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User acceptance of wireless electric vehicle charging

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Summary

This study presents results of an analysis on user acceptance of wireless electric vehicle charging. A structural equation model is developed based on Davis' technology acceptance model (TAM). It is expanded integrating elements of Ajzen's theory of planned behavior (TPB). Main factors influencing acceptance of wireless electric vehicle charging are evaluated and analyzed. Empirical findings indicate that survey participants' acceptance of wireless electric vehicle charging is mainly influenced by their affective evaluations of wireless charging, subjective norms, perceived usefulness of wireless charging and environmental awareness. The results indicate a high degree of acceptance for wireless charging. Even individuals with lower degrees of acceptance are willing to use wireless charging within car-sharing or commercial fleets.

Keywords: wireless charging, user behavior, inductive charger, battery charge, EVSE (Electric Vehicle Supply Equipment)

1 Introduction

According to the German Climate Action Programme 2020 the transport sector is supposed to contribute to the 2020 climate targets even though its contribution is missing so far [1]. One of the measures to achieve this goal is increasing the share of electric vehicles (EV). Accordingly, in 2014 the German government confirmed the ambitious targets of one million EVs in 2020 and six million EVs in 2030 [2]. Additionally, several German cities are having difficulties to meet the thresholds for particulate matter and nitrogen oxide emissions required by the European Commission and are therefore discussing partial driving bans for vehicles with combustion engines [3]. The German government decided to subsidize EVs firstly registered after May 2016 with up to 4,000 Euros [4]. However only 11,652 buyers (20,627 including plug-in hybrid electric vehicles) applied for this subsidy until May 2017 [5], increasing the total number of EVs to 42,015 [6, 7]. Recently even Chancellor Merkel doubts that German EV targets for 2020 will be reached [8]. Besides other reasons like limited range and high purchase prices [9], the lack of comfortable charging options might be a reason for still low adoption rates [10]. According to the former head of AUDI's technical development division Mr. Hackenberg „…plug-in hybrids and electric cars will never reach their full market potential unless wireless inductive charging spreads across the fleet [11].“ Surveys conducted by the National Renewable Energy Laboratory seem to support this statement [12]. Different authors have evaluated user acceptance of wireless charging for EVs [13, 14], some of them asking for possible reasons concerning the preference of wireless charging [15, 16]. In [10] an ANOVA was performed to measure affective, cognitive and conative dimensions of wireless EV charging process acceptance. To our knowledge, the main factors influencing acceptance of wireless EV charging have not been analyzed with the help of regression- or

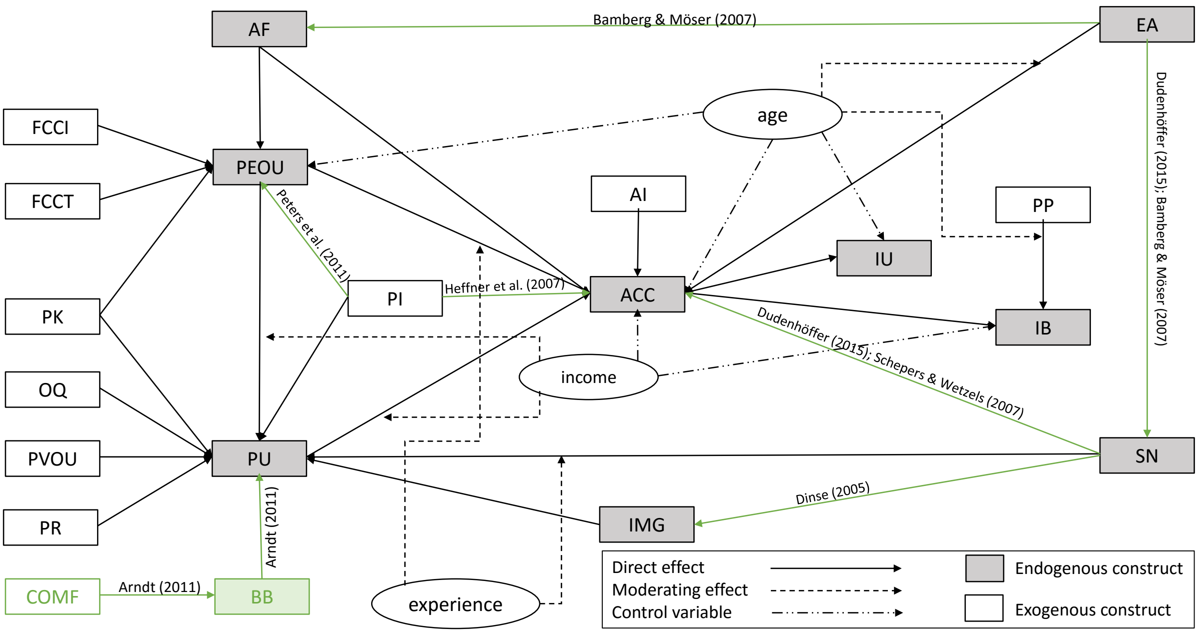
structural equation models (SEM) so far. This article intends to fill this gap in literature by analyzing factors potentially influencing acceptance of wireless EV charging. Additionally we analyze differences between commercial (fleet-) users and private users as well as between individuals who regularly use EVs and those who do not.
This paper is structured as follows: In Section 2 the methodology and the empirical data used to evaluate our structural equation model are described. Section 3 shows exemplary results including acceptance scores, quality measures and main effects of our SEM, as well as findings of our multigroup analyses. In Section 4 potential limitations of our work are discussed, before conclusions are provided in Section 5.

2 Methodology and data

2.1 Structural equation modelling

Our model is mainly based on [17, 18], where two models explaining user acceptance of EVs are introduced. The models are based on the technology acceptance model originally developed by Davis [19]. We extend the model using elements of [20], where a model for user acceptance of driver assistance systems based on the theory of planned behavior by Ajzen is presented [21]. The complete structural model depicting the hypotheses is shown in Figure 1.

The latent variables and their definitions are presented in Table A.1 in the Appendix. In accordance with [22] we mainly use reflective constructs in order to represent the latent variables. However, for some latent variables, such as comfort, it is necessary to consider different aspects (e.g. the need to park more accurately and not having to handle a potentially dirty power cable), which as a whole form the construct. Hence, these constructs are specified as formative. The measurement models for all constructs and their abbreviations are described in Table A.2 in the Appendix. We chose a partial least squares structural equation model (PLS-SEM), as is recommended for model extensions and exploratory research [23]. The validity of this approach is discussed in Section 3.



ACC: Acceptance; AF: Affect; AI: Automotive involvement; BB: Behavioral beliefs; COMF: Comfort; EA: Environmental awareness; FCCI: Facilitating conditions charging infrastructure; FCCT: Facilitating conditions charging time; IB: Intention to buy; IMG: Image; IU: Intention to use; OQ: Output quality; PEOU: Perceived ease of use; PI: Personal innovativeness; PK: Perceived knowledge; PP: Price perception; PR: Perceived risk; PU: Perceived usefulness; PVOU: Perceived visibility of use; SN: Subjective Norm;

Figure 1: Structural equation model

2.2 Survey Data

After pretesting, empirical data to validate the SEM was collected with an online survey between December 2015 and January 2016. 435 respondents started the survey. Finally 266 individuals finished the survey. 2 responses contained the same value for all answers and were therefore removed. Additionally 8 responses were removed due to more than 15% missing values [20] and another 6 responses because of too short answering times (faster than 7m 57s equaling half the median response time) [cf. 29]. According to the "ten times rule" a minimum sample of 90 is required for the presented model [33], meaning that the acquired sample size is sufficient. The total of 250 valid samples consisted of 137 survey participants that were recruited in various car or electric mobility related internet forums and 113 participants of the Get eReady research project carried out in south-western Germany between 2013 and 2016 [30]. The participants of the Get eReady project were either fleet users or fleet managers of organizations (e.g. companies, public authorities or associations) using EVs.

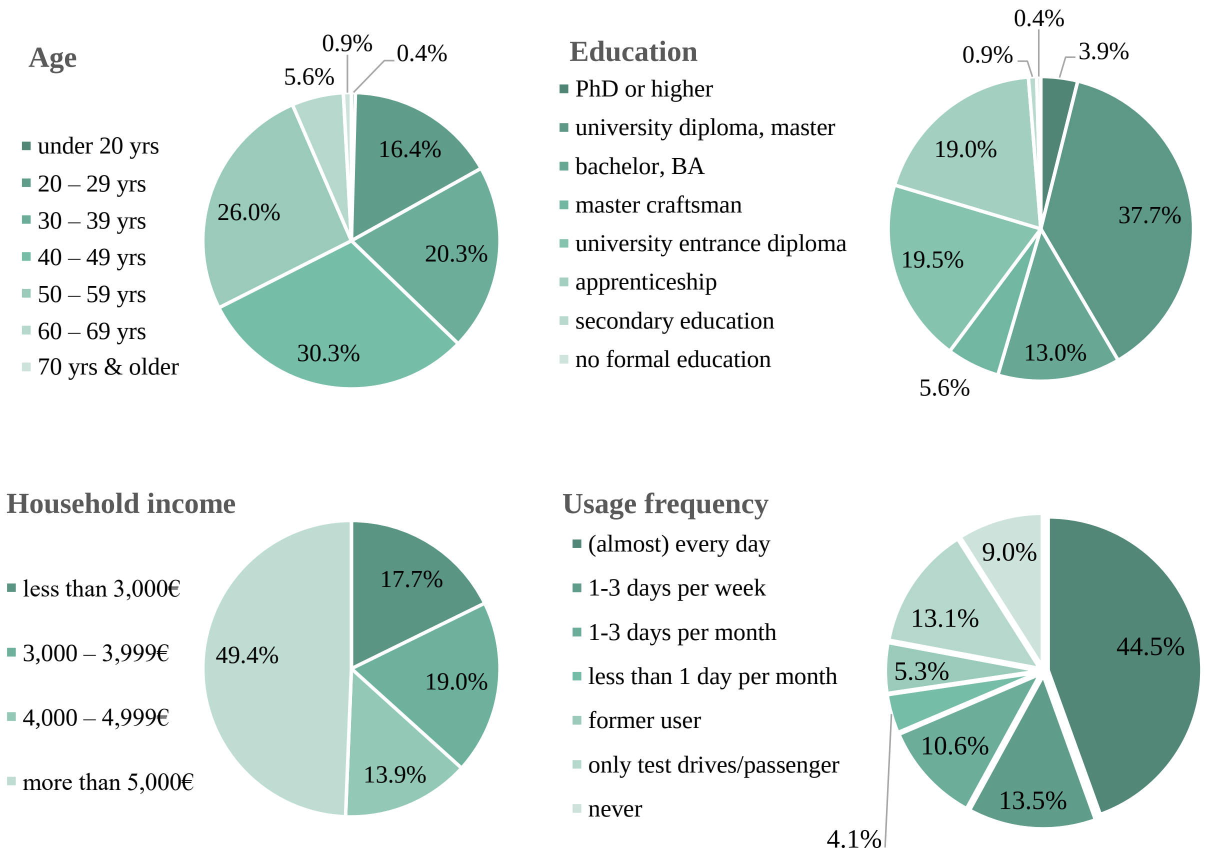


Figure 2: Demographics and EV experience of the sample

Our sample is not representative of the German population as only 6% of the respondents are female. On average the sample's respondents are 42.6 years old, one third (30.3%) being between 40 and 49 and 76% being between 30 and 59 years old. The household incomes per month are comparably high with 32.9% ranging between 3,000€ and 5,000€ and 49.4% being above 5,000€. Potential explanations for that are twofold: first, the share of people living in multi-person households is very high (82.4%). Second, education levels are very high as well with 54.5% of the respondents having a university degree. Most respondents are experienced EV users. Only 9% have never driven an EV. More than two thirds use EVs at least once a month, 58% even more than once a week. Figure 2 summarizes demographic information and EV experience levels of the respondents. Lots of similarities to [14], a large study on early EV adopters in Germany, can be observed. In this study most of the participants were also males (89%), had a university degree (50%), lived in multi-person households (89%) and had above average incomes.

3 Evaluation

3.1 Acceptance

Figure 3 shows average scores of the latent variable acceptance and its indicators. A Likert scale ranging from 1 ("completely disagree") to 6 ("completely agree") was used for all indicators. Values of 4 and higher are regarded as consent (respectively called positive values), values of 3 and lower as dissent (respectively called negative values). About two thirds of the respondents would generally like to have a wireless charger in their vehicle and would prefer wireless charging over wired charging (scores of 4 and higher). With scores of 5 or 6, the majority even has a strong consent to those two indicators. Even though more than half of the survey participants would recommend wireless charging to their friends, the average value for this indicator is only weakly positive (3.75). More than 40% stated, that wireless charging increases their interest to use and buy EVs. The average values are however weakly negative (3.26 and 3.14). A possible explanation might be the high share of respondents with high EV experience levels. EV users already have a high interest in EVs that is not increased by wireless charging. The resulting construct value for acceptance is weakly positive with an average of 3.71. For the majority of respondents the average value of acceptance reaches scores of four and higher.

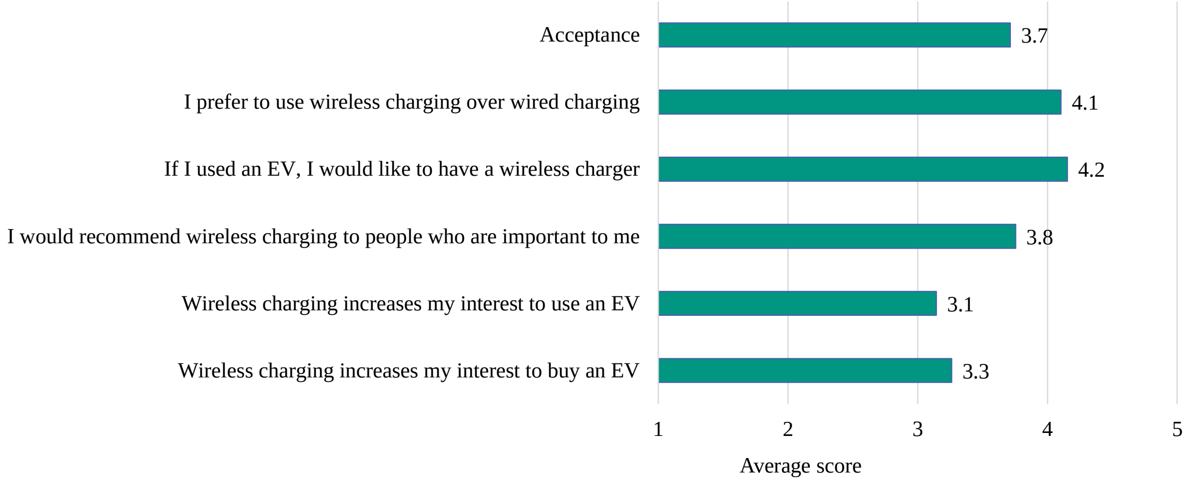


Figure 3: Average values of the construct “acceptance“ and its indicators

In addition to acceptance, the intention to buy a wireless charger and to use wireless charging offered in fleet cars was analyzed. 63% of the survey participants stated that they would be willing to buy a wireless charger, if they buy a new EV (scores of 4 and higher). For leasing the share is 7.2% lower. The average values are only weakly positive, almost neutral, with 3.77 and 3.62. About 46% of the respondents are generally willing to pay premiums for wireless charging, on average 3.14. The resulting average of the construct “intention to buy” is neutral with 3.52. Willingness to use wireless charging offered in fleet cars is much higher. More than 80% of the persons stated that they could imagine using wireless charging in car sharing vehicles, and 85% stated that they would at least try it. Averages are 4.80 and 4.53. The resulting construct value for “intention to use” is 4.67.

3.2 Quality criteria

All reflective measurement models are tested on reliability and validity. To assure indicator reliability the factor loadings (≥0.4), the significance levels (t≥1.6) and the item-to-total-correlations (≥0.4) are analyzed [31–33]. Construct reliability is tested by Cronbach’s alpha (≥0.65), factor reliability (≥0.6) and average variance extracted (≥0.5) [34–36]. Convergence validity is automatically given, if the average variance extracted and the factor reliability are above the thresholds for all constructs [37]. The Fornell/Larcker-criterion is met for all constructs, ensuring discriminance validity [36]. As correlations between indicators of formative measurement models are not necessary, statistical quality assessment as for reflective measurement models cannot be applied [37]. Some authors even state that it is not possible at all to test them for reliability and validity [22, 38]. Nevertheless, we chose formative measurements for the five constructs shown in Table A.2 in the Appendix. Reflective measurement models would not have been able to cover all necessary aspects of the constructs. Meta-analyses support the decision to use formative constructs. They have shown, that up to 35.2% of measurement models in peer reviewed articles are erroneously specified as reflective [39–41]. As statistical quality assessment is not possible, we follow the C-OAR-SE approach to assure content validity [38]. Additionally the variance inflation factors (≤ 5) are analyzed to ensure the absence of critical levels of multicollinearity [23].

The R^2-value for acceptance is 0.82 and considered as substantial [42]. The predictive value Q^2 for acceptance is 0.69 so the model has predictive relevance [43]. These are excellent values indicating a good explanatory value of our model. More details are available in [44].

3.3 Main effects of PLS-SEM

Affect (0.35), subjective norms (0.20), perceived usefulness (0.51), perceived ease of use and behavioral beliefs (0.12) have significant positive total effects on acceptance of wireless charging. Environmental awareness on the other hand has a significant negative (-0.29) total effect on acceptance. However, only environmental awareness (-0.07), affect (0.33) and perceived usefulness (0.51) have significant direct effects on acceptance. Furthermore, the effects of affect and environmental awareness are amplified through indirect effects. Factors influencing endogenous constructs that influence acceptance should be analyzed. All direct effects are listed in Table A.3 in the Appendix.

Environmental awareness has a substantial negative impact on affect (-0.44) and subjective norms (-0.30). The former has a positive influence on perceived ease of use (0.27), which also increases with facilitating conditions charging infrastructure (0.37) and personal innovativeness (0.12). In addition, comfort has a strong positive impact on behavioral beliefs (0.66), perceived ease of use (0.19), subjective norms (0.28) and behavioral beliefs (0.23) for their part have positive influences on perceived usefulness. Except for the effect of personal innovativeness on respondents' perceived ease of use, which is only weakly significant, all effects mentioned in this section are strongly significant.

Besides the already mentioned endogenous constructs, perceived usefulness is also influenced by four exogenous constructs. Perceived usefulness decreases significantly with perceived risk (-0.11) and perceived knowledge (-0.17). Output quality (0.11) and perceived visibility of use (0.14) on the other hand have a positive influence on perceived usefulness. These effects are weakly significant respectively significant. Further details concerning our analyses of main effects are available in [44].

3.4 Multigroup-analysis

In order to test for moderating effects of different discrete variables we used the PLS-multigroup-analysis as described in [45]. We analysed the different user groups in our sample distinguishing between private users and commercial (fleet-) users and between fleet users and fleet managers. Exemplary results include positive effects of perceived visibility of use and perceived ease of use on perceived usefulness, which are only significant for commercial (fleet-) users. For private users (weakly) significant positive influences of facilitating conditions charging time on perceived ease of use and of subjective norms on acceptance can be observed. Differences between fleet managers and fleet users include positive impacts of perceived ease of use and personal innovativeness on perceived usefulness, which are only significant for fleet managers. Positive influences of affect on acceptance are also significantly higher for fleet managers. In contrast, negative impacts of perceived risk on perceived usefulness are only (weakly) significant for fleet users. In addition the positive impacts of subjective norm on affect, behavioral beliefs on perceived usefulness and charging time on perceived ease of use are (weakly) significantly stronger.

We divided the participants into two groups based on the amount of experience (i.e. EV usage frequency) they already had with EVs. We found that experience levels with EVs have various moderating effects. For instance, negative moderating effects are observable on the paths between perceived technological risk and perceived usefulness, ecological awareness and acceptance as well as between personal innovativeness and perceived ease of use. Moreover, the EV experience levels have weakly significant positive moderating effects on the relationships between affect and acceptance, subjective norms and image as well as comfort and behavioral beliefs.

4 Limitations

We used formative measurement models for some constructs (c.f. Section 3.2), whose reliability and validity are hard to confirm by statistical means. As discussed in Section 2.2, we collected survey data from early EV adopters. Therefore, our sample is not representative for the German population. Furthermore, most respondents have high experience levels with EVs. E.g. gender can have a significant influence on the factors influencing EV acceptance [17, 18]. It was not possible to test for the effect of gender on acceptance of wireless charging due to the low number of female respondents. Especially taking into account that wireless charging might have the potential to attract new customer groups to EVs and current early adopters are mostly high-educated males, further studies should try to gather more balanced samples and survey people without any EV experience. Since there is only low availability of wireless charging systems in Germany yet, experience with EVs was used as a proxy. Personal experience has significant influence on EV acceptance [17, 18]. With increasing availability of wireless chargers, future studies should investigate if personal experience with wireless charging also influences acceptance. The multigroup-analysis show significant differences in the factors influencing acceptance of wireless charging. While there seem to be plausible reasons for most of them, these reasons should be confirmed by additional research.

5 Conclusions and future work

Our research indicates that in general there is a high level of acceptance for wireless EV charging. Even individuals with lower degrees of acceptance are willing to use wireless charging within car-sharing or commercial fleets. Acceptance is higher among commercial customers and especially high for fleet users. According to [46, 47] private users and fleet managers who participate in surveys can be characterized as “early adopters” with a high affinity towards electric mobility, while fleet users represent rather “normal users”. We could observe that acceptance of wireless charging and increasing interest in electric mobility caused by wireless charging is highest among “normal users”. User acceptance of wireless charging and corresponding increasing interest in electric mobility caused by wireless charging is higher amongst users with less EV experience. Interpretation of these findings lead to the conclusion that wireless charging has indeed the potential to increase adoption rates of EVs. Factors that might be important for the adoption of wireless charging have been derived from the SEM and multigroup-analysis results. E.g. the perceived discomfort caused by having to plug-in seems to be smaller for users who already have considerable experience with EVs. According to our results experienced EV users are not willing to tolerate an increase in electricity consumption of 5-6%. Hence, wireless charging systems for this target group need to be especially efficient. For users with only little EV experience the perceived technological risks have a significant negative effect on acceptance. Information on reliability and safety issues, e.g. concerning the shielding from electromagnetic radiation, are very important for potential adopters with rather low EV experience levels. For commercial (fleet-) users perceived usefulness increases significantly with increasing perceived ease of use. Therefore, a wireless charging system for commercial EV users should be especially user friendly.

This analysis is based on survey data of EV users with rather high EV experience levels. However, our sample’s respondents have not actively experience wireless charging. As experiencing new technologies might increase corresponding acceptance levels, future work should focus on surveying wireless charging EV users in addition. Wireless charging EV user needs could then be analyzed in detail. Communication strategies for promoting wireless EV chargers could be developed based on the results of SEM and corresponding multigroup-analysis distinguishing between wired charging EV users and wireless charging EV users.

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Appendix

Table A.1: Latent variables and their definitions

Latent variable	Definition
Affect	The degree of emotional and affective liking of wireless charging [18, 48].
Automotive involvement	The degree to which a person is interested in cars [18].
Comfort	The degree to which a person believes that wireless charging increases the comfort of using electric vehicles [20].
Personal innovativeness	The degree of interest in innovations and willingness to try innovative products [49].
Price perception	The degree to which a person has a positive perception of costs for wireless charging [18, 20]
Output quality	The degree to which a person believes that wireless charging systems perform well [50].
Facilitating conditions charging time	The degree to which a person believes that the use of wireless charging is hindered by lacking infrastructure [17, 51].
Facilitating conditions charging infrastructure	The degree to which a person believes that the use of wireless charging is enabled or hindered by the charging time [21, 22].
Subjective norms	The degree of approval for the use of wireless charging that a person perceives from his social environment [52].
Image	The degree to which the use of wireless charging is perceived to enhance one's status in one's social system [53].
Environmental awareness	The degree to which a person's decisions are influenced by environmental concerns [54]
Behavioral beliefs	The degree to which a person believes that the use of wireless charging will have positive effects [21].
Perceived ease of use	The degree to which a person believes that using wireless charging would be free of effort [18, 19].
Perceived usefulness	The degree to which a person believes that using wireless charging would be useful [18, 19].
Perceived risk	The degree to which a person believes that using wireless charging is safe [17].
Perceived knowledge	The degree to which a person believes to have a broad knowledge about alternative fuel vehicles [18].
Perceived visibility of use	The degree to which it is important to a person that the use of wireless charging is visible to one's social environment [49].

Table A.2: Overview of measurement models

Latent variable	Composition	# of indicators	Source
Affect (AF)	Reflective	3	[17, 46]
Acceptance (ACC)	Reflective	5	[20, 46, 55]
Automotive involvement (AI)	Formative	3	[18]
Comfort (COMF)	Formative	3	[20]
Personal innovativeness (PI)	Reflective	5	[56–59]
Price perception (PP)	Reflective	4	[18, 20]
Output quality (OQ)	Reflective	3	[17]
Facilitating conditions charging time (FCCT)	Reflective	3	[17]

Facilitating conditions charging infrastructure (FCCI)	Formative	3	[17]
Subjective norms (SN)	Reflective	3	[17, 46]
Image (IMG)	Reflective	3	[17, 20]
Environmental awareness (EA)	Formative	4	[17, 60]
Intention to use (IU)	Reflective	3	[17]
Intention to buy (IB)	Reflective	3	[17]
Behavioral beliefs (BB)	Reflective	4	[20]
Perceived ease of use (PEOU)	Reflective	3	[17, 18, 20]
Perceived usefulness (PU)	Reflective	5	[17, 18, 46]
Perceived risk (PR)	Reflective	5	[17, 18]
Perceived knowledge (PK)	Reflective	4	[17, 18]
Perceived visibility of use (PVOU)	Reflective	4	[17]

Table A.3: Results of SEM Analysis

Factor	Target	Path coefficients	t	Hypothesis	f²
ACC	IB	0.686	15.364	yes	1.118
ACC	IU	0.599	14.174	yes	0.572
PU	ACC	0.507	8.044	yes	0.310
PEOU	ACC	0.010	0.399	no	0.000
PEOU	PU	0.187	3.467	yes	0.058
AF	ACC	0.326	5.293	yes	0.124
AF	PEOU	0.270	4.162	yes	0.070
SN	ACC	0.051	1.431	no	0.006
SN	IMG	0.642	17.497	yes	0.702
SN	PU	0.283	5.527	yes	0.116
PI	ACC	0.004	0.201	no	0.000
PI	PU	0.019	0.561	no	0.001
PI	PEOU	0.119	1.664	yes (weak)	0.017
PK	PU	-0.172	3.551	yes (opposite sign)	0.057
PK	PEOU	0.021	0.458	no	0.001
EA	ACC	-0.073	2.073	yes (opposite sign)	0.020
EA	AF	-0.441	8.985	yes (opposite sign)	0.241
EA	SN	-0.296	4.655	yes (opposite sign)	0.096
AI	ACC	0.026	0.992	no	0.003
IMG	PU	0.027	0.629	no	0.001
WVN	PU	0.136	2.287	yes	0.027
OQ	PU	0.108	1.834	yes (weak)	0.021
COMF	BB	0.629	21.135	yes	0.757
BB	PU	0.234	3.756	yes	0.077
PR	PU	-0.107	2.088	yes	0.026
FCCT	PEOU	0.067	1.434	no	0.007
FCCI	PEOU	0.366	4.601	yes	0.127
PP	IB	0.257	5.228	yes	0.158

6 References

[1] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), "Climate action report 2015: The German Government's Climate Action Programme 2020," 2015.

[2] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), "The German Government's Climate Action Programme 2020: Cabinet decision of 3 December 2014," Dec. 2014.

[3] Regierungspräsidium Stuttgart, "Konzept Luftreinhaltung für die Landeshauptstadt Stuttgart: Konkretisierende Stellungnahme für die Europäische Kommission," Jul. 2015.

[4] Bundesministerium für Wirtschaft und Energie (BMWi), "Richtlinie zur Förderung des Absatzes von elektrisch betriebenen Fahrzeugen (Umweltbonus)," Jun. 2016.

[5] Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA), "Elektromobilität (Umweltbonus): Zwischenbilanz zum Antragstand vom 31. Mai 2017," May. 2017.

[6] Kraftfahrt Bundesamt (KBA), "Fahrzeugzulassungen (FZ): Bestand an Kraftfahrzeugen nach Umwelt-Merkmalen," Jan. 2017.

[7] Kraftfahrt Bundesamt (KBA), "Monatliche Neuzulassungen," 2016.

[8] S. Wimmelbücker, "Keine Million Elektroautos bis 2020: Merkel verabschiedet sich vom Elektroauto-Ziel," *Automobilwoche*, 16 May., 2017.

[9] J. Schäuble, P. Jochem, and W. Fichtner, Eds., *Cross-border Mobility for Electric Vehicles: Selected results from one of the first cross-border field tests in Europe*. Karlsruhe: KIT Scientific Publishing, 2016.

[10] T. Muellerleile, M. Orner, M. Grimm, V. Nissen, and H.-C. Reuss, "Fully Charged: Process Acceptance of Different EV Charging Processes," *SSRN Journal*, 2016.

[11] M. Taylor, "Unplugged: Audi Readying Wireless Induction Charging for Q7 e-tron," *Car and Driver*, 10 Apr., 2015, http://blog.caranddriver.com/unplugged-audi-readying-wireless-induction-charging-for-q7-e-tron/.

[12] M. Singer, "Consumer Vehicle Technology Data," Jun. 11 2015.

[13] K. Papendick, U. Brennecke, J. S. Sánchez Márquez, and B. Deml, "Nutzerverhalten beim Laden von Elektrofahrzeugen," (de), *Forschung und Innovation*, vol. 10, 2011.

[14] I. Frenzel, J. Jarass, S. Trommer, and B. Lenz, "Erstnutzer von Elektrofahrzeugen in Deutschland: Nutzerprofile, Anschaffung, Fahrzeugnutzung," Deutsches Zentrum für Luft- und Raumfahrt e. V, 2015.

[15] K. Weßner, "Marktpotenziale von induktivem Laden als Aufladetechnologie für Elektrofahrzeuge," 2011.

[16] H. Perik, "CED Project Results: Feasibility Study on Inductive Wireless Vehicle Charging," Oct. 2013.

[17] L. Fazel, *Akzeptanz von Elektromobilität: Entwicklung und Validierung eines Modells unter Berücksichtigung der Nutzungsform des Carsharing*. Techn. Univ., Diss.--Chemnitz, 2013. Wiesbaden: Springer Gabler, 2014.

[18] K. Dudenhöffer, *Akzeptanz von Elektroautos in Deutschland und China: Eine Untersuchung von Nutzungsintentionen im Anfangsstadium der Innovationsdiffusion*. Wiesbaden: Springer Gabler, 2015.

[19] F. D. Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly*, vol. 13, no. 3, p. 319, 1989.

[20] S. Arndt, *Evaluierung der Akzeptanz von Fahrerassistenzsystemen: Modell zum Kaufverhalten von Endkunden*. Techn. Univ., Diss.--Dresden, 2010, 1st ed. Wiesbaden: VS Verl. für Sozialwiss, 2011.

[21] I. Ajzen, "The theory of planned behavior," *Organizational behavior and human decision processes*, vol. 50, no. 2, pp. 179–211, 1991.

[22] C. Homburg and M. Klarmann, *Die Kausalanalyse in der empirischen betriebswirtschaftlichen Forschung: Problemfelder und Anwendungsempfehlungen*: Mannheim : Universität Mannheim Institut f. Marktorientierte Unternehmensführung, 2006.

[23] J. F. Hair, C. M. Ringle, and M. Sarstedt, "PLS-SEM: Indeed a Silver Bullet," *The Journal of Marketing Theory and Practice*, vol. 19, no. 2, pp. 139–152, 2011.

[24] S. Bamberg and G. Möser, "Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour," *Journal of Environmental Psychology*, vol. 27, no. 1, pp. 14–25, 2007.

[25] J. Schepers and M. Wetzels, "A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects," *Information & Management*, vol. 44, no. 1, pp. 90–103, 2007.

[26] G. Dinse, *Akzeptanz von wasserstoffbetriebenen Fahrzeugen: Eine Studie über die Verwendung eines neuen und ungewohnten Kraftstoffs*, 5th ed. Berlin: Inst. für Mobilitätsforschung, 2005.

[27] R. R. Heffner, K. S. Kurani, and T. S. Turrentine, "Symbolism in California's early market for hybrid electric vehicles," *Transportation Research Part D: Transport and Environment*, vol. 12, no. 6, pp. 396–413, 2007.

[28] A. Peters, M. Popp, R. Agosti, and B. Ryf, "Electric mobility–a survey of different consumer groups in germany with regard to adoption," *Proceedings to ECEEE Summer Study*, 2011.

[29] D. J. Leiner, "Too Fast, Too Straight, Too Weird. Post Hoc Identification of Meaningless Data inInternet Surveys," Ludwig-Maximilians-Universität Munich, 2013. [Online] Available: http://www.websm.org/uploadi/editor/1404997690Leiner_2013_Too_Fast_Too_Straight_Too_Weird.pdf.

[30] A. Ensslen *et al.*, "Willingness to Pay for E-Mobility Services: A Case Study from Germany," in *Proceedings of Karlsruhe Service Summit Workshop*, 2016.

[31] J. Hulland, "Use of partial least squares (PLS) in strategic management research: a review of four recent studies," (en), *Strategic Management Journal*, vol. 20, no. 2, pp. 195–204, 1999.

[32] F. Huber, A. Herrmann, F. Meyer, J. Vogel, and K. Vollhardt, *Kausalmodellierung mit Partial Least Squares: Eine anwendungsorientierte Einführung*. Wiesbaden: Betriebswirtschaftlicher Verlag Dr. Th. Gabler | GWV Fachverlage GmbH Wiesbaden, 2007.

[33] L. Zarantonello and V. Pauwels-Delassus, *The handbook of brand management scales*. London: Routledge, 2015.

[34] R. F. DeVellis, *Scale development: Theory and applications*, 2nd ed. Thousand Oaks, Calif.: Sage Publ, 2003.

[35] R. P. Bagozzi and Y. Yi, "On the evaluation of structural equation models," *Journal of the Academy of Marketing Science*, vol. 16, no. 1, pp. 74–94, http://dx.doi.org/10.1007/BF02723327, 1988.

[36] C. Fornell and D. F. Larcker, "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error," *Journal of Marketing Research*, vol. 18, no. 1, pp. 39–50, 1981.

[37] K. Backhaus, B. Erichson, W. Plinke, and R. Weiber, *Multivariate Analysemethoden: Eine anwendungsorientierte Einführung*, 14th ed. Berlin, Heidelberg: Springer Gabler, 2016.

[38] J. R. Rossiter, "The C-OAR-SE procedure for scale development in marketing," *International Journal of Research in Marketing*, vol. 19, no. 4, pp. 305–335, 2002.

[39] C. B. Jarvis, S. B. MacKenzie, and P. M. Podsakoff, "A Critical Review of Construct Indicators and Measurement Model Misspecification in Marketing and Consumer Research," *J CONSUM RES*, vol. 30, no. 2, pp. 199–218, 2003.

[40] G. Fassott, "Operationalisierung latenter Variablen in Strukturgleichungsmodellen: Eine Standortbestimmung," *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung : Zfbf*, vol. 58, no. (02), pp. 67–88, 2006.

[41] M. Eberl, *Formative und reflektive Indikatoren im Forschungsprozess: Entscheidungsregeln und die Dominanz des reflektiven Modells*: München : Inst. für Organisation, Seminar für Empirische Forschung und Quantitative Unternehmensplanung, 2004.

[42] W. W. Chin, “The partial least squares approach for structural equation modeling,” in *Methodology for business and management, Modern methods for business research*, Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers, 1998, pp. 295–336.

[43] C. Fornell and F. L. Bookstein, “Two Structural Equation Models: LISREL and PLS Applied to Consumer Exit-Voice Theory,” *Journal of Marketing Research*, vol. 19, no. 4, pp. 440–452, 1982.

[44] D. Fett, A. Ensslen, P. Jochem, and W. Fichtner, “Nutzerakzeptanz induktiven Ladens von Elektrofahrzeugen,” Institut für Industriebetriebslehre und Industrielle Produktion (IIP), Working Paper Series in Production and Energy 24, 2017.

[45] J. Henseler, “A new and simple approach to multi-group analysis in partial least squares path modeling,” in *Causalities explored by indirect observation: Proceedings of the 5th international symposium on PLS and related methods*, 2007, pp. 104–107.

[46] E. Dütschke *et al.*, “Elektromobilität in Haushalten und Flotten: Was beeinflusst die Kauf- und Nutzungsbereitschaft?: Begleitforschung zu den Modellregionen Elektromobilität des BMVI - Ergebnisse des Themenfeldes Nutzerperspektive,” Fraunhofer-Institut für System- und Innovationsforschung ISI, 2015.

[47] A. Ensslen, P. Jochem, M. Rometsch, and W. Fichtner, “Adoption of EV in the French-German context,” in *Cross-border Mobility for Electric Vehicles: Selected results from one of the first cross-border field tests in Europe*, J. Schäuble, P. Jochem, and W. Fichtner, Eds., Karlsruhe: KIT Scientific Publishing, 2016, pp. 141–171.

[48] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, “User Acceptance of Information Technology: Toward a Unified View,” *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, 2003.

[49] E. M. Rogers, *Diffusion of innovations*, 5th ed. New York, NY: Free Press, 2003.

[50] V. Venkatesh and F. D. Davis, “A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies,” *Management Science*, vol. 46, no. 2, pp. 186–204, 2000.

[51] R. L. Thompson, C. A. Higgins, and J. M. Howell, “Personal Computing: Toward a Conceptual Model of Utilization,” *MIS Quarterly*, vol. 15, no. 1, pp. 125–143, 1991.

[52] M. Fishbein and I. Ajzen, *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading, Mass.: Addison-Wesley, 1975.

[53] G. C. Moore and I. Benbasat, “Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation,” *Information Systems Research*, vol. 2, no. 3, pp. 192–222, 1991.

[54] J. A. Roberts, “Profiling Levels of Socially Responsible Consumer Behavior: A Cluster Analytic Approach and Its Implications for Marketing,” *The Journal of Marketing Theory and Practice*, vol. 3, no. 4, pp. 97–117, 1995.

[55] F. Jabeen, D. Olaru, B. Smith, T. Braunl, and S. Speidel, “Acceptability of electric vehicles: Findings from a driver survey,” *Transport Research Board of the National Academics. Perth*, 2012.

[56] A. Ensslen, P. Jochem, and W. Fichtner, “Experiences of EV users in the French-German context,” in *World Electric Vehicle Symposium and Exhibition (EVS27)*, 2013, pp. 1–12.

[57] A. Parasuraman, “Technology Readiness Index (Tri): A Multiple-Item Scale to Measure Readiness to Embrace New Technologies,” *Journal of Service Research*, vol. 2, no. 4, pp. 307–320, 2000.

[58] M. Wietschel, E. Dütschke, S. Funke, A. Peters, and P. Plötz, “Kaufpotenzial für Elektrofahrzeuge bei sogenannten "Early Adoptern",” Fraunhofer ISI, Karlsruhe, 2012.

[59] K. C. Manning, W. O. Bearden, and T. J. Madden, “Consumer Innovativeness and the Adoption Process,” *Journal of Consumer Psychology*, vol. 4, no. 4, pp. 329–345, 1995.

[60] C. Wippermann, M. Calmbach, and S. Kleinhückelkotten, “Umweltbewusstsein in Deutschland 2008: Ergebnisse einer repräsentativen Bevölkerungsumfrage.,” Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMU), 2008.

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