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Acceptance of E-Motorcycles: A Longitudinal Survey at Loewensteiner Platte, South Germany

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Abstract: The acceptance of e-motorcycles among German motorcyclists is the focus of this quantitative longitudinal study. By comparing survey results from 2017 and 2022, questions about changes in perception of e-motorcycles over time as well as possible stimulating factors are analyzed. The research design is built upon literature research, a secondary literature analysis, and a survey of motorcyclists. Statistical procedures are used for data analysis and interpretation. The literature analysis enables the present study to be integrated into the current state of research. The findings show that the willingness to consider an e-motorcycle as the next purchase was low in 2017 and dropped from 20% to 5% in 2022, which contrasts with the rising sales figures of e-motorcycles in the German market. Based on these findings, conclusions are drawn about the market potential of e-motorcycles in Germany and an overview of the general assessments and concerns of motorcyclists is provided.

Keywords: sustainable mobility; electro-mobility; e-motorcycle technology; motorcyclists; social acceptance; behavioral economics

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1. Introduction

One of the biggest problems associated with the operation of conventional vehicles is the pollution emitted by combustion engines. Globally, internal combustion engines in vehicles are now responsible for a large part of air pollution [1]. Electrically powered vehicles are seen as a means of reducing the consumption of oil and gasoline and lowering the emission of pollutants from individual traffic. Electro-mobility is playing an increasingly important role in Germany. Car manufacturers such as Volkswagen, with its id-models, are establishing a market segment. However, the focus is mainly on e-cars. While motorcycles have been appearing in the e-mobility segment for some time, the public has hardly noticed them. Currently, there is no state support for e-motorcycles in the form of purchase premiums or environmental bonuses. In this respect, e-motorcycles can represent an alternative to the e-car that has received little attention in Europe to date. Pollutant emissions can be reduced by replacing conventional motorcycles with e-motorcycles. This can be an important factor, especially in cities with high levels of air pollution. Looking at the environmental impact of e-motorcycles compared to conventional motorcycles, it should be noted that although the use of e-motorcycles reduces pollutant emissions, the production of e-motorcycles consumes significantly more energy than the production of conventional motorcycles [2]. While research on acceptance of e-motorcycles is growing, it is rarely examined in the German context, e.g., [2–6]. Several studies have investigated the specific technological, environmental, political, and economic factors of e-motorcycles worldwide [3]. In these studies, it became obvious that the assessments and concerns of motorcyclists play an important role in the acceptance of e-motorcycles. This paper

first seeks to gain empirical insights into the acceptance level of e-motorcycles, obtained by questioning German motorcyclists at a popular motorcycling spot, and then to detect possible changes over time by executing the same survey at two different points in time. The study aims to fill a research gap by answering the following two research-guiding questions:

RQ 1: Are there differences in e-motorcycle acceptance when considering gender and age?

RQ 2: Has e-motorcycle acceptance changed between 2017 and 2022?

This study is divided into theoretical, methodological, and empirical parts. In the theoretical part, the relevant scientific fields are presented and an overview of the current state of research is provided. The methodological part explains the procedures used to answer the research questions. Finally, the empirical part presents and evaluates the results of the survey on acceptance of e-motorcycles.

2. Literature Review

2.1. Motorcycle Technology

According to German Federal Motor Vehicle Office (Kraftfahrzeugbundesamt) [7] in accordance with Directive 2002/24/EG [8] and EU Regulation No. 168/2013 [9], motorcycles are classified as two- or three-wheelers with an internal combustion engine of more than 50 ccm or a speed of more than 45 km/h. Looking at the technology of e-motorcycles, the electric motor and high-voltage-battery are the main parts that determine the vehicle concept, and therefore the whole driving experience. While the weight of the battery is considerable, the electric engine delivers maximum torque instantly, whereas the torque curve of a combustion engine only reaches its maximum at a specific rotation speed [10]. There is no remarkable engine sound, no need for a gearbox, and the overall concept is simpler. Due to less wear on parts, the effort required for maintenance and repair is lower than for conventional motorcycles [11]. Looking at the ecological sustainability of e-motorcycles, there is substantial potential to reduce in-use exhaust emissions worldwide [1]. E-motorcycles beat conventional motorcycles in terms of greenhouse gas emissions as well as energy consumption in all categories: tank-to-wheel, wheel-to-wheel, and over the full lifecycle [2].

2.2. Sustainable Mobility

In addition to the avoidance of pollutants, the operation of electric motorcycles offers other advantages that sustainably reduce the burden on the environment. For example, electric drives are significantly more efficient than conventional gasoline-powered engines, as the energy in electric drives is converted directly into motive power while internal combustion engines convert part of the energy into heat. In addition, electric motorcycles are significantly quieter than conventional motorcycles, actively reducing the noise pollution caused by traffic [12].

Despite the environmental benefits that would result from a switch to electrically powered motorcycles, there has not yet been any great success on the market for e-motorcycles. This is due not least to their higher acquisition costs and existing technical problems. Their lower range compared to conventional motorcycles, together with limited charging infrastructure, has prevented the sustainable success of e-motorcycles to date [1].

In light of these issues, technological, economic, and social developments are important for the sustainable market development of e-motorcycles. A growing market, especially in Asia, is leading to falling prices due to economies of scale and increasing competitive pressure. Because of falling prices, the market attractiveness of e-motorcycles is increasing. Market developments in East Asia show that falling electricity prices together with rising gasoline prices and an increased demand for mobility can accelerate the market for electrically powered vehicles. Thus far, however, developments have not resulted in an increasing market share for e-motorcycles in either Europe or Asia. The main problem is that e-motorcycles do not offer their buyers any direct benefits for their higher price com-

pared to conventional motorcycles. In contrast, e-bikes offer their customers an additive benefit through an additional e-drive compared to normal bicycles [2].

2.3. Social Acceptance and Behavioral Economics

Social acceptance is a key element in many debates surrounding the sustainability transition [13,14]. Fournis and Fortin described a socio-technical paradox known from the context of wind energy, where everybody supports wind energy while nobody likes it in the nearby vicinity: "The social dimension has become a factor of equal importance to technology in the wind farms implementation" [13]. This paradox can probably be applied to sustainable mobility and the acceptance of e-motorcycles. In addition, various studies have concluded that social acceptance is vital in terms of technology and innovation transfer [15–18].

According to Upham et al. social acceptance can be understood as "A favorable or positive response (including attitude, intention, behavior and—where appropriate—use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)" [17] and p. 102 in [18]. Social-acceptance can be divided into three dimensions, as proposed by Wüstenhagen et al. [14] and p. 3 in [18]:

- Socio-political acceptance points to the overall "Societal climate towards a technology or innovation within a society" (p. 3 in [18]). In the case of this study, this dimension would refer to how approaches to achieve sustainable mobility, in particular the diffusion of e-motorcycles, are positively or negatively perceived by the public and opinion leaders [14,18].
- Community or local acceptance focuses on "Attitudes and behaviors exhibited by those indirectly affected" (p. 3 in [18]). Relating to e-motorcycles, this could describe charging infrastructure located near residents.
- Market acceptance can be understood as "The process of market adoption of an innovation" (p. 2685 in [14]). Stakeholders such as consumers and investors are relevant in this dimension. Market acceptance is measurable, for example, in the market share of motorcycles and related purchasing behavior (p. 3 in [18]).

Whether a general transition towards sustainable mobility, including an increase in electric mobility, will be successful is dependent on acceptance levels in the above-mentioned three dimensions, among other things. For this study, the sociopolitical and market acceptance dimensions are the focus.

Looking at the situation in Germany from a behavioral economics perspective, Augenstein [19] stated there seems to be a dichotomy of opinion. On the one hand, people have a generally positive attitude towards the topic and diffusion process of electro-mobility. On the other hand, there is a blockade against recognizing electro-mobility as a holistic substitute for existing drive systems [19].

However, this study focuses specifically on the e-motorcycle vehicle segment. In Southeast Asia, where transportation is dominated by motorcycles, the economic aspect of the customer plays an essential role, as, apart from the European view, the motorcycle represents an essential medium for locomotion [1]. Because an e-motorcycle has lower consumption and emission values than a conventional motorcycle, one would think that in these countries there is a fundamental acceptance and will to opt for an e-motorcycle. However, a societal dichotomy is evident here as well. A study by Guerra [20] which looked at the acceptance of e-motorcycles in Indonesia showed important technical prerequisites that must be in place to promote social acceptance. The time required for recharging, recharging infrastructure, and higher purchase costs in relation to conventional motorcycles do not yet overlap with the ideas of potential customers. From Guerra's empirical analysis, it is possible to depict individuals who possess the following characteristics and demonstrate acceptance regarding e-motorcycles. This applies to younger people who are critically concerned with environmental influences and lead a healthy lifestyle [20].

Despite the ecological advantages, market success is not seen apparent due to additional costs and technological immaturity. With a share of nearly 2% of the German motorcycle sales in 2021, e-motorcycles are a small yet fast-growing segment, with an increase of 149% in the first half of 2022 [21]. Their relatively low range in combination with limited charging infrastructure is seen as a main disadvantage for e-motorcycles [1]. Looking at Germany, the generally positive attitude towards e-mobility contrasts with a low willingness to change mobility patterns and technologies [18,19]. Focusing on the motorcycle segment in Germany, purely economic criteria cannot explain customer behavior.

Several German studies focus on the social acceptance of electric vehicles on the demand side, especially by private users [18,22,23]; however, until now research has largely neglected the role of motorcyclists in the transition to e-mobility [2,5].

3. Methodology

The research design was built around literature research, a secondary literature analysis, and a survey of motorcyclists. Statistical procedures were used for data analysis and interpretation. A literature analysis enabled the integration of the present study into the current state of research [24,25].

A longitudinal quantitative survey based on a non-probabilistic convenience sample was used to build the empirical core approach of this study [26–28]. By using standardized closed questions, comparable data should be generated to answer the research questions. The questions included in the questionnaire can be divided into two basic types. On the one hand, there were identification questions, the aim of which was to identify the respondent, for example, by gender and age. Participants were asked about their gender (male/female) and their age. Regarding the latter, they were asked to assign themselves to one of the following age groups: younger than 25, 25–29 years, 40–59 years, or older than 60 years. No identification questions asked about personal information which could endanger the anonymity of the respondent. On the other hand, the selection type questions provided alternative options to answer a question. Regarding these questions, the respondent decided on a combination of a yes–no type, where only one yes or no answer can be selected, for example, Q2 "Would you consider an e-motorbike for your next motorbike purchase"? and Q5 "Would you buy an e-motorbike if a state bonus of approximately EUR 4000 were introduced, as in Italy/Austria"? A variation of the selection type question was used for Q1, in which respondents could choose one of several options about whether or not they already have experience with e-motorbikes. In addition, scale was used for several questions, allowing respondents to develop a certain tendency with respect to a statement concerning the maintenance costs, noise level, and reduced environmental impact of e-bikes (Q3). This scale was used to learn about possible concerns the participants might have related to e-motorbikes regarding state-of-the-art of the technology, charging times, and charging infrastructure (Q4). Participants could choose on the following scale: strongly agree, somewhat agree, somewhat disagree, strongly disagree, and no response. As a third type, multiple-choice questions were used in the context of the selection type of question, in which more than two answer categories were selectable [29–31]. This question type applies to Q6, in which participants were asked whether they already own an e-bike, e-car, or e-scooter. The content of the questions was derived from the literature review mentioned above, e.g., other studies about acceptance aspects [18–20].

With the help of a scientific questionnaire, we analyzed the acceptance of e-motorcycles. The Löwensteiner Platte in the town of Löwenstein in Baden-Württemberg was selected as the location for the survey. This choice was based on the high visitor frequency of motorcyclists who rest at this location. In addition, the surveys were conducted at the end of the regular motorcycle season, on 28 October 2017 and again on 22 October 2022. Both times, 41 people were surveyed. This included 33 male and 8 female motorcyclists. The survey contained seven questions, two of which were used to identify the respective age classification and gender of the person. The remaining questions were intended to elicit clarifying results on acceptability in the areas of vehicle technology, sustainability, and

behavioral economics. The set of questions was mostly identical for the two survey dates in order to allow a comparison of changes in acceptance of e-motorcycles. Two questions were added to the survey in 2022 to investigate willingness to buy an e-motorcycle if it were supported with a state premium and whether the participants already owned another type of e-vehicle.

4. Findings

4.1. Differences in E-Motorcycle Acceptance Considering Gender and Age

The mean value of the communicated answers was classified into four asymmetric categories when evaluating the questionnaires. Thus, the significance of the results in columns one and four of Table 1 of a smaller interval should be strengthened.

Table 1. Result classification of the mean values (own table).

No Acceptance	Rather No Acceptance	Rather High Acceptance	High Acceptance
$X \leq 1.5$	$1.5 < X \leq 2.5$	$2.5 < X \leq 3.5$	$3.5 < X \leq 4$

The results of the survey yielded a cumulative mean value of 2.1 in 2017 and 1.7 in 2022, which means that there is a rather negative consensus regarding the acceptance of e-motorcycles within the scope of this study (Table 2).

Table 2. Result classification of the mean values for 2017 and 2022 (own table).

Mean Value	2017	2022
Frequency 1 (≤ 1.5)	4	14
Frequency 2 ($1.5 < x \leq 2.5$)	29	25
Frenquency 3 ($2.5 < x \leq 3.5$)	8	2
Frequency 4 ($x > 3.5$)	0	0
	41	41

In order to answer the first research question ("Are there differences in e-motorcycle acceptance by considering gender and age"?), the means difference test between gender and the total sum of the mean value was used. In this way, a low link can be found with a value of −0.27 for 2017 and 0.17 in 2022. Thus, the results for women were never in the range of positive acceptance. Men, on the other hand, tended to rate acceptance positively, with a percentage of 24%. It was striking that no results could be assigned to a high acceptance of a value greater than 3.5 in either year. When considering the means difference test between the criterion of age and the mean value, a higher degree of link of 0.40 can be determined for 2017, whereas in 2022 the link dropped to −0.15. Only male persons with an age of over 60 years were classified as having a rather high level of acceptance, which was indicated by a value greater than 3.0.

4.2. Differences in E-Motorcycle Acceptance between 2017 and 2022

To answer the second research question ("Is there a difference in e-motorcycle acceptance between 2017 and 2022"?), the participants' answers that showed tendencies towards acceptance or non-acceptance were analyzed.

The results reveal a rather critical view of e-motorcycles. Even though the prominence and visibility of e-motorcycles among participants increased by 25% in 2022, the willingness to buy such a vehicle decreased by 27% compared to 2017 (Table 3).

The willingness to consider an e-motorcycle as the next purchase was low in 2017, and dropped even further from 20% (eight survey participants) to 5% (two survey participants) in 2022. This is interesting, as knowledge about e-motorcycles grew significantly over this period. The participants seemed to be less tentative or show greater acceptance with regard

to other kinds of electrically powered vehicles, as 15% of the participants already owned an e-bike, e-scooter, or e-car.

Table 3. Result classification of the mean values for 2017 and 2022 by survey question (own table).

Year		Age	Q1	Q2	Q3.1	Q3.2	Q3.3	Q4.1	Q4.2	Q4.3	Q5	Q6	Average MV (Without Q5+6)
2017	Mean value	2.05	1.39	1.59	2.61	1.80	2.63	2.19	2.08	1.73			2.09
2022	Mean value	2.88	1.73	1.15	1.87	1.39	2.25	1.81	1.79	1.48	1.15	0.20	1.67
Delta 2022–2017		0.83	0.34	−0.44	−0.74	−0.41	−0.38	−0.38	−0.28	−0.26			−0.42
Change in % compard to 2017		40%	25%	−27%	−28%	−23%	−15%	−17%	−14%	−15%			−20%

In 2022, 78% of the participants considered the technology to be in the development stage. The lower costs of ownership in comparison with a conventional motorcycle were not seen as a countable advantage by 74% of respondents. The greater environmental friendliness and the lower noise emission were not relevant factors for 58% of the motorcyclists. On the contrary, the missing acoustic profile of a combustion engine seemed to be a negative factor for the acceptance of e-motorcycles for 88% of respondents. Charging duration and low range, together with limited charging infrastructure, were seen as weaknesses for e-motorcycles. Adding to the picture, only 5% of those questioned would buy an e-motorcycle in the case of a state purchase bonus of approximately EUR 4000, such as is available in Italy or Austria.

In conclusion, the acceptance scores consistently decreased slightly between 14% and 28% (Q3.1 to Q4.2) (Table 3). In addition, the general acceptance indicator (average of all MV) decreased by 20% when comparing the results of the 2017 and 2022 surveys. These are remarkable results, as the sales figures of e-motorcycles in the German market rose significantly in the first half of 2022 [1].

When looking at the results of the two additional questions used in the 2022 survey, social acceptance remains low even in the scenario where incentives are in place. Only two of the 41 survey participants (5%) would be willing to buy an e-motorcycle if they were to receive a state subsidies of EUR 4000 such as the one provided in Austria and Italy. Thus, when considering the second research question, the social acceptance of e-motorcycles among participants remained low and even dropped from 2017 to 2022. Presumably this is because the diverging driving experience of e-motorcycles, continuing technical immaturity, and high acquisition costs have not been resolved from the viewpoint of the survey participants.

5. Discussion

Unlike in other countries, e.g., Asian countries, two-wheeled vehicles play a minor role in everyday traffic in Germany. In many Asian countries, motorcycles and scooters form an important means of transport, as they are cheaper, space saving, and often replace cars [2,4]. In Germany, on the other hand, the car is the main means of transportation for a large part of the population with regard to commuting. In 2020, 68% of Germans regularly used a car to reach their workplace. Motorcycles fell into the other 1% of vehicles [32]. Even though urban areas in Germany are electrified, two-wheeled vehicles are increasingly used for fulfilling micro-mobility needs or in the context of sharing offers in more sustainable way, e.g., e-scooters or e-bike-sharing, while riding a motorcycle is predominantly a leisure activity [1,2]. The power of the engine and sound of the motor are part of the experience for many motorcyclists, and might not be same when riding an e-motorcycle. For many users riding such a powerful and loud vehicle is part of their lifestyle. The "move into the wild" syndrome, as described for car drivers by Viola [33], could be applied to motorcyclists as well. The results of this survey support the above-mentioned statements, as the participants viewed the missing or varying features of e-motorcycles concerning the motor sound and

noise as negative attributes. As motorcycling in Germany is mainly a leisure activity, the importance of positive emotions such as happiness, flow, or self-image congruency as part of the driving experience might be higher than in other countries in which motorcycles are mainly used for transport and commuting. In addition to terrain characteristics, vehicle dynamics are important features, while range and accompanying infrastructure might contribute to the driving experience as well [34,35]. Thus, the driving experience of e-motorcycles might be different from riding a combustion engine motorcycle, potentially leading to lower acceptance of e-motorcycles among the participants.

Market acceptance, i.e., the adoption process of market innovations, seems to be slow for e-motorcycles when looking at the "traditional" consumer segments of motorcyclists.

There is only a limited supply of e-motorcycles from the leading motorcycling companies; in particular, the German manufacturer and market leader BMW does not offer e-motorcycles. Therefore, there is no electric equivalent model for the best-selling conventional motorcycle in Germany, the BMW GS 1250. At the same time, there is strong growth in sales figures driven by new market competitors. It would be interesting to find out whether new target groups are responsible for the growing sales figures of e-motorcycles and how this increase can be explained.

6. Conclusions

Our analysis of motorcycle technology, ecological sustainability, and behavioral economics reveals insights into the structure of the e-motorcycle segment. The relevant aspects were addressed through two surveys during 2017 and 2022, showing that motorcyclists' acceptance of e-motorcycles was relatively low and declined over the study period. Our results further suggest that technical immaturity cannot be overcome through incentives.

Considering limitations, the surveys only asked about the lower maintenance costs of e-motorcycles as a possible important factor for acceptance. The potentially higher purchase price of e-motorcycles could be another impeding factor, along with technical immaturity; however, this factor was not considered in the survey. In addition, it has to be mentioned that this study only involved motorcyclists in South Germany, and used a non-probabilistic convenience sample. Apart from these limitations, the sample size is very small. Due to these framework conditions, the power of generalization of these findings is limited. Further research steps should consist of sending the questionnaire to other European regions.

In terms of the social implications and the dimension of socio-political acceptance of e-motorcycles, the results of this study suggest that even though there is a political desire for an increase in electrically powered vehicles and traffic, technical immaturity leads to them finding little acceptance in the market among classic motorcyclists.

Regarding practical and managerial implications, the results of this study could help e-motorcycle manufacturers to enhance their marketing and product strategies. Trying to sell e-motorcycles to classic motorcycle customers using established marketing concepts and selling propositions does not seem to be very promising, while investing in research and development to create the best e-motorcycle to meet classic customer requirements might not succeed either. Instead, the challenge may involve creating new marketing strategies against the background of e-motorcycle technology, sustainable mobility, social acceptance, and customer behavior. One promising way to increase acceptance of e-motorcycles could be to create new types of two-wheelers which may not be direct competitors to classic motorcycles. This could be achieved by using additional engineering degrees of freedom available thanks to not having to integrate a combustion engine. In addition, new ways of promoting e-motorcycles should be developed and tested, for instance, not rationally as better means of ecological and sustainable transport, but emotionally charged, for example, as a joyful and exciting adventure for the young and brave.

From the managerial perspective, it is important to examine whether the traditional motorcycle brands have the potential to be expanded to e-mobility or whether new brands have to be created. To reach new customer types, e-motorcycle manufacturers need better

overviews as well as insights from possible focus groups. The findings of this study could help decision-makers to better understand the mindset of motorcyclists. It could be a promising approach to use the results of this study to identify and analyze these customer segments. Theoretical implications could be developed in further research by following up on the questions around whether traditional motorcyclists are reluctant to buy e-motorcycles and what the profiles of the new e-motorcycle buyers are from marketing and behavioral economics perspectives.

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