Mobile sensors on electric bicycles – a qualitative study on benefits and requirements from user perspective

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Abstract

Electric bicycle (e-bike) sales have enjoyed tremendous growth in recent years. As the e-bike market is maturing, the collection, analysis and display of usage data is becoming an important source of differentiation for competitors. Several alternatives are conceivable as to how usage data might be collected, one of them being mobile sensing devices, which are permanently attached to the bicycles. While the technical feasibility of such devices appears within reach, little is known about the benefits and requirements from user perspective. This qualitative study presents findings from interviews with 33 potential users. User requirements concerning the sensor specification are derived and insights provided into users' interest in bicycle-related data and their assessment of data sensitivity.

1 Introduction

In recent years, a new means of transportation has been becoming a more and more common sight on European streets. The market for electric bicycles (e-bikes) is booming at double digit annual growth rates. In Germany, the largest European market for e-bikes, more than one million e-bikes have already been sold [16]. Unlike regular bikes, e-bikes require additional user interfaces for the selection of individual motor support levels and for controlling of the battery status. These interfaces are typically implemented as small devices mounted on the handlebars and often additionally provide basic information about the speed and mileage of the e-bike. Recently, some producers have started to integrate more comprehensive features into these e-bike computers, such as navigation functionality, fitness applications and smartphone connections, and to provide data-based services to the e-bike users (c.f. [14]).

The idea of collecting and displaying data about bicycle usage is not new. Cyclometers as well as a range of smartphone applications have been offering functionality for tracking and displaying bicycle routes for years [5]. Compared to cyclometers and smartphone applications, e-bike computers however offer the advantage that additional e-bike-specific data and in some cases more exact data can be displayed. On the other hand, in order to offer these extra features, additional sensors are being integrated into the e-bike computers, which results in an increase in size. A further drawback lies in the fact that the sensing unit is usually removed from the e-bike after usage, thus potentially preventing some interesting applications of the sensors.

An alternative solution to collect e-bike-related data would be a sensing unit, which is separate from any display and built into the e-bike. First initiatives are already investigating the idea of a fixed bicycle sensor, especially from the perspective of theft protection applications (c.f. [1]). However, little is known about the evaluation of such an approach by potential users. This study seeks to investigate the requirements for and potential benefits of such a fixed e-bike sensor from user perspective. We are specifically addressing three research questions:

- What reactions and expectations do users have towards an e-bike sensor?
- What bicycle-related data are e-bike users interested in seeing?
- How do users evaluate the sensitivity of e-bike-related information?

Based on semi-structured interviews, we derive requirements regarding the specification of potential e-bike sensors. We provide insights into the interest, which e-bike users show in bicycle-related data, and their assessment of data sensitivity for e-bike-related data.

2 Theoretical background and related work

There are two fundamental domains of related work essentially focusing on bike sensor data. First of all, technical aspects of capturing bike data have been addressed by prior research. The essential questions behind the corresponding research are “Can we capture high quality data in the bike context with today’s technology?” and “How can we improve the recording of bike data?” Second, more usage oriented research focuses on the question of “What can we do with the data?”

Researchers have reported field study results to monitor routes taken by bicyclists using GPS data (e.g. [3;6]). Hood et al. provide evidence that route traces from GPS units in smartphones can indeed be used to inform transportation route choice models [6]. By comparing routes taken by cyclists to shortest routes, they could identify key factors that influence cyclists’ choices of routes. Other research in this domain is dedicated to comparing the accuracy of smartphone GPS tracking systems with high-quality external GPS units [11]. Furthermore, accuracy of GPS measurements is challenged in various urban environments such as “urban canyons” or “open streets”. Lindsey et al. demonstrate that GPS route traces recorded by external GPS units were significantly more accurate than traces recorded by the GPS units in the smartphones [11]. They conclude that while indeed general route information can be captured on the basis of GPS units in smartphones, even high-quality external GPS receiver cannot generate accurate enough data to monitor bicyclists’ use of bike lanes or other facilities.

Because devices with motion sensors and enough computing power for real-time data processing have only been around for a couple of years, research in the field of corresponding bike applications is very scarce [5]. However, some consumer products are available in the market, leveraging GPS data for bicyclists [5;8]. These GPS-trackers capture outdoor activity on the basis of information like route taken, distance travelled, time taken, average pace, and an estimation of burnt calories. Popular examples are Endomondo, Runtastic and RunKeeper [5;8]. The different apps provide similar functionality [5;8]. Most often, the route, which was taken, can be visualized on a map. Furthermore, a history of earlier activities is kept, some apps provide navigation features, and to increase motivation, it is possible to get voice feedback on the actual performance via ear buds. Moreover, it is possible to set goals for oneself and share workout summaries via social media. The usage of GPS data for cyclist is also discussed in the context of location-based services (LBS). Lehrer et al. for example conducted a field study over the course of two weeks [10]. The results show that when looking for location-related information, users mainly searched for four types of information: navigation information, addresses and telephone numbers, weather information, and arrival and departure times of transportation. LBS were mainly used when people were on the move, either by foot, bike or car, (45% of instances), followed by use at home (26% of instances). People generally used their smartphone to acquire location-related information. On their smartphone, people favoured specialized LBS apps instead of searching for information through the mobile Internet browser.

Alternative approaches include the proposal of Kawachi et al. [7], who developed a driving environment sharing system based on measurements of the cycling speed through photoelectric sensors as well as the rudder angle of the handlebars through a rotary encoder, to derive insights on the crowdedness of a street and feed the information back to the user. Shin et al. [15] investigate the usage of wireless sensor networks and bike devices including ZigBee identification modules, which they argue may be applicable e.g. for large-scale establishments, such as national parks, for controlling of the location and safety of tourists. Taking a somewhat broader perspective, Outram et al. [13] present the results of a team of researchers, who have been investigating the potential of e-bikes for collecting not only location, direction, and fitness but also environmental data. They developed an electric bicycle system, which features a number of environmental sensors, incl. CO, NOx, temperature, noise and humidity, and which has recently also been launched as a commercial product [4]. Through a corresponding iPhone user interface, the bicycle user can control the bike while riding, locate the bike and analyse data from recent trips, as well as share data with friends or the city, thereby making fine-grained environmental information available by means of a crowd sourcing approach [13].

Summing up, existing research in the context of bike sensors focuses on GPS. Prior research has shown that route traces from GPS units in smartphones can be leveraged to identify route choice. However, monitoring bicyclists' use of bike lanes or other facilities is technically not possible yet. While research in the field of corresponding bike GPS applications is very rare, several consumer products do exists leveraging GPS data. Furthermore, with regard to alternative technologies, only limited research has been conducted to date, investigating e.g. the usage of wireless sensor networks for locating bicycles. However, to the best of our knowledge there is no information publically available on use case attractiveness or user requirements for sensing devices.

3 Methodology

Due to the explorative character of the research questions, a qualitative research approach based on semi-structured interviews was chosen. This method offers the advantage that the researcher can keep a more open mind about the topics to be covered or discussed in more detail during the interview, so that concepts and theories can emerge out of the data [2].

In total, 33 participants (15 women, 18 men) at the age of 22 to 64 years (M = 35.5; SD = 11.8) were interviewed. All interviewees were employees of a Swiss insurance company, who had signed up to participate in an e-bike field study to evaluate the suitability of e-bikes for commuting.

In order to structure the responses and ensure that all relevant topics would be covered, an interview guideline was developed [2], which was evaluated in two mock interviews and refined based on the results. All interviews were audio recorded with a smartphone and the interview length was M = 22

(SD = 4) minutes. All relevant personal information about the interviewees had already been collected in advance of the interviews through an online survey.

The analysis of the interviews was conducted following inductive category building. This method allows for a systematic and structured analysis of content while avoiding a distortion of results by the researcher as much as possible [12] and is thus especially suited in view of the described research questions. In line with the approach of inductive category building, the material was systematically reviewed and analysed in two main steps. In a first step, answer categories were derived based on an examination of a first part of the interview material. Relevant passages were reduced, rephrased and generalized and answers were either subsumed under existing categories or new categories were created where appropriate. The compilation of a first comprehensive set of categories was considered complete when no new categories could be formed, after 48% of the material had been reviewed. Subsequently, a formative check of inter-coder reliability was conducted to assess the quality of the constructed categories. For this purpose, two coders independently reviewed a randomly selected excerpt (18%) of the material, based on coding instructions and guidelines as well as an exact description of the categories including typical coding examples [12]. Afterwards, the inter-coder reliability was assessed by means of Krippendorff alpha, a coefficient which assesses the agreement among coders relative to what could be expected by chance [9]. The calculation of the coefficient resulted in $\alpha = .687$ (95% CI (.492, .851), which is already a level of reliability at which cautious conclusions can be drawn from the data [9]. In a second step, differences in the coding of the interviews were then discussed by the coders and the categories and coding guidelines revised accordingly. Based on the enhanced categories and coding guidelines, the remaining 52% of the material were then coded. Ultimately, a final assessment of inter-coder reliability was conducted. For this purpose, two further coders independently coded a randomly selected excerpt (18%) of the entire material. The summative inter-coder reliability was computed and resulted in a coefficient of $\alpha = .805$ (95% CI (.642, .918), a magnitude, which establishes confidence in the reliability of the coding system and at which variables can be relied on [9].

4 Results

The interviews were very insightful and yielded many interesting results, of which we are highlighting the most important. We are presenting our findings following the order of our previously outlined research questions.

4.1 Reactions and expectations towards a bicycle sensor

When asked about their spontaneous reaction toward the idea of a sensor, which could collect data about the usage of an e-bike, specifically geoposition, distance, barometric pressure, altitude, speed and service information, and transmit the information via the mobile phone network, the interviewees provided reactions that could be classified into five categories as depicted in table 1. We found that only two interviewees reacted negatively to the idea, voicing spontaneous concerns about a potential surveillance and data sensitivity. All remaining respondents were either indifferent towards the idea of an e-bike sensor or had positive associations.

Category	Description	Citations (#)	Percentage of respondents
positive, personally	sensor perceived as exciting, interesting, useful	17	52%
positive, conditionally	sensor perceived as interesting under certain circumstances, e.g. if data is not publicly accessible	1	3%
positive, for others	no personal interest in sensor, but potentially interesting for others	3	9%
indifferent	sensor perceived as unproblematic, not interesting, does not matter	10	30%
negative	sensor perceived negatively, e.g. association of surveillance	2	6%

Table 1: Reactions to idea of an e-bike sensor, n=33, single answer

The interviewees were further asked to explain what they could imagine such a sensor would look like and which requirements the sensor should fulfil. A multitude of answers was provided by the respondents as illustrated in table 2.

Category	Description	Citations (#)	Percentage of respondents
not visible	not visible, concealed, hidden	20	61%
small	small	18	55%
light	light	9	27%
specific user interface	sensor has display, button or specific computer interface, e.g. USB cable	7	21%
no additional hardware required	data can be accessed through existing hardware, no additional hardware required	5	15%
not manipulable	not manipulable, not accessible, not removable	5	15%
not disturbing	not disturbing for user	4	12%
simple	easy, not complicated, simple	4	12%
weatherproof	weatherproof, robust	4	12%
good data availability	data collected by sensor is of good quality and readily accessible	3	9%
removable	sensor can be removed from e-bike or attached to e-bike	3	9%
specific colour	sensor has specific colour, e.g. black	2	6%
specific position on e-bike	sensor has specific position on e-bike, e.g. top front	2	6%
no user action required	user does not have to do anything with sensor	2	6%
disengageable	sensor/data collection can be stopped	2	6%
long-lasting battery	sensor battery has specific performance	2	6%

Table 2: Expectations towards an e-bike sensor, n=33, multiple answers

The most common notion appeared to be that of a small, light object, which would not be visible on the bicycle. Further associations were mentioned regarding the appearance of the sensor, e.g. that it might have a specific colour, a specific user interface, such as a display or button, or a specific position on the bicycle. With respect to the data collection through the sensor, interviewees expected that the data should not be manipulable, that it would be of good quality and that the sensor could be removed or switched off. Additionally, interviewees felt that the sensor should be simple, not disturbing, not require any additional hardware or action by the user and have a long-lasting battery.

As summarized in table 3, when asked about a potential benefit, which they might have from an e-bike sensor, two thirds of the interviewees stated that they would see a benefit in gaining access to some sort of data, e.g. about the e-bike usage, technical data about the e-bike, or data about their own health while riding the e-bike, e.g. heart rate or calories burnt. Additional benefits that were mentioned included explicitly motivational effects of a sensor, the protection of an e-bike against theft through a sensor, the locating of the e-bike and benefits provided by 3rd parties, which would become accessible through the sensor, such as improved maintenance services on the basis of the e-bike data. Only five interviewees, i.e. 15% of respondents, did not see any benefit, which an e-bike sensor could generate.

Category	Description	Citations (#)	Percentage of respondents
access to data in general	gaining access to data, e.g. usage data, technical data, health data	25	76%
motivation	motivation, competition, incentive	5	15%
theft protection	protect e-bike against theft, locate e-bike in case of theft	3	9%
locating of e-bike	locate e-bike when not stolen, e.g. locate children's bikes	2	6%
benefit through 3rd party	integrate 3rd party data, e.g. from heart rate monitor or maintenance service	2	6%
no benefit	sensor does not generate benefit	5	15%

Table 3: Perceived benefit of e-bike sensor, n=33, multiple answers

4.2 Interest in own e-bike-related data

It becomes evident from table 3, that one of the main benefits of an e-bike sensor from the perspective of a user would be to gain access to e-bike-related data. During the interviews, we investigated which data about the e-bikes or their trips with the e-bikes, the interviewees might be interested in seeing, and where they would like to see it.

The most frequently mentioned type of information respondents were interested in seeing addressed data associated with the movement of a vehicle, i.e. information around distance, usage and speed. Less frequently mentioned but certainly interesting answers were more specific to the usage of electric bicycles as opposed to traditional bicycles. Interviewees for instance expressed their interest to know how much of the total effort it took to move the e-bike and the e-bike user was effectively achieved by the physical effort of the e-bike user and how much could be attributed to the support by the electric power train. Various further answers were provided as shown in table 4.

Category	Description	Citations (#)	Percentage of respondents
distance	distance completed on e-bike incl. average distance, distance per week,…	19	66%
usage	e-bike usage, incl. frequency of usage, time of usage, duration of usage, etc.	13	45%
speed	speed, incl. average speed	12	41%
altitude	altitude, incl. Inclination	9	31%
route	location of where e-bike was used	6	21%
kcal	calories burned during e-bike usage	6	21%
extent of motor assistance	total effort for moving e-bike broken down to motor assistance vs. physical human effort	5	17%
technical data	technical data about e-bike incl. battery information	5	17%
comparison e-bike vs. bike	comparison of data generated on e-bike vs. on regular bike	3	10%
health info	pulse, heart rate, weight, etc.	2	7%
competition	competition, game, comparison with others	2	7%
exogenous data	3rd party data, not directly generated by e-bike e.g. public transport data	1	3%
general supplementary data	additional data, e.g. about type of e-bike, user reviews, etc.	1	3%

Table 4: Type of e-bike-related information interviewees are interested in, n=29, multiple answers

When asked on which device the respondents would like to view the data mentioned in table 4, three standard answers emerged during the interviews as listed in table 5. The smartphone was the most frequently mentioned device, followed by a computer or laptop and a specific display on the e-bike itself. Other, less frequently mentioned responses included e.g. via e-mail or as pdf document, which would thus also be viewed either on a smartphone or on a computer or laptop.

Category	Description	Citations (#)	Percentage of respondents
smartphone	smartphone, mobile phone, iPhone	21	72%
computer	computer, PC, laptop	16	55%
device on e-bike	device on e-bike, e.g. tachometer, bike computer	9	31%
other	e-mail, pdf document, Nike Fuelband, etc.	5	17%

Table 5: Devices on which interviewees would like to view information, n=29, multiple answers

4.3 Interest in comparison of e-bike-related data

The collection of data about one person’s e-bike trips allows for the review of individual trips as well as analyses of developments and trends over time. While this is certainly interesting and may have a motivating effect on the user, a further source of insightful information becomes accessible when one person’s data is compared to that of others. Some respondents spontaneously addressed this topic already when asked which e-bike-related data they would be generally interested in seeing, as pointed out in table 4. When we asked interviewees specifically whether they would be interested in comparing their own e-bike data with that of others, approximately 60% of respondents voiced their curiosity in a data comparison, e.g. saying that it would be exciting or funny, while about 40% of respondents had no interest in comparing their data or were still undecided, as shown in table 6.

Category	Description	Citations (#)	Percentage of respondents
yes	yes, definitely	17	52%
yes, conditionally	interesting but not so important, or only interesting under certain circumstances, e.g. comparison within same age group	2	6%
undecided	undecided, not sure yet whether interesting	2	6%
no	not interested in comparing	12	36%

Table 6: Interest of interviewees in comparing own e-bike data with others, n=33, single answer

On the topic of whom interviewees would like to compare themselves with, two thirds of respondents stated that the reference would have to be someone, who would be comparable to themselves, e.g. somebody within the same age group, with a comparable route or the same type of e-bike, as detailed in table 7. Slightly over one third of interviewees mentioned that they would like to compare themselves with somebody they knew, e.g. a family member, friends or colleagues at work.

Category	Description	Citations (#)	Percentage of respondents
comparable person	comparable person, e.g. with comparable way to work, same age group, same e-bike	13	65%
known person	known person, e.g. family, friends, colleagues at work	7	35%
top e-biker	professional biker, strong biker, person with whom to compare would be challenging	2	10%
self	self, comparison with historic values	1	5%

Table 7: Reference groups interviewees would compare themselves with, n=20, multiple answers

4.4 Assessment of data sensitivity of e-bike-related data

In order to provide e-bike users with information about their trips and comparisons of their usage with that of others, data would have to be collected and analysed to provide meaningful information. Since this analysis would most probably require the expertise of a third party, the sensitivity and protection of the data becomes a relevant topic.

We therefore asked interviewees whether they would consider data about the geoposition of the e-bike, distance, barometric pressure, altitude, speed, and service information as collected by an e-bike sensor, as sensitive information. We found that almost 40% of respondents did not consider the data to be sensitive, for 42% only the geoposition was sensitive information, while 18% thought that the data was sensitive or sensitive under certain conditions, e.g. when combined with personal information, as shown in table 8.

Category	Description	Citations (#)	Percentage of respondents
yes	yes, sensitive data	3	9%
yes, conditionally	only some data is sensitive or data is sensitive only under certain conditions	3	9%
no, only location	only location data is sensitive	14	42%
no	no, data is not sensitive	13	39%

Table 8: Assessment of e-bike-related data sensitivity, n=33, single answer

Similar results were obtained when interviewees were asked whether they could imagine sharing their e-bike data with 3rd parties. Only 12% of interviewees said that they would not share their data or part of their data, while almost one fourth of respondents had no problem sharing their data even unconditionally, as highlighted in table 9.

Category	Description	Citations (#)	Percentage of respondents
yes, unconditionally	yes, would have no problem to share data in general	8	24%
yes, if trustworthy addressee	would share data only with trustworthy addressees, e.g. physician, friends, research institutions, service providers where no commercials	10	30%
yes, if personal benefit	would share data if personal benefit from sharing, e.g. cheaper insurance, access to data analytics tool	9	27%
yes, if individual approval	would share data if decision could be taken case by case	6	18%
yes, if anonymous	would share anonymous data	6	18%
no	no, would not share data	3	9%
no, not location	would not share location data	1	3%

Table 9: Willingness to share e-bike data with 3rd parties, n=33, multiple answers

5 Discussion

Following the detailed insights into the results of our interviews, we shall now discuss which implications may be drawn from the results for each of the three research questions we set out with. We will also propose a potential segmentation of bicycle sensor customers based on our overall impressions from the interviews, and finally outline the limitations of our study.

5.1 User reactions and expectations towards an e-bike sensor

With regard to our first research question, “What reactions and expectations do users have towards an e-bike sensor?” we found that first, the idea of an e-bike sensor was well received by the interviewees. 64% of respondents showed interest in such a sensor, either for themselves or for others, while a further 30% of interviewees were indifferent towards the sensor and only 6% of participants reacted negatively. Second, the sensor should be invisible. 61% of interviewees wanted the sensor to be hidden, 55% expressed that it should be small, and 27% thought it should be light. Third, the sensor is perceived as a source of interesting data, as mentioned by 76% of interviewees.

While the respondents’ requirements towards the sensor appear straight forward, we would not have expected such a positive reaction towards the idea of an e-bike sensor, with only 6% or respondent voicing explicitly negative associations. In light of the on-going public privacy discussions, we would have projected a more critical perception of a device, which tracks location data. The high number of interviewees, who see a benefit in the access to data about their e-bike or their usage of the e-bike, similarly exceeds our expectations. The perceived value of the data apparently outweighs potential risks of data misuse.

5.2 User interest in bicycle-related data

Regarding our second research question, “What bicycle-related data are e-bike users interested in seeing?” we established that first, interviewees expressed a high interest in their own travel-related data with travel distance (66%), bike usage (45%) and speed (41%) being the most important information. Second, we found that smartphones and desktop computers were considered the most important interfaces for reviewing bike-related information. 72% of respondents indicated that they would like to review their data on a smartphone, making it the most popular device. Desktop computers (55%) were also still very relevant, while special devices on the e-bike itself (31%) appeared less important. Third, a majority of interviewees (58%) expressed an interest in comparing their own data with that of others, where others were typically considered to be comparable (65%) or known persons (35%).

The interest of interviewees in their own travel-related data did not come as a surprise to us, as this is in line with what existing consumer products are providing today. However, we would not have expected that desktop computers should turn out such a popular device for the reviewing of e-bike-related data, especially compared to the less frequently mentioned bicycle computers. Similarly, the interest of respondents in comparing and sharing their data with others was higher than we would have thought, again in view of the publicly on-going privacy discussion and also the relatively diverse group of interviewees across genders and age groups.

5.3 User evaluation of e-bike-related data sensitivity

With respect to our third research question, “How do users evaluate the sensitivity of e-bike-related information?” our findings confirm that first, location data is still considered sensitive data. 42% of respondents indicated specifically that this type of data was sensitive. Second, on the other hand a very large proportion of interviewees (39%) did not see any data sensitivity issues with data about e-bikes or e-bike usage. And third, we found a high willingness of respondents to share their data with third parties. 24% of participants indicated they would share their data unconditionally, while 30% would share with trustworthy recipients and 27% if they enjoyed a personal benefit from sharing.

The finding that location data was considered sensitive is in line with on-going public discussions, which have already revealed the sensitivity of people to share very personal data. On the other hand, it was astonishing for us to discover that an almost equally large proportion of interviewees did not consider any of the e-bike related data to be sensitive. We imagine that people might have grown used to sharing their data including locations since many smartphone applications capture this sort of information nowadays. It was further surprising to find that nearly 90% of respondents explained that they would share their data with third parties, either conditionally or unconditionally. Obviously, the value people see in leveraging their data exceeds associated risks.

5.4 Potential segmentation of bicycle sensor customers

While the analysis of chapter 4 focuses on individual aspects of e-bike sensor usage, market segmentation is about identifying customers with similar needs across individual aspects. Several rigorous techniques exist to identify market segments. Due to the exploratory nature of our work, we do not apply statistical techniques for segmentation. However, based on the results of our interviews and impressions we collected during the interview process, we would like to put forward a first suggestion as to what customer segments might be identifiable with regard to bicycle sensors. We suggest five groups into which potential bicycle sensor customers may be segmented: rational advocates, health profiteers, fitness enthusiasts, technology admirers and non-users.

Excluding the non-users, who do not perceive any value in a sensor, are not interested in seeing their own nor others' data and would not be willing to share their data, four segments of potential users remain. We propose a group of rational advocates, who are generally attracted by an e-bike sensor and considers it potentially useful. They are interested primarily in their own e-bike-related usage data, e.g. distance, speed, frequency of usage, and some of them might be interested in comparing their own data with that of others, e.g. friends or colleagues at work. They would also be willing to share their data with trustworthy recipients or if they enjoyed a personal benefit from it. Second, we see a group of health profiteers, who also perceive the sensor as a useful device and are on top of their own general usage information particularly interested in health-related data, as they might e.g. want to lose some weight. This group would not necessarily want to compare their health data with others, but might be interested in other comparisons. They might share their data especially with trustworthy recipients, such as their physicians. Third, the segment of fitness enthusiasts perceive an e-bike sensor as useful, especially to collect fitness-related data. They would like to review training statistics and their own performance progress and are eager to compare themselves to others and participate in competitions. For this purpose, they would be happy to share their own data with others. Finally, we propose that a group of technology admirers sees a value in an e-bike sensor especially for gaining access to more technical data about the e-bike. They would like to understand how individual e-bike components behave over time and under specific conditions, e.g. how the battery capacity develops over time and what impact the weather might have on the performance of the battery. This group might be interested in comparing their data and would probably share their own data with trustworthy recipients or for a personal benefit, e.g. to help an e-bike manufacturer improve the product.

We have not specifically investigated the potential size of each of these segments, but based on our impressions from the interviews, we would expect roughly 50% of users to be rational advocates, 20-30% health profiteers, 15-25% fitness enthusiasts and 5-15% technology admirers.

5.5 Limitations

There are of course limitations to our study. First of all, we interviewed the participants of an e-bike field study, who had volunteered to participate in this study and received an e-bike from us in the context of the study, which they could use free of charge. Therefore, responses might have been overly positive. On the other hand, we feel that the interviewees' interest in the usage of e-bikes must not necessarily have any influence on their assessments of an e-bike sensor. Also, the interviewees had already received confirmation of their participation in the field study so that this should not have biased their responses. The findings might additionally be influenced by the fact that all interviews were conducted in Switzerland and with employees of an insurance company. Results may therefore be over- or understated compared to what employees in other sectors or countries might say. Finally, this study is focused on users of electric bicycles. While a generalization of our insights to regular bicycles and their users might be fruitful, it may also be restricted, e.g. because of different user group characteristics.

6 Conclusions and outlook

Currently, different alternatives of how e-bike-related data could be measured and displayed are feasible, each with its own benefits and drawbacks. Mobile sensors, which are permanently attached to the e-bike, certainly constitute an interesting alternative, as they enable the offering of services, which cannot be realized on the basis of removable sensors. The user acceptance of such devices appears promising.

Interest of users in e-bike data seems high, even across gender and age groups. Such e-bike-related information may ultimately be useful for motivating people to increase their level of physical exercise and change behaviour. In this context, it is important to understand that different types of information appeal to people. The four user segments outlined based on the results of this study, which reflect upon the varying degrees of interest users may show in general bike usage information, health, fitness and technical data, may provide a starting point for the development of services in this area.

Future research should certainly investigate specific use cases for e-bike sensors in more detail as well as explore the most effective form of analysis and display of data to support and motivate users. Provided the apparently high willingness of users to share their data, use cases including third parties should also be considered. Finally, users' willingness to pay for specific use cases and bicycle-related data is certainly a topic to be investigated further in order to evaluate the sustainability of such an approach.

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