A User Perspective on current Drivers and Barriers for Electric Vehicle Usage in Austria

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ABSTRACT

The global electric vehicle market is rapidly growing, which is an important step, as electro-mobility is an essential driver for achieving climate targets. However, acceptance of electric vehicles is still lacking among potential users. To overcome their skepticism, it is necessary to understand the decisive factors for the consumers' decision-making process. Therefore, this work investigates essential drivers and barriers to electric vehicle adoption derived from international literature. Electric vehicle users from the electro-mobility-club Austria were interviewed by means of an online survey. Importance-performance analysis was conducted to analyze the data. Interpretations are supported by means of receiver operating characteristic analysis. The results show that the environmental performance of electric vehicles is a key motivator for participants and that this is already perceived as satisfying. Major barriers governments and manufactures should address are acquisition cost, range and time consumption associated with the usage of electric vehicles.

KEYWORDS

Electric vehicle, climate protection, climate targets, electro-mobility adoption, importance-performance analysis, receiver operating characteristic analysis

INTRODUCTION

The global electric vehicle (EV) market is rapidly growing due to a general increased awareness in terms of climate change and protection [1]. This is an important step, as electro-mobility is an essential driver for reducing carbon dioxide (CO_2) emission and eventually for achieving climate targets around the globe [2]. According to Miotti et al. [3], a shift to 100%-carbon free EVs in passenger transport is necessary to meet climate targets set for 2050.

While China holds the lead in EV sales, the market in Europe is also growing remarkably [1]. In fact, Europe is the second largest market for EVs worldwide [4]. In European countries with high EV market share national and local governments take several policy incentive measures to foster EV adoption among the population. These include financial components in form of monetary benefits, charging infrastructure expansion as convenience factor and promotion campaigns to raise awareness [4]. Either financial benefits are granted in form of direct subsidies or in form of tax breaks, whereas the latter seems to be a more effective measure to increase EV market share in a country. In addition, fee exemptions for EV drivers, like free parking, and road priority for EVs (e.g. permission to drive in a bus lane), which increases convenience for EV users, are significant drivers for the market share of EVs [5].

With a view to the Austrian market, it can be seen that new EV registrations have almost quadrupled since 2017 [6]. This could be due to the fact that several policy incentives in Austria encourage early adoption, whereby these are mainly of financial nature with the aim to raise attractiveness of EVs [7].

While monetary incentives are the most commonly used measure to overcome consumer skepticism, performance barriers such as range, battery life, charging time, speed, safety and reliability seem to be underestimated, even though they have a negative impact on EV adoption currently. The situation is similar for consumers' cognitive effort. The lack of understanding concerning fuel and maintenance cost increases uncertainty of potential users, which subsequently decreases acceptance. Nevertheless, not many measures address this issue at the current time [8]. Consumers' perception on barriers and motivators in terms of electro-mobility plays a major role when it comes to EV adoption and is therefore already focus of several research projects. However, studies on user acceptance and demand related influencing factors in Austria are rare. Adapting existing policy measures to the needs of consumers could increase the adoption of EVs in the country. Therefore, this work analyses influencing factors for EV usage and focuses on users' perception and assessment of these factors.

THEORETICAL BACKGROUND

Several studies that analyse user acceptance for EVs show that demographic factors influence consumers purchasing behaviour. Typical EV buyers are described as middle-aged male persons with high level of education and high income [9]. In addition to demographic factors, consumers' attitude, environmental values, beliefs and norms, social influences and the general awareness and experience concerning electro-mobility are crucial for adoption [10]. Even if consumers often state that they have a positive attitude toward EV technology and consider it as forward-looking and sustainable, their willingness to buy is still generally low [8]. The segmentation approach of Priessner et al. [7] confirms this low intention to buy an EV among the Austrian population. About half of their study participants stated to have absolute no intention to buy an EV. One third had at least an interest in purchasing an EV in the long term and only 16% had already purchased an EV or had an intention to buy one as their next car. A reason for this rather low purchase intention could be that barriers associated with EV usage predominate in relation to motivators. Positive aspects of EVs are often associated with negative connotations to a certain extent. While environmental protection is one of the key selling propositions of EV manufactures, many potential EV buyers doubt about it when they consider the emissions of EVs, especially the batteries, throughout their life cycle. Economic benefits in form of lower refuelling cost are offset by the high acquisition costs. And even though many users find it more convenient to charge their cars at home rather than at a gas station, the range of the battery charge means that trips have to be planned more precisely, which involves more mental effort [10]. It can thus be seen that certain aspects concerning electro-mobility cannot be assessed in only one direction, but should be seen from different angles, as they could be both, drivers and barriers. Flämig et al. [11] summarized several demand related attributes that are important for EV users and/or decision-makers of EV purchases. The authors found that the importance level of these attributes varies between decision-makers (e.g., fleet managers of companies) and individual EV users. However, they did not examine whether these factors are perceived as motivators or barriers and ultimately have a positive or negative influence on the acquisition decision. Therefore, the evaluation of the factors mentioned by Flämig et al. will be considered in more detail on the basis of previous studies.

Monetary factor and environmental compatibility

Monetary incentives are one of the main instruments governments in different countries use to increase user adoption of EVs. This is plausible as the financial aspect is, similar as the environmental aspect, one of the most powerful influencing factors for consumers when it comes to an EV purchasing decision [12]. Consumers' concerns about high costs associated with EVs is simultaneously one main barrier for adoption. Thereby, acquisition costs and recurring maintenance costs are distinguished. Running costs are lower for EVs than for conventional internal combustion engine vehicles, but they are associated with a higher uncertainty factor for consumers as electricity prices can be volatile [13].

Environmental performance of EVs is considered as another highly important aspect in the purchasing decision [12]. Pro-environmental behaviour is an essential factor that motivates consumers to adopt EVs. However, often consumers are not fully convinced that EVs are more climate-friendly than combustion cars [10]. Especially if electricity is used for charging that is not generated from renewable energy sources [14]. In addition, high costs can lead consumers to decide against buying an electric car despite an environmentally friendly attitude, especially if they also perceive the complexity of using an EV to be high [15].

Mental effort, range, flexibility and time consumption

While a single trip may not be too complicated to arrange, whole day usage can lead to more mental effort for EV users and a loss of flexibility [10]. Maximal range of an EV has to be considered in this context, speed-ups must also be taken into account, charging stations on the route have to be determined and charging operations have to be planned precisely, ideally parallel with activities performed on the trip [16]. He and Zhan [15] confirm that the higher the perceived complexity of using an EV is for consumers, the lower is their intention to adopt. Research approaches to solve this problem by providing optimized EV mobility plans already exist. However, without this knowledge about drive optimization, EV drivers rely on their intuition or experience [16]. Experience gives users a higher self-confidence when driving an EV. They find it easier to understand operating, charging and maintenance [17]. This also applies to the range estimate. EVs have a shorter range on one battery charge than combustion cars and furthermore have a longer charging duration compared to a fuelling of a conventional vehicle. This can lead to the so called range anxiety which puts the driver in a stressful situation and causes negative emotions, especially among people with little EV experience [18]. Charging duration, charging infrastructure and concerns on the battery usage are perceived as less restricting by persons who have already gained experience in driving an EV [19]. To counteract the range anxiety Noel et al. [20] suggest implementing policies that aim to reduce range-based barriers.

Usefulness, comfort and dependency

Perceived usefulness of e-mobility is subject of several studies. The Technology Acceptance Model (TAM) from Venkatesh and Davis [21] is often used for such investigations. Perceived usefulness in the context of electro-mobility can be understood as the perceived benefits that users of EVs receive from their use. The perceived usefulness of an EV has an influence on consumers' intention to adopt. Factors influencing this perceived usefulness are, in turn, the perceived ease of use, which depends, among other things, on the existing charging infrastructure and on the cost of EVs [22]. The fact that EVs can be comfortably charged at home or at work increases the convenience factor for users, as they are no longer dependent on gas stations. Ideally, users can even charge the battery using electricity generated by own photovoltaic systems, which raises their independence to a maximum [23]. However, poorly developed charging infrastructure and few service stations, as is often the case in rural areas, mean that users are forced to plan longer routes depending on the locations of individual charging stations. In consequence, this dependency increases their risk perception [24]. In terms of comfort, Wikström et al. [25] found that some users feel obligated to sacrifice their driving comfort if they are concerned about range. When they get into range anxiety, they deactivate climate systems (heating or cooling) to ensure sufficient range, which is a crucial disadvantage compared to conventional vehicles. The relative advantage of EVs compared to conventional vehicles is essential for adoption and if these advantages are not perceived by consumers or disadvantages predominate, adoption rate will remain low [26].

Individuality and public perception

Driving an EV does not only have functional benefits for users. Symbolic benefits can also be motivating factors. By purchasing an EV, a consumer can express his or her self-identity (e.g. social status), group affiliation can be a motivator and furthermore, to be an inspirer for other persons [27]. Lifestyle identities (such as "being green") that represent a person's values to the external environment are a key factor when it comes to EV adoption [9]. Priessner et al. [7] found that environmental-friendly persons are more likely to adopt EVs, while persons with a rather individualistic worldview tend to not purchasing them. Technology enthusiasts in particular feel the need to attract attention and make a public appearance by purchasing an EV, which can then lead to other consumers becoming enthusiastic about the technology. This makes them an important target group for manufacturers [23].

Technical characteristics

The speed factor is clearly associated with cars and influences consumers' purchasing decisions. For potential EV drivers it is essential that the vehicle meets their expectations in terms of maximum speed [14]. Concerning consumers' expectations, a difference can be seen between car users in urban areas and those in rural areas. In cities where predominantly low speed limits exist, low-speed EVs are preferred [24]. In addition, the size of a car is taken into account by buyers. Li et al. [24] suggest that manufacturers should additionally develop EVs with greater transportation capacity. This would meet the needs of large households.

As it can be seen, several factors influence consumers' perception on EVs and, consequently, adoption of this technology. However, the variables cannot be clearly divided into positive and negative influencing variables, since they are two-sided in most of the cases. Therefore, this study aims to identify which factors are perceived as drivers and which as barriers on the consumer side and furthermore, as how important consumers assess the single variables.

METHODS

An online survey was conducted with users from the electro-mobility-club Austria. They were interviewed about their type of EV use and charging behaviour. Main part of the survey was the rating of the above mentioned factors concerning EV adoption in terms of importance and performance (either as driver or barrier). Importance was rated using 5-point Likert items with *5 = very important*, *3 = neutral*, and *1 = very unimportant*. Furthermore, performance was rated using 5-point Likert items with *5 = strong driver*, *3 = neutral*, and *1 = strong barrier*. To interpret the drivers and barriers, an importance-performance analysis (IPA) is conducted. This tool helps to examine consumer satisfaction, which depends on both the importance and the performance of certain attributes [28]. The results are illustrated in a two-dimensional matrix, based on which four quadrants (A: "keep up the good work", B: "concentrate here", C: "possible overkill", and D: "low priority") can be distinguished in terms of interpretation and managerial implications [29]. Furthermore, attributes with higher importance than performance ratings and vice versa are split using the iso-rating line [30].

Discrimination thresholds within the IPA matrix are typically set as data- or scale-centred cut-off points. Due to methodical issues concerning the choice of such thresholds [30], receiver operating characteristic (ROC) analysis is used to set an optimal threshold [31]. The gold standard (GS) to determine satisfying ($GS = 1$) and dissatisfying ($GS = 0$) elements is set by means of the iso-rating line via equation (1):

$$GS = \begin{cases} 1, & PERF - IMP \geq 0 \\ 0, & PERF - IMP < 0 \end{cases} \tag{1}$$

with $PERF$ indicating the performance and IMP the importance of an element. A series of discriminating thresholds of performance scores is estimated by ROC analysis. The predictive accuracy measures sensitivity (SENS), specificity (SPEC) [32], informedness (INF) and the Matthews Correlation Coefficient (MCC) [33] are calculated. The obtained threshold by ROC analysis is used to conduct the final IPA.

RESULTS

The sample consist of n = 74 EV users. Out of them 64 own an EV (86.49%). Besides, participants predominantly use electric company vehicles for occupational purposes (18.92%) in addition to private use. Car sharing offers with EVs are adopted by 10.81%, a further share of 4.05% use rental EVs. Concerning their charging behaviour, most charging processes take place at EV users' residences; 20.31% of the EV drivers stated that they always charge their EVs at home, 43.75% charge at home often, 7.81% sometimes, 12.50% rarely and 15.63% never. Many fewer use public charging points; 11.11% charge their EV always on public charging points, 20.64% often, 23.81% sometimes, 42.86% rarely and 1.59% never. Also, charging frequency at work places is low; only 6.78% always use charging possibilities at work, 10.17% often, 6.78% sometimes, 10.17% rarely and 66.10% never charge their EV at work.

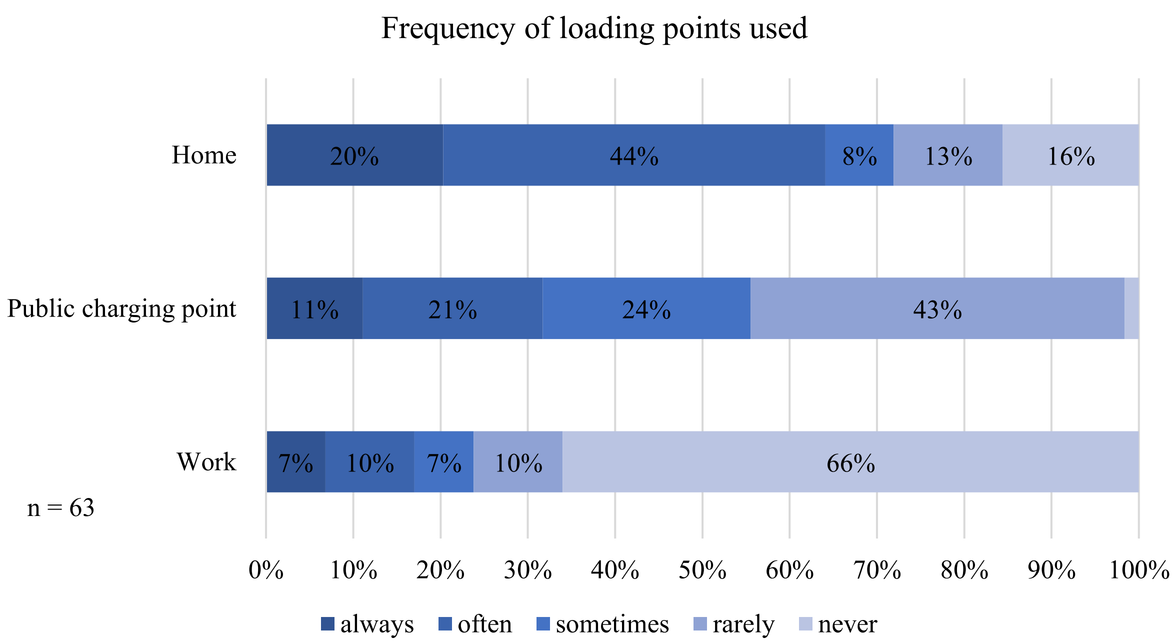

Figure 1. Frequency of loading points used

Out of the participants, 51.56% indicated that they own a photovoltaic system and 33.93% have the possibility to use a smart charging solution to charge their EV with the surplus production from their photovoltaic system. Regarding monitoring, 62.50% are able to monitor the EV charging status remotely (e.g., with a mobile app) and 65.63% to monitor the charging process remotely.

Table 1 shows the performance and importance ratings of the introduced factors concerning current EV drivers and barriers. The environmental compatibility factor performs best (M = 4.34, SD = 0.84) and is considered most important (M = 4.50, SD = 0.78). Cost effectiveness (M = 3.57, SD = 1.16), usefulness (M = 3.54, SD = 0.95), comfort (M = 3.44, SD = 1.06), individuality (M = 3.41, SD = 0.72), and public perception and image (M = 3.41, SD = 0.98) are considered further well performing factors. The importance of usefulness (M = 4.21, SD = 0.87) and flexibility (M = 4.16, SD = 0.75) is considered rather high. However, in terms of performance, flexibility is only assessed as neutral (M = 2.87, SD = 1.01). Public perception, speed, and mental and emotional effort perform better than their importance is rated. Hence, these factors can be classified as satisfying. Acquisition cost (M = 2.24, SD = 1.12) performs relatively low, whereas it is considered as rather important (M = 3.71, SD = 0.96), this turns out to be a dissatisfaction factor. Performance of transport capacity (M = 2.87, SD = 0.73), dependency (M = 2.85, SD = 0.92), time consumption (M = 2.69, SD = 0.87) and range (M = 2.62, SD = 1.32) are all rated as neutral, whereas they are considered as rather important.

Table 1. Performance and importance assessment of EV usage factors

Factor	PERF[a]	(SD[b])	IMP[c]	(SD[b])	GS[d]
Environmental compatibility	4.34	(0.84)	4.50	(0.78)	0
Cost effectiveness	3.57	(1.16)	4.01	(0.91)	0
Usefulness	3.54	(0.95)	4.21	(0.87)	0
Comfort	3.44	(1.06)	4.01	(0.86)	0
Individuality	3.41	(0.72)	3.53	(1.06)	0
Public perception/image	3.41	(0.98)	2.93	(1.33)	1
Speed	3.21	(0.84)	2.99	(0.91)	1
Mental and emotional effort	2.96	(0.76)	2.85	(0.97)	1
Flexibility	2.87	(1.01)	4.16	(0.75)	0
Transport capacity	2.87	(0.73)	3.57	(0.95)	0
Dependency	2.85	(0.92)	3.44	(1.11)	0
Time consumption	2.69	(0.87)	3.40	(1.00)	0
Range	2.62	(1.31)	3.85	(0.72)	0
Acquisition costs	2.24	(1.12)	3.71	(0.96)	0

Note: [a] PERF = performance, responses based upon 5-point scale with *5 = strong driver* and *1 = strong barrier*, [b] SD = standard deviation, [c] IMP = importance, responses based upon 5-point scale with *5 = very important* and *1 = very unimportant*, [d] GS = gold standard.

Subsequently, a proper threshold of 2.90 is set from the ROC analysis to discriminate important drivers and barriers. This threshold yields the optimal accuracy measures to classify the factors compared to the GS. In terms of informedness, classifications have a 54% edge compared to random classifications (INF = 0.54). Furthermore, a threshold of 2.90 yields in a rather high correlation of the classifications with the gold standard (MCC = 0.45). Table 2 summarizes the accuracy measures for different cut-off points.

Table 2. ROC summary statistics for different cut-off points

Performance score	TP	FP	TN	FN	SENS	SPEC	INF	MCC
2.60	3	1	10	0	1.00	0.09	0.09	0.14
2.75	3	3	8	0	1.00	0.27	0.27	0.27
2.90[a]	3	6	5	0	1.00	0.54	**0.54**	**0.45**
3.00[b]	2	6	5	1	0.67	0.54	0.21	0.17
3.14[c]	2	6	5	1	0.67	0.54	0.21	0.17
3.30	1	6	5	2	0.33	0.54	-0.12	-0.10

Note: TP = true positives, FP = false positives, TN = true negatives, FN = false negatives, SENS = sensitivity, SPEC = specificity, INF = informedness, MCC = Matthews Correlation Coefficient.
[a] Cut-off point specified by the ROC approach and the criteria INF and MCC.
[b] Cut-off point specified by the standard IPA scale-centred approach.
[c] Cut-off point specified by the standard IPA data-centred approach.

IPA results with adjustment of the discriminating threshold show that all but one of the factors addressed are rated as important by participants of the survey. Results are illustrated in Figure 2 and interpreted in this section.

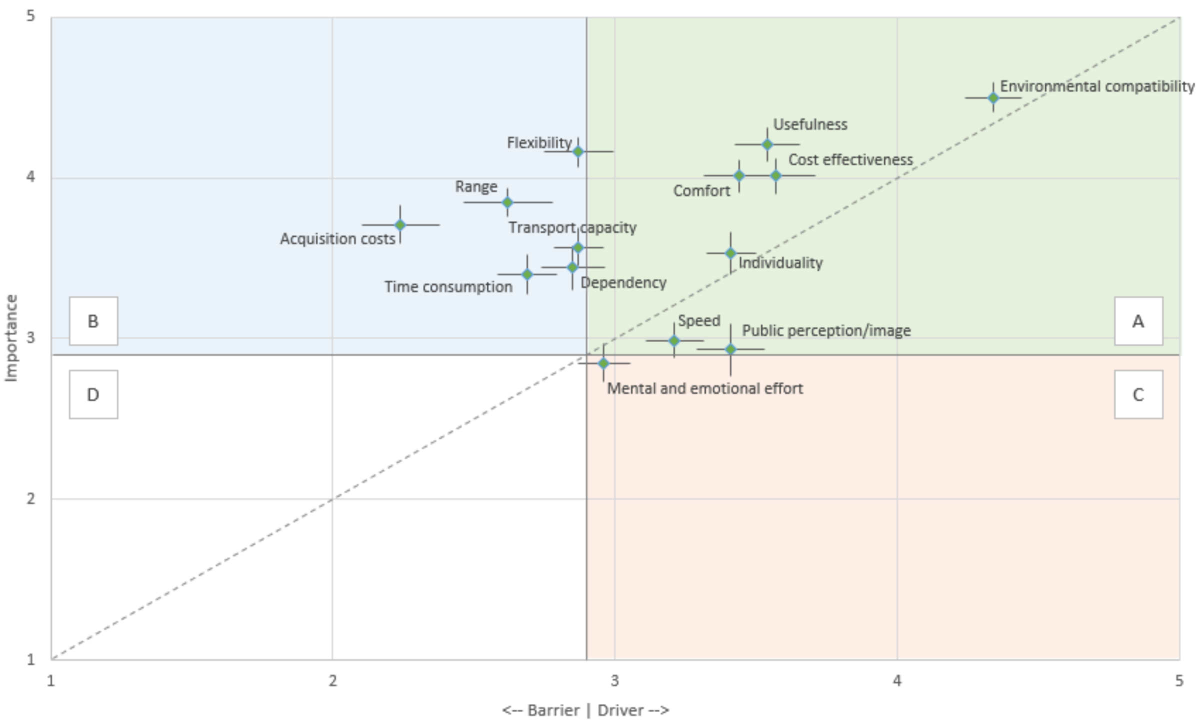

Figure 2. Final IPA matrix to elicit important EV usage drivers and barriers

Quadrant A ("keep up the good work") contains the factors environmental compatibility, usefulness, cost effectiveness, comfort, individuality, speed and public perception/image. Environmental compatibility, which several studies [12, 14] confirm to be one of the most effective aspects to foster EV adoption, is best performing and most important for the participants. It can be therefore implied that this attribute of EVs is satisfying for users and that in this case manufacturers and policy makers should continue with their measurements to maintain the environmental friendliness of EVs. Speed of EVs and public perception are both satisfying for EV users, which leads to the suggestion that such technical characteristics do not

have to be extended extraordinarily and that image campaigns of EVs do not need any major changes.
To be considered separately are the factors usefulness, cost effectiveness, comfort and individuality. Users are satisfied with these factors to a certain extent, which is consistent with current conditions. According to previous scientific findings, running costs for EVs in relation to combustion engine vehicles are lower, which in turn has a positive effect on the perceived usefulness [22]. In addition, the charging infrastructure, which is being expanded in many countries as part of governmental measures to increase EV adoption [4], influences both usefulness and comfort positively. However, importance ratings of these four attributes are higher than their performance ratings. Due to this high level of importance, more investment could be made here to enhance these factors and improve their performance to users.

Quadrant B ("concentrate here") includes acquisition costs, range, time consumption, flexibility, transport capacity and dependency. Flexibility, transport capacity and dependency lie at the border to quadrant A, which leads to the conclusion that there is space for improvement, but it is not an urgent issue. In order to increase EV adoption, more focus should be set on acquisition costs, range and time consumption. Although financial incentives are used as governmental measures in many countries to promote the adoption of EVs [4, 5], such as in Austrian [7] the purchase cost is perceived as a major negative influencing factor in the purchase decision. This barrier, perceived by consumers, must be overcome to increase the adoption of EVs. Same with the range and time consumption associated with EVs, which are interrelated in a certain way. The low range of EVs, which puts drivers in range anxiety when driving on long routes [18] and forces them to invest time in planning trips precisely [16], are significant disadvantages compared to conventional vehicles. As the queried participants are mainly EV users, the thesis that range anxiety decreases with an increasing experience level [19] does not apply here. Range is still a negative issue for experienced drivers. It is a merely technical problem that manufacturers need to address.

Quadrant C ("possible overkill) which includes only mental and emotional effort indicate that the participants, who are to a large extend experienced EV drivers, do rate this attribute positively, but also not as seriously important. This could be because experienced drivers learn how to plan their routes more efficiently over time. If there exist measures that aim to help current EV drivers to overcome mental and emotional effort, these can be reduced and investments reallocated to measures that focus on Quadrant B factors, or to targeting existing campaigns to overcome such mental effort issues at potential EV drivers with little experience.

Quadrant D ("low priority") remains empty, indicating that main elements addressed in this and several former studies are considered as important for consumers, which means that these factors should continue to be discussed in the context of EV adoption.

CONCLUSION

By querying Austrian EV users, it was possible to get an overview of their perception concerning drivers and barriers of EV adoption. Both perceived performance and importance of various factors influencing EV acceptance were investigated. In order to interpret the results of the survey in terms of user satisfaction and use this interpretation for managerial implications, IPA was applied. To improve its empirical validity and usefulness, it was complemented by ROC curve analysis. Thereby, a reliably threshold at 2.90 was identified. By applying iso-rating line to split factors with higher importance than performance or vice versa, differences between attributes located in the same quadrants can be handled more precisely.

These methodical aspects were important for interpreting the results and managerial implications correctly.

Results show that environmental compatibility of EVs is the main driver when it comes to adoption and that users' are satisfied with this attribute of EVs. This indicates that existing measures to this regard are performing well, consumers are aware of the positive impact EVs have on reducing CO_2 emission and environmental protection. Investments, on part of governments and on part of manufacturers, should therefore be continued as they currently are. The same applies to technical characteristics of EVs concerning speed and on the image and public perception of EV usage.

The situation is a little bit different with the factors usefulness, cost effectiveness, comfort and individuality. EV users are predominantly satisfied with the points mentioned, but the individual factors are of rather great importance to them, while regards performance, there is still room for improvement. Governments and manufactures should consider taking more effort here to enhance these factors for potential users.

Further factors that should be considered more carefully by governments and manufacturers are the acquisition costs of EVs, their range, and the large amount of time they require of their users in terms of planning routes. Flexibility, transport capacity and dependency are borderline cases, but fall more into the "keep up the good work" category, which means there is no urgent need for change.

Mental and emotional effort associated with EV usage, which is considered to be an obstacle according to previous studies, is no great issue for participants of this study. However, it should be noted that most of the respondents are already EV users, so the mental and emotional effort required of them has decreased over time and is therefore rated as rather unimportant.

Since there were no attributes that were identified as low priority, it can be said that all of these factors are essential to consumers' purchase-decisions and thus to EV adoption. Future studies on the use and acceptance of EVs should therefore examine the factors addressed in this paper in more detail and on a larger scale.

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