of the acceptance of EVs in the workplace. First, while the original TAM clearly differentiates between either voluntary or mandatory use in the workplace and roots in the intention to use the new technology, in our study it depends on the specific situation at the CEP delivery bases. Therefore, we cannot clearly state whether the use of EVs is voluntary or mandatory (i.e. depending on
whether drivers can choose between an EV and an ICEV). Second, following from that, some TAM constructs cannot be used in our study, since the scope for decision-making and the scope of action do not align in the mandatory use of EVs (BMU 2011b). Brown et al. (2002) suggest a model applied in acceptance of information systems research. Yet, the model merely focuses on the social side, i.e. attitudes and beliefs, and hence, does not grasp the technical side of system use. In contrast to TAM research, we let drivers compare the old technology (ICEV) with the new one (EV). We refine the determinants of the TAM constructs, especially for perceived ease of use. Finally, the TAM omits measures such as experience and affect variables that literature finds important for studies at the workplace. While the TAM2 connects the social influence processes such as subjective norm and intrafirm image with experience, the TAM3 and the UTAUT, as also Sovacool (2017) discusses, focus on performance measures such as effort expectancy and output quality that could be essential to our purpose. Yet, German privacy regulations interfere with measuring work performance. From these theoretical as well as practical thoughts on how drivers perceive and evaluate the substitution of ICEVs with EVs, we develop the UTAM (Figure 1 and Table B.1). The UTAM assumes that when substituting ICEVs with EVs, there will be a change in drivers’ perceived efficiency in the long term. In addition, it assumes that the degree of drivers’ happiness or satisfaction with the EV determines the degree of drivers’ perceived efficiency, or vice versa. Further, PEOU and its further determinants determine happiness or satisfaction with the EV, whereas perceived PU and its further determinants determine efficiency. Figure 1 shows the UTAM and its construct definitions of drivers’ perceived efficiency (blue edging) and drivers’ perceived satisfaction (green edging). The pluses and minuses on the arrows describe the hypothesized direction of effects.

7 In any case, CEP drivers are dependent on some kind of light-duty vehicle, either EV or ICEV, to fulfill their tasks.
Figure 1: UTAM explaining EV acceptance and perceived efficiency by commercial drivers in the German logistics sector

Notes: (+) and (+/-) attached to the arrows explain the hypothesized direction of effects. Blue edging: drivers’ perceived efficiency. Green edging: drivers’ perceived satisfaction.
Source: own illustration based on TAM2 (Venkatesh and Davis 2000).

In short, the UTAM is an adaptation of the TAM2-3 and the UTAUT, using the Diffusion of Innovation Theory (Rogers 2003) as well as qualitative insights from German EV field trials, which allows us to measure the perceived effects the electrification of a delivery service fleet has on the drivers. More specifically, we structure the UTAM in three steps. First, in order to model acceptance effects at the organizational level (i.e. effects among employees), we use the measurement scales of the TAM2 of Venkatesh and Davis (2000), the TAM3 of Venkatesh and Bala (2008) and the Unified Theory of Acceptance and Use of Technology (UTAUT, Venkatesh et al. 2003). Second, for the modeling of the acceptance effects at the technical level (i.e. effects among users due to a change in technology), we use, next to the TAM or TAM-related measurement scales of the most recent TAM studies by Dudenhöffer (2013a, 2013b) and Fazel (2014), well-proven scales on private EV use and EV procurement intentions. These measurement scales were developed by Globisch et al. (2013), Bühler et al. (2011), Cocron et al. (2011), and Peters et al. (2011), who also base their models on Rogers (2003). For example, we follow Peters et al. (2011) and replace the TAM’s subjective norm by social norm. Finally, to summarize these acceptance effects, we theorize accordance with the UTAUT (Venkatesh et al. 2003), that two theoretical concepts summarize our research questions: drivers’ perceived satisfaction (PEOU-related) and their perceived efficiency (PU-related). We verbalize the theoretical concepts with well-proven multi-item measurement scales taken from the cited literature. In Appendix A we describe the constructs loading on PU and subsequently those loading on PEOU.

3.3 Distinction between PU and PEOU

The distinction between PU- and PEOU-related EV characteristics appears to be straightforward for pure handling of the vehicle (driving and charging). However, often a clear allocation of EV characteristics (in comparison to ICEV characteristics) to PU or PEOU seems to be problematic. For example, in comparison to ICEVs’ rather blaring engine noises, EVs hardly emit any engine noise at all.

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8 Already Davis (1986) faced the challenge of allocating the consequences of using the technology to either PU or PEOU. He therefore formed the construct perceived output quality loading on PU, which describes to what extent the employees trust the new technology to deliver the required quality (Venkatesh and Davis 2000). In this case study, we cannot measure the real output quality, real efficiency, or output quality. We could have defined output quality as the number of delivered parcels over time. Nevertheless, this measure is influenced by numerous external factors, such as route characteristics (e.g., route length, number of parcels, traffic density, and number of parcels per recipient). Therefore, we do not include the construct perceived output quality in our model. Similar argumentation applies to job relevance (Venkatesh and Davis 2000).
On the one hand, the noiselessness of the EVs during usage (except tread noises of the tires) seems advantageous to the drivers (BMU 2011b). On the other hand, the noiselessness of the EVs during usage requires an elevated concentration level by drivers, as it might happen that other traffic participants fail to hear the EV, e.g., when the EV approaches pedestrians from behind. We allocate this aspect item to \( PU \).\(^9\) Based on these interpretational complications, we opt for an allocation of technical aspects to \( PU \) in order to highlight the economic character of this study. Correspondingly, we let drivers evaluate the technical differences between EV and ICEV through the scale of \( PU \). This reasoning can also be found in Rogers’ (2003) work: the construct \( PU \) overlaps with Rogers’ criterion of relative advantage, whereas \( PEOU \) overlaps with his criterion of complexity (Wissmann 2013; Moore and Benbasat 1991). In addition, Davis (1986) suggests considering \( PU \) as utility and \( PEOU \) as costs of new technologies. Therefore, we consider \( PU \) as a factor of happiness or satisfaction with the EV. In turn, we view \( PEOU \) as ‘with the EV, I get more done in less time than with ICEV’ which we denominate as a drivers’ perceived efficiency (change). Due to this reasoning, we interpret \( PEOU \) itself and all constructs loading on \( PEOU \) as drivers’ happiness or satisfaction with the EV, whereas we interpret \( PU \) itself and all constructs loading on \( PU \) as drivers’ perceived efficiency.

Apart from technical matters, non-technical issues also determine the degree of \( PU \), i.e. to what extent the EV contributes to environmental protection (Dudenhöffer 2013b). Thus, we also include items on the ‘greenness’ of the EV (\( PU\)-environmental in Table B.1).

4. Survey design

4.1 Multi-item questionnaire based on EV acceptance studies

Our UTAM, the Unified Technology Acceptance Model, consists of constructs with several scales, so that the model results in a multi-item questionnaire. We base all items used on EV acceptance studies in both the private as well as the commercial context. Therefore, we adjusted the item wording to fit the context of LDEVs, as shown in Table B.1. In doing so, the items represent advantages and disadvantages that have been identified as crucial for EV acceptance in Germany (Peters et al. 2011). Where a direct comparison of EVs and ICEVs is necessary, it is stated so in the instructions or the item itself. In cases where drivers have not used ICEVs for a long time, the study faces retrospective limitations.\(^{11}\) More specifically, we gave drivers a list of general \( PU \) questions, followed by a list of EV-specific items. The EV-specific items include differences between EVs’ automatic gearboxes vs. ICEVs’ manual gearboxes,

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\(^9\) For example, the omission of engine noises might lead to a reduction of health problems such as headaches after spending an entire working day in a car emitting heavy engine noises. This aspect can be allocated to both \( PU \) as well as \( PEOU \), since reduced health problems could determine the degree of usefulness as well as ease of use.

\(^{10}\) See \( PU \) in Table B.1, e.g., “Due to noiseless driving, other traffic participants fail to hear the EV.”

\(^{11}\) The longer the drivers have not been using any ICEVs, the less likely they are able to remember usage correctly.
EVs’ vs. ICEVs’ engine noises, energy recovery (recuperation) effects, comfort and acceleration. We did not ask about technical car design issues (e.g., loading capacity, seat belts, and car entrance/exit) because these were covered in previous questionnaires implemented by the Deutsche Post itself. Our survey, instead, focuses on the socio-economic acceptance processes.

Analogously, we give drivers a list of PEOU questions: as mentioned earlier, we first ask questions concerning ease of learning on how to handle EVs and the charging infrastructure. Second, we ask questions concerning ease of handling the vehicle, i.e. ease of driving and ease of battery charging (including ease of use of cables and plugs) in comparison to refueling the ICEV at the gas station. Third, we list items targeting drivers’ evaluation of the range display. We collected data through a cross-sectional paper-based questionnaire at Deutsche Post. We then conducted a Principal Component Analysis, followed by multiple regression analyses, i.e. applying the procedures of Venkatesh and Davis (2000) and comparable TAM studies with similar sample sizes.\(^{12}\)

### 4.2 Data sample: Drivers at Deutsche Post

In the region of Bonn, Germany, Deutsche Post operates around 170 EVs (as of mid-2016) in rural as well as urban districts. At the delivery bases of Deutsche Post in Bonn, both EVs and ICEVs (only in reserve, though) are in use. The reserve of ICEVs is operated in case the EVs cannot be used, e.g., due to breakdowns or insufficient range for the delivery routes. Our paper-based questionnaire was distributed among the drivers of Deutsche Post at three delivery bases in Bonn during the busy winter period of week 48 in 2016 (from November on, delivery service personnel is caught up in the Christmas cycle).\(^{13}\) In the questionnaire, we asked the drivers to evaluate and describe their usage behavior of EVs compared to that of ICEVs. The EVs are being driven Monday-Saturday from approx. 09:00 am to 05:00 pm. The EV fleet includes StreetScooter, IVECO DAILY electric, VW E-Caddy, VW T5 electric, Mercedes Vito eCell, and Renault Kangoo Z.E. The few ICEVs kept in reserve at the delivery bases are VW T5, VW Caddy, Ivec, and Mercedes Sprinter.\(^{14}\) The majority of respondents have been driving

\(^{12}\) A TAM meta-analysis by Legris et al. (2003) lists TAM studies with small sample sizes, e.g., Lucas and Spitler (1999), who used factor analysis as well as multiple regression analyses with \(n = 54\). Franke and Krems (2013) apply factor analyses for scrutinizing different subscales followed by multiple regression analyses with \(n \leq 77\).

\(^{13}\) The functionality of the EVs might be affected by weather conditions, i.e. extreme temperatures. In addition, heavy rain makes the work tasks uncomfortable for delivery personnel. Therefore, it is noted that during that week the weather week was very sunny; dry but cold.

\(^{14}\) When comparing delivery vehicles with different engine technologies, one has to keep in mind that the car models are not identically constructed and that subjective biases towards one or the other car brand might exist. Also keep in mind that the StreetScooter was especially designed for the purposes of CEP deliveries and that the interiors of some VW models were redesigned and adapted to fit optimized operation procedures e.g., seat belt, doors, lights in the cabin, load capacity, etc. For further insights into daily operations, see BMU (2011b, p. 86).
EVs on a daily work basis since 2013/14, i.e. for approximately three years at the time of the survey. This means that our study gives insight into the long-term effects of incorporating EVs into a large vehicle fleet. Our sample represents a distinctive population and not a random sample, since we surveyed all EV drivers of Deutsche Post at the three delivery bases in Bonn.

5. Results

5.1 Descriptive results

The paper-based questionnaire was distributed among 120 drivers of which \( n = 66 \) responded (response rate 55%). Of all respondents, 88.52% were male, 4.92% female, and 6.56% put themselves in the category ‘other’. We could not to ask for drivers’ specific age but for age intervals; the mean age was between 36-45 years (min. 18 years, max. > 61 years). Table 1 shows job-related demographics: Mean job tenure at Deutsche Post is 12.72 years (min. 1 month, max. 42 years). 58.73% of drivers work for the compound delivery, whereas the remaining 41.27% work for the parcel delivery only. The delivery routes vary between 10-55 km (mean = 23.58 km) per day, approx. 11,000 km p.a. Regarding EV usage, drivers got used to the EVs within 0-14 days (perceived settling-in period). On average, drivers have been driving the EVs for 2.6 years for 10-55 km/day (mean 23.58 km/day).

Table 1: Summary statistics: Job-related demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>( n )</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job tenure</td>
<td>Job tenure at Deutsche Post, in months at January 1, 2017</td>
<td>44</td>
<td>152.66</td>
<td>153.63</td>
<td>1</td>
<td>508</td>
</tr>
</tbody>
</table>

15 Since external factors, such as charging infrastructure, range restrictions in combinations with route optimizations, etc. are taken care of by their employer Deutsche Post, drivers are not being asked about that, i.e. those factors are not included in the questionnaire.

16 German privacy regulations interfere with comparing groups of EV drivers with a control group of ICEV drivers, both being equal in important aspects such as gender and age. Therefore, a multi-group analysis is not possible even though a direct comparison of EV and non-EV drivers would be the most straightforward approach. However, an anonymous, personalized code serves as a proxy to check whether a person has sent both the first questionnaire as well as the reminder questionnaire back.

17 We waited for the optimal moment to mail the survey, i.e. in December 2016 and a reminder after the very busy Christmas period in January 2017.

18 We coded gender as female (0), male (1), or other (99) respondents.

19 The age of respondents is given in 10 groups: 20 years or younger, 21-25, 26-30, 31-35, 36-40, 41-45, 46-50, 51-55, 56-60, 61 years or more.

20 We coded the type of delivery service that the respondent works for the most as (1) compound delivery and (2) parcel delivery.

21 Due to rapidly increasing quantities of parcel shipments in Germany, especially in inner-city districts, a high number of stopovers and stop-and-go traffic characterize delivery routes.
Duration EV usage: Duration of EV usage, in months at January 1, 2017: 54, 31.48, 19.29, 0, 105
Average daily distance traveled by EV, in km: 62, 23.58, 8.90, 10, 55
Settling-in period (PEOU-determinant): Perceived ease of use settling-in period (getting used to the EV), in days: 46, 2.15, 2.39, 0, 14
Intention to use: Whether drivers choose the EV if they had a choice between ICEV and EV: 63, 3.92, 1.12, 1, 5
Satisfaction with EV: Satisfaction with the EV used the most in the past 4 weeks: 62, 3.71, 1.26, 1, 5
Specific satisfaction with EV: Which EV do you prefer and why? (first mention): 36, 4.61, 0.80, 1, 5
Satisfaction with DV: Satisfaction with the ICEV used the most in the past 4 weeks: 25, 3.68, 1.149, 1, 5

Table 2: Frequency tables of Satisfaction with EV and ICEV and Intention to Use

<table>
<thead>
<tr>
<th>Values labels on the 5-point Likert scale</th>
<th>Satisfaction with EV</th>
<th>Satisfaction with DV</th>
<th>Intention to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(1)</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>6.45</td>
<td>6.45</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>14.52</td>
<td>20.97</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>14.52</td>
<td>35.48</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>30.65</td>
<td>66.13</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>33.87</td>
<td>100.00</td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
<td>100.00</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes: (1) Frequency. (2) Percent. (3) Cumulative. Measured on a 5-point Likert scale where 1 = strongly disagree to 5 = strongly agree or where 1 = very dissatisfied to 5 = very satisfied.

If drivers were able to choose between an EV and an ICEV (DV), more than 70% would go for the EV (intention to use in Table 2). Findings suggest that, on average, drivers are slightly more satisfied with their assigned LDEVs than with the available ICEVs (Table 2). Combining satisfaction levels and age, our descriptive results contradict the widely believed hypothesis that the older the employees, the less they accept new technologies. We find that drivers above the age of 56 do not behave differently than their younger colleagues.22

5.2 Principal Component Analysis and Principal Component Regressions

Our data set consists of 69 items (i.e. variables) that causally sum up to the 11 constructs shown in Table 1 and Table B.1. Trying to estimate the model using these 69 variables would result in multicollinearity concerns because some of these 69 variables are highly correlated. Following the procedure of a Principal Component Analysis (PCA) of Venkatesh and Davis (2000), we erase the problem of multicollinearity for subsequent regression analysis (Hill et al. 1977). A PCA reduces the dimensionality of the data (i.e. number of variables) by computing a series of uncorrelated linear combinations of the variables that contain most of the variance and it extracts the most variations of a data set in an iterative process. In doing so, PCA explains “the maximum amount of total variance (not just common variance) in a correlation matrix by transforming the original variables into linear combinations.

22 We show in section 0 that according to Chi-Squared tests, age does not have a significant effect on satisfaction with the EV or the DV.
components” (Field 2011, p. 667). For example, PCA reduces the answers to 25 PU questions down to six components explaining 75% of the variance in the data. We conducted a PCA on 69 unstandardized items (25 PU items + 16 PEOU items + 21 other items + 7 satisfaction with EV items) with varimax rotation and a 1.0 eigenvalue cut-off criterion resulting in 15 components (Table B.1). 23 For the further analyses, we take into consideration only component loadings above 0.4 (Mummendey 2008). We made a few exceptions in cases where the first component did not load with values > 0.4. In those cases, we opted for a cut-off value of 0.35 (e.g., for the first component of PU). Before running the PCA, we conducted tests for measurement scale reliability using Cronbach’s alpha and interitem correlations, where low item-test and item-rest correlations would be followed by a removal of items to achieve higher values of scale reliability. We can increase Cronbach’s alpha by deleting the construct EV usage anxiety as it does not load on any components (i.e. it lacks sufficient explanatory power). 24 Also, before undertaking the PCA, we deleted items with many non-answers from the list of items in order to achieve a greater sample size. 25 After the PCA, a warranty for component reliability and a justification to apply PCA was given by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of > 0.5 (Backhaus et al. 2011). With the PCA, we show that e.g., the five items we selected indeed measure the social norm. We conduct the PCA in such a way that we transform PCA values back to the original units on the 5-point Likert scale.

After having computed the principal components, we predict intention to use and measure several effects on the 11 constructs using two types of regression models (ordered probit and ordinary least squares, OLS). The advantage of regressions after PCA is that the causally related PCA components are independent of one another and can now be used as explanatory variables. Thus, we can predict how much of the variation in the dependent variable is explained by each of the individual components now

23 We did not standardize variables before PCA because all variables used for a PCA are measured on the same 5-point Likert scale in the same units. For the same reason, we conducted the PCA based on the correlation matrices and not on covariances. We applied varimax rotation because it rotates the components orthogonally to each other, so that the components are independent of one another, which is a prerequisite for conducting regression analyses later on. We normalized data using Kaiser-normalization. We used PCA varimax rotation with a 1.0 eigenvalue cut-off criterion similarly to Davis et al. (1989). Venkatesh and Davis (2000) use PCA with direct oblimin rotation.

24 Without the two items describing the construct EV usage anxiety, we can achieve a higher Cronbach’s alpha for the scales of perceived enjoyment and technophilia (it increases from 0.83 to 0.85.). To confirm the lack of explanatory power of EV usage anxiety, we ran both, PCA and OLS regressions with and without it EV usage anxiety. However, in both cases only technophilia yields significant regression results on PEOU-learning, i.e. they yield the same p-value and R². EV usage anxiety remains insignificant.

25 For example, dropping the two items on PU-acceleration with many non-answers from the PCA leads to n = 55 instead of n = 36 (see Table B.1).
used as explanatory variables.\textsuperscript{26} As Fahrmeir et al. (2009) suggest, we retain those components as variables for regression that explain the most variation in the original data, i.e. those with the highest eigenvalues. Yet, Hill et al. (1977) and Jolliffe (1982) argue that also components with less variance should be used as explanatory variables in principal component regression to prevent the loss of causal information. More specifically, we use ordered probit regression models for predicting the ordinal dependent variable intention to use because on the 5-point Likert scale with equally distributed intervals from 1-5 it is a categorical and ordered variable with more than two outcomes. Moreover, with ordered probit models, the actual values used to label the five categories (1 = strongly disagree to 5 = strongly agree) make no difference other than through the order they imply. With ordered probit models, this ordering information is not discarded. With ordinary least squares (OLS) regression models, however, the value labels 1-5 are not accounted for. When predicting nominal dependent variables such as the PCA components PU and PEOU, we use OLS regression models. We follow an approach by Long (1997) who discusses whether Likert scales should be ordered or not. McKelvey and Zavoina (1975) developed an ordered probit model for the application in the social sciences. The ordered probit model estimates an underlying score as a linear function of the independent variables and a set of cutpoints. The probability of observing outcome \( j \) corresponds to the probability that the estimated linear function, plus random error, is within the range of the cutpoints \( \kappa_{i-1} \) and \( \kappa_i \) estimated for the outcome (Long 1997):

\[
\Pr(\text{outcome}_j = i) = \Pr(\kappa_{i-1} < \beta_1 x_{1j} + \beta_2 x_{2j} + \cdots + \beta_k x_{kj} + u_j \leq \kappa_i)
\]

The error term \( u_j \) is assumed to be normally distributed. We estimate the coefficients \( \beta_1, \beta_2, \ldots, \beta_k \) together with the cutpoints \( \kappa_1, \kappa_2, \ldots, \kappa_{I-1} \), where \( I \) is the number of possible outcomes, \( \kappa_0 \) is taken as \(-\infty\), and \( \kappa_I \) is taken as \(+\infty\). Ordered probit has been applied to small sample sizes (\( n = 66 \), Chambers et al. 1983). With respect to EVs, already Beggs et al. (1981) applied ordered logit models to analyze survey data on potential EV consumers.\textsuperscript{27}

\subsection*{5.2.1 Satisfaction with the EV}

Before we test our hypothesized regression models, we scrutinize the most obvious causalities such as the influence of age on satisfaction. We do not find statistical support for our descriptive result above that older drivers do not accept EVs less than younger drivers: by means of Pearson’s \( \chi^2 \) test as well as Fisher’s exact test, we do not find any statistically significant association between drivers’ age and drivers’ satisfaction with the EV (\( p < 0.05 \)).\textsuperscript{28} Also, we do not find any statistically significant association

\textsuperscript{26} Another widely used method, Structural Equation Modeling (SEM), could not be applied due to underidentification restrictions.

\textsuperscript{27} When applied to our data set, ordered logit models show similar results to ordered probit models.

\textsuperscript{28} We still do not find statistical support when merging the 10 age intervals into two groups (20 years or less to 40 years, 41 years to 61 years or more).
between drivers’ *duration of EV usage* and drivers’ *satisfaction with the EV*. Where we find a statistically significant association is between *satisfaction with the EV* and *ecological attitude* (*p* < 0.05). This relationship, however, overcomes a theoretical border because we defined *ecological attitude* as a *PU*-construct, whereas we defined *satisfaction with the EV* as a *PEOU*-construct. In addition, *ecological attitude* has a significant positive effect on *PU-environment-recuperation* (the *PU*-component with the lowest eigenvalue) which verifies the usefulness of our theoretical model.

### 5.2.2 Intention to use

*Intention to use the EV* is a proxy for EV acceptance. In the following, we test whether the four parameters *satisfaction with the EV*, *PEOU*, *PU*, and *social norm* affect EV acceptance directly, respectively. First, we use Pearson’s *χ²* test as well as Fisher’s exact test to find a statistically significant association between *satisfaction with the EV* and *intention to use* (*p* < 0.001).²⁹ An ordered probit regression model refines this significant association (coefficient estimate 0.68 at *p* < 0.001 level, standard error 0.14).³⁰ Marginal effects ascribe this statistical relationship onto the 5-point Likert scale. For reasons of comparison, we calculated two types of marginal effects in our analysis, marginal effects at the mean and average marginal effects.³¹ Table 3a. exhibits the marginal effects of *satisfaction EV* on *intention to use*: for a 1-unit increase in *satisfaction EV*, *intention to use* takes on the values 1-5 according to the listed probabilities. For both types of marginal effects, the effect sizes and standard errors are similar and the sum of negative marginal effects add up to the sum of positive marginal effects. The signs on the marginal effects change as soon as the 5-point Likert scale crosses the respective (rounded) mean values. For example, the signs of the marginal effects at the mean of *satisfaction EV* (3.75) change from negative to positive as soon as the rounded mean has been reached, i.e. from 4 to 5 on the Likert scale. Negative marginal effects imply that the probability of drivers ticking a box below the mean is less likely. For average marginal effects, more levels of the 5-point Likert scale are significant. Calculating the marginal effects at the mean on the 5-point Likert scale, the two outcomes 3 and 5 are significant. The marginal effects at the mean tell us that given *satisfaction EV* at its mean (3.75), a 1-unit increase in *satisfaction EV* will decrease the probability of being in the group of *intention to use* = 3 (neither agree nor disagree) by 10% (*p* < 0.01). Likewise, a 1-unit increase in *satisfaction EV* will increase the probability of being in the group of *intention to use* = 5 (strongly agree) by 27% (*p* < 0.001),

---

²⁹ We do not find a statistically significant association between *intention to use* and *average daily distance driven by the EV*.

³⁰ Venkatesh and Davis (2000) use hierarchical regression when testing for relationships between *intention to use* and all the other possible predictors.

³¹ Marginal effects at the mean describe the marginal effects given that all predictors are set to their mean values. In this ordered probit model, *satisfaction EV* is set to its mean (3.75). Average marginal effects describe the marginal effects over the average of the whole distribution of the predictors.
given that the predictor satisfaction EV is set to its mean (3.75). Given the conditional marginal effect at satisfaction EV = 5 (strongly agree), the probability of intention to use = 5 (strongly agree) is 73% (p < 0.001). As hypothesized, a low satisfaction results in a low intention to use: if satisfaction with the EV is the lowest (i.e. satisfaction EV = 1 = strongly disagree), the probability of ticking a box at the lowest intention to use level (intention to use = 1) is 53% (p < 0.01). If satisfaction with the EV is the lowest (i.e. satisfaction EV = 1 = strongly disagree), the probability of the second-lowest intention to use level (intention to use = 2) is 18% (p < 0.05) and the probability of the third-lowest intention to use level (intention to use = 3) is as well 18% (p < 0.05). Table 3a. also includes the predicted probabilities of intention to use at the mean value of satisfaction EV. Four levels of intention to use (intention to use = 2 – 5) are statistically likely to appear in a range from 6% – 41%. For the predicted probabilities of intention to use at the average, this range slightly shifts (7% – 44%). The conditional marginal effect at the mean satisfaction EV = 3.75 equals the predicted probabilities and standard errors listed in column (3) in Table 3a. Second, we use an ordered probit regression model to predict the effect of perceived ease of use on intention to use. The coefficient estimates in line (5) in Table 3b. indicate that all three components have significant effects on intention to use. The direction of the signs are as hypothesized: e.g., PEOU-hindrance-all, which is defined as being a usage hindrance, indeed has a negative effect on intention to use. Calculating the marginal effects at the mean, Table 3b. validates that intention to use takes on values 1-5 with significant probabilities given a 1-unit increase in PEOU. For reasons of comparison, we include average marginal effects in the analysis. PEOU-learning has two significant marginal effects at the mean on intention to use, the highest being a 42% decrease in the probability of being in the group of intention to use = 5 (strongly agree) induced by a 0.1% increase in PEOU-learning. A 1-unit increase in PEOU-hindrance-all decreases the probability of being in the group of intention to use = 5 (strongly agree) by 8%, given that all predictors are set to their mean values. Here, we observe an empirically meaningful change in signs: usage hindrance shows positive effects for value labels 1-4, however, for value label 5 it shows a negative sign. A 1-unit increase in PEOU-cognitive-operative decreases the probability of being in the group of intention to use = 2 (disagree) and intention to use = 3 (neither) by 4% and 9%, respectively, given that all predictors are set to their mean values. The probability of being in the group of intention to use = 5 (strongly agree) increases by 7.26% due to a 0.1-unit increase in PEOU-cognitive-operative, given that all predictors are set to their mean values. The predicted probabilities at mean values (column (3) in Table 3b.) are significant for three levels of intention to use: given that the three PEOU variables are set to their mean values, the probabilities for intention to use = 3, 4 and 5 are 18%, 37% and 39%, respectively. For further multiple regressions, we use only the one component with the highest eigenvalue (PEOU-learning) as dependent variable. Third, we predict the effect of perceived usefulness on intention to use. Here, only one of four components has a significant effect on intention to use, i.e. PU-automatic-gear (coefficient estimate 1.05 at the p < 0.001 level, standard error 0.225). Table 3c. draws a clearer picture: at the mean of PU-automatic-gear (3.32), a one-unit increase in PU-automatic-gear decreases the probability of intention to use = 2 and 3 by 10%
and 16%, respectively. Likewise, a one-unit increase in PU-automatic-gear increases the probability of intention to use = 5 by 40%. Fourth, we measure the effect of social norm on intention to use (coefficient estimate 0.51 at the p < 0.01 level, standard error 0.2). Again, the marginal effects at the mean in Table 3d. draw a clearer picture of the impact of social norm on intention to use: a one-unit increase in social norm decreases the probability of intention to use = 1 by 7%, given that the predictor social norm is at its mean (4.11). Likewise, a one-unit increase in social norm increases the probability of intention to use = 5 by 19%. To sum up this section on intention to use, the predicted probabilities are similar to actual outcomes and the signs of the marginal effects are as hypothesized. Therefore, we continue to interpret intention to use as acceptance because higher levels of PU, PEOU, and satisfaction EV entail higher predicted probabilities of intention to use. Our results are consistent with direction and size of effects obtained in Venkatesh and Davis (2000) in two aspects. First, our regressions indicate the impact of social norm on intention to use in a mandatory usage environment, i.e. social norm is statically significant only in the univariate ordered probit regression predicting intention to use (Table 3d.) or as a direct impact on PU (Figure 3). Second, Figure 2 shows a PU-coefficient of comparable size (1.00 on the 99% significance level and similarly small sample sizes between n = 36 and n = 43). Marginal effects at the mean show that increasing satisfaction concerning PU-automatic-gear by one unit will increase the probability of a complete acceptance, i.e. attaining the highest intention to use (i.e. agreeing very strongly to use the EV) by 38%, given that all three predictors are set to their mean values.32

Measuring direct effects on intention to use. We take the components with the highest eigenvalues of PU and PEOU and combine them with social norm to predict their direct influence on intention to use (Figure 2).

32 PU-automatic-gear mean = 3.28, PEO-learning mean = 4.29, social norm mean = 4.13. Means differ from other regressions due to varying sample sizes.
Table 3a.-d. Predictors of intention to use

a. Satisfaction EV as predictor of intention to use

<table>
<thead>
<tr>
<th>Value labels on the 5-Point Likert scale</th>
<th>Marginal effects of satisfaction EV on intention to use</th>
<th>Predicted probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>1</td>
<td>-0.05 0.028</td>
<td>-0.06 0.025</td>
</tr>
<tr>
<td>2</td>
<td>-0.06 0.031</td>
<td>-0.04 0.02</td>
</tr>
<tr>
<td>3</td>
<td>-0.10 0.036</td>
<td>-0.06 0.018</td>
</tr>
<tr>
<td>4</td>
<td>-0.05 0.038</td>
<td>-0.04 0.02</td>
</tr>
<tr>
<td>5</td>
<td>0.26 0.056</td>
<td>0.22 0.03</td>
</tr>
</tbody>
</table>

b. Three PEOU-components as predictors of intention to use

<table>
<thead>
<tr>
<th>Value labels on the 5-Point Likert scale</th>
<th>PEOU-learning</th>
<th>PEOU-hindrance-all</th>
<th>PEOU-cognitive-operative</th>
<th>Predicted probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1</td>
<td>0.58 (0.36)</td>
<td>0.50 (0.30)</td>
<td>0.92** (0.236)</td>
<td>-1.01 (0.61)</td>
</tr>
<tr>
<td></td>
<td>1.07** (0.34)</td>
<td>0.92*** (0.23)</td>
<td>-1.85*** (0.52)</td>
<td>0.02 (0.025)</td>
</tr>
<tr>
<td>2</td>
<td>0.84 (0.46)</td>
<td>0.72 (0.37)</td>
<td>0.44* (0.76)</td>
<td>-1.45 (3.9)</td>
</tr>
<tr>
<td></td>
<td>0.06* (0.23)</td>
<td>0.44*** (0.76)</td>
<td>-0.9** (3.9)</td>
<td>0.04 (0.026)</td>
</tr>
<tr>
<td>3</td>
<td>2.02* (0.86)</td>
<td>1.73** (0.38)</td>
<td>0.83** (0.67)</td>
<td>-3.48* (1.38)</td>
</tr>
<tr>
<td></td>
<td>0.18* (0.20)</td>
<td>1.68** (0.67)</td>
<td>-1.68** (1.38)</td>
<td>0.15*** (0.622)</td>
</tr>
<tr>
<td>4</td>
<td>0.76 (0.64)</td>
<td>0.65 (0.54)</td>
<td>0.54 (1.10)</td>
<td>-1.32 (0.54)</td>
</tr>
<tr>
<td></td>
<td>0.37*** (0.31)</td>
<td>0.54*** (0.54)</td>
<td>-1.19* (0.54)</td>
<td>0.27*** (0.054)</td>
</tr>
<tr>
<td>5</td>
<td>-4.20** (1.23)</td>
<td>-3.2*** (0.70)</td>
<td>-3.61*** (0.83)</td>
<td>-2.74*** (0.534)</td>
</tr>
<tr>
<td></td>
<td>0.39*** (1.81)</td>
<td>5.26*** (1.81)</td>
<td>7.51*** (1.06)</td>
<td>0.44*** (0.070)</td>
</tr>
</tbody>
</table>

(5) -10.97** -9.40*** 18.94***
(6) 3.20 2.17 4.74

c. PU as predictor of intention to use

<table>
<thead>
<tr>
<th>Value labels on the 5-Point Likert scale</th>
<th>PU-automatic-gear</th>
<th>Predicted probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>1</td>
<td>-0.75 0.048</td>
<td>-0.11 0.034</td>
</tr>
<tr>
<td>2</td>
<td>-0.10* 0.048</td>
<td>-0.07* 0.035</td>
</tr>
<tr>
<td>3</td>
<td>-0.16* 0.067</td>
<td>-0.09* 0.030</td>
</tr>
<tr>
<td>4</td>
<td>-0.06 0.067</td>
<td>-0.06 0.034</td>
</tr>
<tr>
<td>5</td>
<td>0.40*** 0.09</td>
<td>0.32*** 0.044</td>
</tr>
</tbody>
</table>

(5) -10.97** -9.40*** 18.94***
(6) 3.20 2.17 4.74
d. Social norm as predictor of intention to use

<table>
<thead>
<tr>
<th>Value labels on the 5-Point Likert scale</th>
<th>Social norm</th>
<th>Predicted probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>1</td>
<td>-0.07* 0.034</td>
<td>-0.075* 0.036</td>
</tr>
<tr>
<td>2</td>
<td>-0.03 0.025</td>
<td>-0.026 0.2</td>
</tr>
<tr>
<td>3</td>
<td>-0.08 0.042</td>
<td>-0.063* 0.025</td>
</tr>
<tr>
<td>4</td>
<td>-0.021 0.261</td>
<td>-0.02 0.019</td>
</tr>
<tr>
<td>5</td>
<td>0.19*** 0.077</td>
<td>0.18** 0.058</td>
</tr>
</tbody>
</table>

Notes: (1) Marginal effects (%) at the means of a. satisfaction EV = 3.75; b. PEOU-learning = 4.3, PEOU-hindrance-all = 4.47, PEOU-cognitive-operative = 4.25; c. PU-automatic-gear = 3.32; d. social norm = 4.11. (2) Average marginal effects (%); b. Regarding the change of signs, PEOU-hindrance-all is defined as usage hindrance, i.e. having a negative influence on PEOU. (3) Predicted probabilities of intention to use at the mean values. (4) Predicted probabilities of intention to use at the average. (5) Coefficient estimates. (6) Standard errors. Significance at the *p < 0.05, **p < 0.01, and ***p < 0.001 level. McFadden’s Pseudo R² a. = 0.14, n = 59; b. = 0.20, n = 61; c. = 0.19, n = 54; d. = 0.14, n = 44. Standard errors in parentheses.
Figure 2: \(PU\), \(PEOU\), and \(social norm\) as predictors of \(intention to use\)

Notes: Ordered probit regression coefficients. Significance at the \(*p < 0.05, \**p < 0.01, \***p < 0.001\) level. McFadden’s Pseudo \(R^2 = 0.28\), \(n = 38\). Standard errors in parentheses.

5.2.3 Perceived usefulness

Measuring direct effects on \(PU\). We measure the effect of \(perceived ease of use\) on \(perceived usefulness\). Table 4 highlights that all facets of \(PEOU\) have a significant effect on \(PU\). Figure 3 depicts the direct effects on \(PU\) when taking those components with the highest eigenvalues of \(PU\). \(Social norm\) and \(ecological attitude\) have significant effects on \(PU\).

Table 4: Three components of \(PEOU\) as predictors of \(perceived usefulness\)

<table>
<thead>
<tr>
<th>Components of (PEOU)</th>
<th>OLS coefficient estimates and standard errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PEOU)-learning</td>
<td>-4.17(^{**}) (1.72)</td>
</tr>
<tr>
<td>(PEOU)-hindrance-all</td>
<td>-5.37(^{***}) (1.00)</td>
</tr>
<tr>
<td>(PEOU)-cognitive-operative</td>
<td>8.91(^{***}) (2.35)</td>
</tr>
</tbody>
</table>

Significance at the \(*p < 0.05, \**p < 0.01, \***p < 0.001\) level. \(R^2 = 0.56\), \(n = 54\). Standard errors in parentheses.

Figure 3: Social norm, intrafirm image, and ecological attitude as predictors of \(PU\)

Notes: OLS regression coefficients. Significance at the \(*p < 0.05, \**p < 0.01, \***p < 0.001\) level. \(R^2 = 0.50, n = 38\). Standard errors in parentheses.

5.2.4 Perceived ease of use

Measuring direct effects on \(PEOU\). In Figure 4 it becomes clear that only the three variables \(technophilia\), \(perceived enjoyment\), and \(satisfaction EV\) are significant with respect to \(PEOU\), when measured simultaneously in a multiple regression. Therefore, we dropped the insignificant variables. Variables that have a statistically significant and positive effect on \(PEOU\) when measured in a simple
regression are: *job satisfaction, specific satisfaction with the EV* (even though the subsample is very small with \( n = 5 \), coefficient 0.71 (\( p < 0.05 \)), standard error 0.2). Variables that have no statistically significant effect on *PEOU* are: *satisfaction ICEV* (possibly due to a low sample of \( n = 24 \)), *PEOU-settling-in-period, duration EV usage, and average daily distance EV*.

![Diagram](image.png)

**Figure 4**: Satisfaction EV, perceived enjoyment, and technophilia as predictors of *PEOU*

Notes: OLS regression coefficients. Significance at the *\( p < 0.05 \)*, **\( p < 0.01 \)*, and ***\( p < 0.001 \)* level. \( R^2 = 0.39 \), \( n = 22 \). Standard errors in parentheses.

### 6. Discussion

First, we investigate whether drivers are more satisfied with the LDEVs than with the ICEVs. Second, we question whether the EVs increase drivers’ *perceived efficiency*. Combining these two perspectives, we show that the greater the drivers’ overall satisfaction with LDEVs, the higher is the drivers’ *perceived efficiency*. Our results are mostly consistent with those EV studies applying TAM2 regarding the size and direction of effects of the UTAM constructs and its determinants. Especially, we extended TAM2 by refining the determinants of *PEOU*. We added items asking the driver to evaluate handling of the vehicle (i.e. driving behavior, usage of the car itself, the charging infrastructure, and range display) which resulted in a clear distancing between the determinants of satisfaction levels.

The summary of results in Table 5 suggest that the some constructs are not significant (indicated by an effect of 0): we find that *EV usage anxiety* (one of the three affect variables) is insignificant to EV acceptance. This is very insightful for human resource managers regarding social impacts of a technology change at the work place. Some interactions and unobservable effects remain unclear. Still, our model describes a real production environment. To answer our two research questions, we can clearly state that (1) drivers are slightly more satisfied with their assigned LDEVs than with the available ICEVs and (2) *satisfaction with the EV* increases drivers’ *intention to use* the EVs and thus *perceived efficiency*. In turn, *PU* and *intention to use* increases with increasing usage duration, i.e. long-term effects of 3-4 years of EV usage seem to be positive. Regarding research questions (2a) and (2b), we demonstrate the positive impacts of *PU* on *perceived efficiency* in (2). In addition, the qualitative answers to *specific satisfaction with the EV* and *PU-acceleration* reveal a higher *perceived efficiency with the EV* with the EV compared to ICEV which align with drivers’ qualitative answers in BMU (2011b). *Specific satisfaction with the EV* was defined as time savings due to EVs’ automatic gearboxes vs. ICEVs’ manual gearboxes, easier parking due to smaller turning circle and better maneuverability,
good driving behavior, noiselessness, faster ready to depart, easier loading of trunk, better acceleration, and reliability. Thus, *PEOU* can be seen as drivers’ perceived smoothness of work and perceived work technology advancement. Regarding *PU*-acceleration, of those 29 drivers who state that the EV accelerates faster than the ICEV, 24 state that they like the sharp acceleration while still driving as cautiously as with the ICEV. Thus, *PU* can be seen as drivers’ *perceived efficiency* (with the EV, I get more done in less time than with the ICEV). Finally, our respondents reveal a short *settling-in period* and irrelevant *EV usage anxiety* suggesting that a change in work equipment (i.e. vehicle technology) does not result in efficiency losses.

Table 5: UTAM’s hypothesized and calculated direction of effects

<table>
<thead>
<tr>
<th>Variables</th>
<th>Effect on variable or PCA component with the highest eigenvalue</th>
<th>Hypothesized direction of effects</th>
<th>Calculated direction of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived usefulness (PU)</td>
<td>intention to use</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>PU</em>-automatic-gear</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>PU</em>-technical</td>
<td></td>
<td>+/-</td>
<td>0</td>
</tr>
<tr>
<td><em>PU</em>-engine-noise</td>
<td></td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td><em>PU</em>-environment-recuperation</td>
<td></td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td><em>PU</em>-acceleration</td>
<td></td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Perceived ease of use (PEOU)</td>
<td>intention to use</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-learning</td>
<td></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-hindrance-all</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-cognitive-operative</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Perceived ease of use (PEOU)</td>
<td><em>PU</em>-automatic-gear</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-learning</td>
<td></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-hindrance-all</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PEOU-cognitive-operative</td>
<td></td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Satisfaction with the EV</td>
<td>intention to use</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Satisfaction with the EV</td>
<td>PEOU-learning simultaneously with perceived enjoyment and technophilia</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Specific satisfaction with the EV</td>
<td>intention to use</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Satisfaction with the DV</td>
<td>PEOU-learning</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Intrafirm image</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Social norm</td>
<td>intention to use</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Social norm</td>
<td>intention to use simultaneously with <em>PU</em>-automatic-gear, PEOU-learning, and <em>EV usage anxiety</em></td>
<td>+/-</td>
<td>0</td>
</tr>
<tr>
<td>Ecological attitude</td>
<td>satisfaction with the EV</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ecological attitude</td>
<td><em>PU</em>-environment-recuperation</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Job satisfaction</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Perceived enjoyment</td>
<td>PEOU-learning simultaneously with satisfaction with the EV</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>EV usage anxiety</td>
<td>PEOU-learning simultaneously with satisfaction with the EV</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Technophilia</td>
<td>PEOU-learning simultaneously with satisfaction with the EV</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Age</td>
<td>satisfaction with the EV</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>PEOU-settling-in-period</td>
<td>PEOU-learning</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Duration EV usage</td>
<td>PEOU-learning</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Duration EV usage</td>
<td>satisfaction with the EV</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Average daily distance EV</td>
<td>PEOU-learning</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>
Notes: +/- = Higher values of the component on the 5-point Likert scale entail higher/lower values on the 5-point Likert scale of the target variable. 0 = no statistically significant effect on the target variable or dropped due to many non-answers.

This study has several methodological limitations that should be noted. First, it faces retrospective limitations in cases where drivers have not used either EVs or ICEVs for a long time. Second, the stated nature of the data – a small sample size and self-assessments – limits the explanatory power of this study. One can argue that due to a small sample size ($n = 66$ respondents), the quality of the estimation remains low while the McFadden’s Pseudo R$^2$ and R$^2$ are of reasonable size. This gives direction for future research with larger sample sizes. With small sample sizes, multiple regressions do not make much sense, and future research should therefore compare subgroups (e.g., one group with high and another with low EV acceptance, as done in Globisch et al. (2013)).

Yet, our results are consistent with those in Venkatesh and Davis (2000) where even lower samples sizes were used. We could not measure real efficiency changes induced by EV usage. Thus, we collected data on self-stated experiences (experience with the EV, perceived settling-in period, and average daily distance traveled by EV). Likewise, we collected data on satisfaction by disclosing preferences, perceptions, and opinions, i.e. commercial drivers’ perception of usefulness and ease of use of the EV during a usual workday. This leads to a third limitation: this data surely is skewed by effects of social desirability, especially at the workplace. Fourth, we look at a very specific slice of population (LDEV drivers in a specific region) which ignores the general users. Thus, there might be endogeneity from sample selection bias so that we cannot derive generalizations from this small sample. Yet, from a managerial perspective, our study nevertheless gives valuable insights into EV usage behavior and satisfaction of commercial drivers so that our insights can in principle be transferred to approximately 500,400 drivers employed in the German logistics sector (Bundesagentur für Arbeit 2014). Finally, one could argue that there exists a bias of satisfaction between different EV models, since the StreetScooter was especially designed for Deutsche Post employees and might be more satisfactory to them than, say, a ‘standard’ VW or Renault model.

7. Conclusions

The EV literature discusses many ways to electrify commercial transport, particularly from the entrepreneurs’ perspective. Therefore, our study on commercial EV drivers’ acceptance is exploratory and necessitates a combination of the TAM (Venkatesh and Davis 2000) with the Diffusion of Innovation Theory (Rogers 2003). This combination, the UTAM, allows us to extend existing theory and to close some of the existing gaps in the literature. We measure satisfaction and perceived efficiency of delivery service EV drivers in long-term usage – 3-4 years after implementation – in Germany in a

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33 The longer the drivers have not been using the ICEs, the less likely they are able to remember usage correctly.
real production environment. We base our UTAM, the Unified Technology Acceptance Model, on the TAM2 of Venkatesh and Davis (2000), the TAM3 of Venkatesh and Bala (2008), the Unified Theory of Acceptance and Use of Technology (UTAUT) of Venkatesh et al. 2003, a socio-technical approach (Wikström et al. 2014), and most recent studies by Dudenhöffer (2013a, 2013b) and Fazel (2014). We enrich the TAM by means of the Diffusion of Innovation Theory (Rogers 2003) as well as insights from numerous German EV field trials. Methodologically, we refine the determinants of PEOU and add items asking the driver to evaluate handling of the vehicle (i.e. driving behavior, usage of the car itself, usage of the charging infrastructure, and managing the range display). Therefore, from a methodological perspective, there is plenty of room for subjective interpretations.

The analysis shows the importance of long-term effects at the workplace. Three to four years after the introduction of EVs into the delivery vehicle fleet, drivers have mostly accepted EVs as their work equipment. We detect patterns of acceptance levels: the higher the levels of PU and PEOU, the higher the intention to use. We find that age and EV usage anxiety are irrelevant to EV acceptance.

By clustering certain user groups, one can elicit managerial implications for fleet managers regarding technical aspects of EV usage, human resource managers regarding psychological and social impacts of a technology change at the work place, and staff training. Finally, car designers can find important hints in the constructs of PEOU. The qualitative results indicate that drivers appreciate the environmental advantages of LDEVs (e.g. reduction in pollution and noise) which might be relevant to the perceived satisfaction and the perceived efficiency.

Following from the preceding discussion, our three contributions are (1) an exploratory methodological approach that allows us to extend existing theory and to close some of the existing gaps in the literature, (2) EVs lead to perceived efficiency gains for commercial drivers, and (3) perceived satisfaction leads to EV acceptance. With intensified deployment of commercial EVs, especially in the CEP sector, future research ought to look at long-term effects of EVs at the workplace and under mandatory use with a larger sample size.

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Appendix A: Detailed Description of UTAM constructs

A.1. Attitude toward using and actual usage: intention to use

In our study, we interchange actual usage and attitude toward using with intention to use and we ask drivers which of the ICEV or EV car models they have used the most in the four weeks prior to the survey. In addition, we ask for average daily distance driven and the type of delivery service the respondent works for the most (compound delivery or parcel delivery). Since drivers might not be allowed to choose between EVs or ICEVs, we cannot assume, as posited in the TAM, that attitude toward using leads to actual usage (Davis et al. 1989). In addition, Moons and Pelsmacker (2012) show that in an early adoption stage, emotions towards EVs have a strong effect on the intention to use. Therefore, for measuring intention to use, we let drivers assume that they can choose between an EV and an ICEV at the beginning of their shift (item (d) in Figure A. 1 and Table B.1). In the case that they accept the EV, we assume that they would prefer EVs to ICEVs.34

Figure A. 1: Example of item adaptation and verbalization to fit the context of LDEV, using two of the four TAM core constructs perceived usefulness (PU) and intention to use

A.2. Perceived usefulness (PU)

Davis et al. (1989, p. 985) state that in the TAM, “perceived usefulness is defined as the prospective user’s subjective probability that using a specific application system will increase his or her job performance within an organizational context”. The literature offers further interpretations of perceived usefulness (PU). Rogers (2003) defines this framework as relative advantage, which “is the degree to which an innovation is perceived as being better than the idea it supersedes”. More precisely, for a comprehensive acceptance, the individual advantageous perception of the innovation is more important than its objective valuation (Rogers 2003). In other words, Davis’ (1989) perceived usefulness is comparable to Rogers’ (2003) relative advantage. According to Rogers (2003), the degree of relative advantage is often expressed in terms of economic profitability. Thus, in this study, we follow Rogers’ (2003) relative advantage and measure the degree of PU in terms of constructs representing drivers’ perceived efficiency which eventually enhances economic profitability. Accordingly, we assume that

34 Further endogenous as well as exogenous constructs might have a positive effect (e.g., intrinsic motivation) or a negative effect (e.g., age) on the attitude toward using.
PU is the degree to which drivers perceive that they can do their job faster or more comfortably with the EV than with the ICEV. This might be the case due to technical differences between the engine types (see items listed in Table B.1). The Theory of Planned Behaviour (Fishbein and Ajzen 2010) highlights the fact that next to psychological factors, also external, objectively perceived factors have to be considered. Benbasat and Barki (2007) suggest to measure usefulness with aspects that go beyond subjectively perceived aspects, i.e. with objectively perceived aspects, such as environmentalism. This is done in Dudenhöffer (2013b). Bruner and Hensel (2013) interpret PU as an increase in drivers’ perceived effectiveness due to the use of new technology. Also, PU includes extrinsic motivation (Malhotra et al. 2008).35 Thus, we adapted these definitions of PU to the context and added the technical aspects of EVs that have an impact on drivers’ PU. Therefore, the construct operationalization consists of a list of general PU questions (e.g., items (a)-(c) in Figure A. 1 and Table B.1), followed by a list of EV-specific items.

A.3. Perceived ease of use (PEOU)

With the introduction of EVs into the daily routines, daily habits need adjustments, such as the charging process in comparison to refueling the car with petrol or diesel (Plötz et al. 2014). Thus, we investigate if those changes might cause disturbance, dissatisfaction and irritation among the drivers. Therefore, we include perceived ease of use (PEOU) because it is “the extent to which a user perceives that using the target system will be free of physical and mental effort” (Davis 1986, p. 136). PEOU “refers to the degree to which the prospective user expects the target system to be free of effort” (Davis 1989, p. 985). Wissmann (2013, p. 72) refers to PEOU as “usability” which gives it a more contemporary connotation. Analogously to Rogers’ relative advantage and to Davis’ perceived usefulness mentioned above, we define Rogers’ perceived complexity as the negative term to Davis’ perceived ease of use (Moore and Benbasat 1991). Similarly, we define PEOU as a positive interpretation of the complexity of using the system. In our study, PEOU concerns simply the process of EV usage itself, i.e. not the outcomes of EV usage, in comparison to ICEV usage. In other words, PEOU does not evaluate the consequences of EV usage (e.g., faster acceleration, thus driving faster and thus delivering faster) but ease of usage only (e.g., ease of handling the vehicle and the battery charging infrastructure).36 In doing so, we clearly allocate technical circumstances of EV usage that differ from using an ICEV (e.g., refueling, acceleration) to either PU or PEOU, which is further explained in section 3.3. Furthermore, we show that higher values of the variable perceived ease of use implicate easier use

35 Perceived usefulness is often distinguished as task-technology-fit e.g., by Goodhue (1995); yet, in this specific case, the technology undeniably fits to the task. Thus, we neglect the task-technology-fit here.

36 Similar interpretations appear for perceived enjoyment, a construct explained later, developed by Venkatesh (2000, p. 351) perceived enjoyment considers enjoyment of driving, i.e. handling the pedals and not the enjoyment/thrill of acceleration.
More generally, PEOU could be defined as employees’ satisfaction with the technology, which is influenced by the ease of use inherent to the handling of the technology. As a result, we interpret PEOU in the EV context according to Dudenhöffer (2013b) and Fazel (2014): both are based on the TAM, but the former divides PEOU of LDEV usage into ease of driving and ease of battery charging, whereas the latter focuses on the ease of switching from ICEV to EV. Thus, we let drivers evaluate ease of learning, i.e. getting familiar with the LDEVs and the charging infrastructure (Table B.1). Second, we let drivers evaluate ease of handling the vehicle (e.g., parking, maneuvering, loading the trunk with delivery goods, and ease of usage of the charging infrastructure, including handling of cables and plugs, in comparison to refueling the ICEV at the gas station). Third, we let drivers evaluate EV characteristics such as user-friendliness of the range display (sometimes, the predicted remaining range increases due to energy recovery (recuperation) effects or decreases very fast) and operational readiness at the beginning of a shift.

A.4. Constructs loading on PU: drivers’ perceived efficiency

We measure drivers’ perceived efficiency by perceived usefulness and its determinants one of them being subjective norm on which the TAM builds upon (Figure 1 and Table B.1). Since subjective norm relies on a clear-cut distinction between mandatory and voluntary use, we cannot apply it here. Instead, we rely on Peters et al.’s (2011, p. 990) social norm in the EV context, which describes the “perceived expectations of relevant others”. Social norm positively determines the PU of EVs (top left corner in Figure 1). In the organizational context, the drivers’ social norm is determined by their employers, colleagues, and maybe family and friends (Lucas and Spitler 1999). Basic demographic variables such as age, gender and job tenure have been proven to influence social norm and thus intention to use. We follow the TAM and its successors and assume that an increase in age has been proven to negatively affect intention to use (Venkatesh et al. 2003). The perceived visibility of usage is important as well. Other traffic participants might perceive EVs positively due to fewer noise emissions. We assume that the higher the perceived visibility of usage, the higher the PU. Therefore, perceived visibility of usage defines a possible reaction or feedback of passerbys or customers in response to the EV, which is articulated towards the driver. Therefore, this construct aims at capturing the effect of passerbys

37 Subjective norm is a “person’s perception that most people who are important to him think that he should or should not perform the behavior in question” (Fishbein and Ajzen 1975, p. 302).

38 Moreover: “Applied to the context of electric mobility, this implies that the probability to use an EV would be influenced by the personal attitude, e.g., personal expectations towards using EVs, as well as the more general societal perception of electric mobility, e.g., EVs as ‘green’ vehicles that should be used in order to contribute towards preventing climate change” (Peters et al. 2011, p. 984).

39 In particular, one EV model in the delivery service fleet, the StreetScooter, was especially designed and built for the purposes of CEP deliveries in Germany. Therefore, the StreetScooter might attract attention due to its new outer form and design, and media coverage.
responses on the driver. However, in Peters et al. (2011), a similar construct capturing this effect, i.e. observability, achieved a low internal reliability and was thus deleted from further analyses. We follow Peters et al. (2011) and define perceived visibility of usage as social norm. In summary, social norm in this context not only describes perceived expectations of relevant others and a general societal perception of EVs but also a possible reaction or feedback of passerby or customers.

Intrafirm image describes the status of drivers who (are being allowed to) drive EVs among their colleagues. In the TAM, this image closely relates to subjective norm and positively influences PU. The image of EV on passerby and friends is included in the construct social norm.

We assume that ecological attitude has an impact on PU. In our study, the use of EV bears no additional costs for the driver. Therefore, a mandatory use of EVs might change the values and preferences of drivers (BMU 2011b) to a more environmentally friendly behavior, which follows the Model of normative Decision-Making by Schwartz and Howard (1981) often applied in environmental psychology (e.g., Klöckner and Matthies 2004). Therefore, a mandatory use of EVs might increase drivers’ ecological attitude so that they behave more environmentally friendly apart from workplace-related actions.

The three items experience with the EV, perceived settling-in period, and average daily distance traveled by EV combine time aspects, getting used to the EV during the ordinary course of business, and the eventual acceptance. The longer and the more often drivers use the EV, the higher the utility from using it because they familiarize themselves with the handling of the EV, particularly with the driving behavior and the charging process. These three items are especially relevant in the commercial usage context of our study because Venkatesh et al. (2003) found out that usage duration explains partly the variance in the TAM. We suggest that not only usage duration but also the usage intensity (i.e. the driving distance) affects PU. In addition, experience affects social norm: with mandatory use, the longer the experience, the smaller is the positive effect of social norm on intention to use. Also, with both mandatory and voluntary use, the longer the experience, the smaller is the positive effect of social norm on PU (Venkatesh and Davis 2000).

A. 5: Constructs loading on PEOU: drivers’ perceived satisfaction with the EV and DV

Analogously to PU, we define perceived satisfaction with the EV by PEOU and its determinants. The following subsections describe the determinants of PEOU in more detail. In case the driver is per se satisfied with the EV, he will more likely accept a regular EV usage. The drivers’ technology acceptance depends on a subjective (general) and a specific (technical) satisfaction with the cars. Therefore, we divide satisfaction into three separate questions: we ask drivers how satisfied they were with the (1) EV and the (2) ICEV used the most in the four weeks prior to the survey. Moreover, we ask

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40 This satisfaction process takes place before the technology acceptance process and can be seen as an intention to use process (Fazel 2014) and as salient beliefs (Ajzen and Fishbein 1980).
drivers about their (3) specific satisfaction with the EV, i.e. which EV model they prefer and why, by combining a Likert scale with an open answer possibility (Table 1). We hypothesize that the higher the specific satisfaction with the EV, the higher the acceptance. In addition to satisfaction with the car itself, job satisfaction aims at psychological factors influencing PU. We chose measurement scales from Fischer and Lück (2014). As Figure 1 (lower left corner) shows, we follow Dudenhöffer (2013a) and consider the three direct determinants of PEOU perceived enjoyment, technophilia, and EV usage anxiety as affect variables. The driver evaluates these variables on affective and emotional grounds, i.e. the answer changes depending on the state of the respondent. First, perceived enjoyment developed by Venkatesh (2000) considers enjoyment of driving, i.e. handling the pedals and not the enjoyment of acceleration. Davis et al. (1992) and Venkatesh and Bala (2008) measure (perceived) enjoyment of using the technology by using three 7-point Likert scale items. Davis et al. (1992) base their assumptions on enjoyment on extrinsic and intrinsic motivation in the workplace. The construct perceived enjoyment enters into the TAM3 and determines PEOU (Venkatesh and Bala 2008). It was originally developed by Venkatesh (2000, p. 351) and measures to what extent “the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use.” The latter means in this context that we should measure the process of EV use and not the pleasure of driving and the thrill of acceleration. Often, these constructs summarize affect variables, e.g., Dudenhöffer (2013b) combines enjoyment as well as anxiety variables into the single construct affect. Second, technophilia aims at the interest and enjoyment of drivers to generally interact with a new technology. Klumpp et al. (2014) list qualifications that employees of different hierarchical business levels need to have in order to implement e-mobility in their daily business routines and logistics departments. Fazel (2014) views it as subjective degree of innovation. Similarly, Rogers (2003) considers it as enjoyment of innovations, i.e. the enjoyment of trying out and accepting new technologies, services, or products. For example, early adopters enjoy using new technologies despite any problems (range restrictions, long charging duration). Since early adopters are more open towards new technologies, they accept new technologies faster. Third, EV usage anxiety. In the TAM3 (Venkatesh and Bala 2008, p. 279) computer anxiety describes “the degree of ‘an individual’s apprehension, or even fear, when she/he is faced with the possibility of using computers’ ” as developed earlier (Venkatesh 2000). Fazel (2014) defines car usage anxiety and perceived risks of EV usage separately, where perceived risks of EV usage determines both PU and PEOU. Since asking about delivery personnel’s car usage anxiety does not make sense (driving cars is an essential part of their job), we omit this construct and focus on perceived risks of EV usage. Therefore, we define the perceived risk of EV usage as the subjective expectation of the driver that driving the EV will be different from driving the ICEV

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41 Venkatesh et al. (2007) offer an extensive overview of job satisfaction in the TAM context.

42 Whereas, e.g., ecological attitude is based on personality traits.
while in operation for delivery purposes. Also, we ask for anxiety before the very first use, i.e. the switching from ICEV to EV (Venkatesh 2014). Even though Franke et al. (2012) and Wikström et al. (2014) found indicators that with growing experience range anxiety will be diminished, we included the item range anxiety here, since it still could prove relevant for drivers’ contentment with EVs.

Appendix B: UTAM measurement scales and reliabilities

Table B.1. UTAM constructs and PCA components

**Intention to use**

If, at the beginning of your workday, you would be able to choose between the EV and DV, would you favor the EV?

*Perceived usefulness (PU): 4 components after PCA. Cronbach’s alpha = 0.88*

- **PU-automatic-gear: positive effects of handling the automatic gear**
  In comparison to the ICEVs’ manual gearboxes, the EVs’ automatic gearboxes lead to
  - relaxed driving.
  - easier handling of the EV than the ICEV.
  - easier driving because through less hand and arm movements because I do not have to shift gears manually.
  - faster driving because I do not have to shift gears manually.
  - faster deliveries because I do not have to shift gears manually.
  - higher concentration of traffic.
  - quicker starts at traffic lights and crossings.
  - easier overtaking of traffic.
  - clumsier driving.

- **PU-technical: general PU, engine noise, and negative effects of recuperation**
  I find the EV useful in my job.
  Using the EV in my job decreases my productivity.
  Using EV for delivery services is a good idea.
  In comparison to the ICEVs’ engine noises, I like the noiseless driving with the EV.
  The recuperation of the EV leads to more difficult driving.

- **PU-engine-noise: positive effects of now non-existent engine noises**
  Due to noiseless driving,
  - other traffic participants fail to hear the EV.
  - I have to concentrate more on traffic.
  - the driving has become more dangerous.
  - I have to drive more anticipatory.

- **PU-environment-recuperation: positive effects of environmental and recuperation impacts**
  The EV is reasonable because
  - it contributes to environmental protection.
  - it avoids noise emissions.
  The recuperation of the EV leads to
  - less braking.
  - steering the car mostly with the accelerator only.

- **PU-acceleration: dropped due to many non-answers**
  The EV accelerates faster than the ICEV. (measured on a yes/no-scale)
  I like the acceleration of the EV compared to the ICEV.
  Because the EV accelerates faster than the ICEV, I drive less cautious with the EV than with the ICEV.

*Perceived ease of use (PEOU): 3 components after PCA. Cronbach’s alpha = 0.82*

- **PEOU-learning: ease of learning on how to use EV and the charging infrastructure and user-friendliness of the range display.**
  Driving with the EV
  The handling of the EV (e.g., parking, maneuvering, loading the trunk)
  The handling of the battery charging infrastructure
  is easy.
  is easy to learn.

- **PEOU-hindrance-all: usage hindrance, i.e. having a negative influence on PEOU. Reversed ease of driving and handling the EV and handling the charging infrastructure, i.e. user-unfriendliness, hindrance of driving and handling the EV, and handling the charging infrastructure.**
Driving with the EV is often frustrating.

The handling of the EV (e.g., parking, maneuvering, loading the trunk)
The handling of the battery charging infrastructure (“is often frustrating.” – removed due to low item-test and item-rest correlations)

*PEOU*-cognitive-operative: explains the cognitive process that lies behind driving and handling the EV and handling the charging infrastructure. It also describes the satisfactory functioning and proper operation of the EV.

You can trust the information given on the range display.
The volatility of the forecasted range on the range display irritates me. (removed due to low item-test and item-rest correlations)

Overall, the EV works flawlessly.

**Satisfaction with the EV**: 1 component after PCA. Cronbach’s alpha = 0.69

How satisfied were you with the EV used in the last 4 weeks?
Overall, I am pleased with the EV.

**Specific satisfaction with EV**: 1 component after PCA (n = 5; preference ranking with free text; answer rated on a 5-point Likert scale). Cronbach’s alpha = 0.99

Which EV do you prefer and why?

**Satisfaction with the DV**

How satisfied were you with the ICEV used in the last 4 weeks?

**Intrafirm image**: 1 component after PCA. Cronbach’s alpha = 0.88

My colleagues who use the EV have more prestige than those who do not.

By using the EV, you attract attention among colleagues.
Using the EV is a status symbol among colleagues.

**Social norm**: 1 component after PCA. Cronbach’s alpha = 0.79

Other traffic participants and customers react positively when they see the EV on the street.

I am proud when other traffic participants and customers react positively towards the EV.

Because other traffic participants fail to hear the EV, they react negatively towards the EV. (removed due to low item-test and item-rest correlations)

Other traffic participants are happy to see the EV on the street.

People who are important to me like the EV.

**Ecological attitude**: 1 component after PCA. Cronbach’s alpha = 0.60

The use of the EV gives me a good conscience.

During delivery service, I choose a driving style that uses least electricity or fuel.

**Job satisfaction**: 1 component after PCA. Cronbach’s alpha = 0.83

One should not expect too much from work.

I really take a pleasure in doing my work.

My work is the same old rut; it cannot be helped. (removed due to low item-test and item-rest correlations)

What do you think? Is your work really interesting and satisfying?

**Perceived enjoyment**: 1 component after PCA. Cronbach’s alpha = 0.96

I enjoy using the EV.
The usage of the EV is enjoyable.
I have fun driving the EV.

**EV usage anxiety** (removed before PCA due to low item-test and item-rest correlations)

I am afraid of having low driving range with the EV.
I was nervous before the first use of the EV.

**Technophilia**: 1 component after PCA. Enjoyment in the interaction with new technology. Cronbach’s alpha = 0.85

I am curious regarding technical innovations.
I take pleasure in technical innovations.
I am always interested in using the newest technical devices.
If I had the opportunity, I would use technical devices more often than I do now.
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