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How does the setup of sample collection influence survey results - an example of new mobility services

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Abstract

Conducting surveys in transportation research is becoming more complex. Depending on the survey subject, the survey format and the circumstances of the sample collection the motivation of respondents to participate and consequently the results can vary substantially. Skewness of samples and sample selection bias occur to different degrees. This study compares different surveys which were created to capture the acceptance regarding shared autonomous minibuses in Germany. By analyzing distributions of behavior, perception and intention to use the services, biases in the datasets are worked out. The results show that voluntary on-site surveys lead to more positive perception of minibuses.

Keywords: sample collection; new mobility services; acceptance of shared autonomous minibuses

1. Introduction

New technologies and mobility services such as on-demand services, sharing services, or last-mile solutions arise and change people's travel behavior. Usually, providers and the public sector would like to get insights into the impact of a new particular service on the transportation system, like changes in travel demand, before introducing such services. It is therefore crucial to examine people's attitudes and expectations towards these services. Among these new technological developments are autonomous vehicles. It is expected that these will impact the mobility sector substantially. Public transport providers currently investigate, for example, the use of small autonomous vehicles, so-called autonomous minibuses, as feeders for bigger public transit stations which are subject of this study.

Test operations and fair appearances can serve the purpose of technical testing on the newly developed vehicles. They further enable people to experience the technology. Hence, these people get insights into what a future autonomous service could look like. Subsequently, many institutions provide surveys to collect people's attitudes and estimate future demand and use cases. The problem occurs that people participating in test operations are usually interested in that new service. Consequently, their opinion is not necessarily representative for the population.

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This research aims to compare different perspectives by providing a comprehensive survey to better understand the effects of sample selection when examining the topic of shared autonomous minibuses (SAMB). We developed a modular questionnaire applicable for people experiencing SAMB during test operations or fairs as well as a more random and representative sample of the total population, which does not necessarily relate to SAMB. For one thing, combining findings from different subsamples permits to deepen knowledge of the future travel behavior and the resulting demand for such a new mobility service. Apart from that, it enables to better understand the biases due to different subsamples resulting from varying recruiting channels. Results from a previous Germany-wide online survey covering the intention to use shared autonomous vehicles combined with key values of travel behavior serve as a reference for this research. A second sample has been collected at different fairs and public events where basic knowledge about the technology and its use in form of a shared autonomous minibus was presented and experienceable with a low threshold: users could either inform themselves using an interactive screen, watch demonstrations of different sensors (e.g., radar and lidar) or could automate their own robot. Both samples are analyzed and compared regarding the acceptance of minibuses, possible use cases, motivation, and fears depending on demographic composition. It is expected that the acceptance varies across the samples for comparable population groups as the motivation to participate in the survey ranged from getting paid when recruited through a panel to special personal interest. Thereby, the study provides insights into biases occurring in different survey formats. This is relevant for the interpretation of survey results in the context of investigating new mobility services.

The study is structured as following. The literature section provides an overview of different theories explaining participation in surveys and describes existing biases in (travel behavior) research. Then, the methodology is explained by delineating the database, describing the sample collection and working out key differences of sample composition. Based upon this analysis, different perceptions and intentions of use are presented being interpreted in the context of the respective survey. The study ends with a conclusion of the main biases and helpful survey settings observed and points to further methods to cope with sample biases.

2. Literature

Travel surveys are important and well-established methods to collect information about current (e.g. through national household surveys) or potential future travel behavior (cf. Hess et al. (2007a,b)). However, collecting data through surveys faces more and more difficulties. While non-response rates increase (e.g., due to more complex survey design or data privacy concerns (Neller, 2005)), so does the risk for strong sample selection bias. Sample selection bias occurs when an omitted variable influences the probability of entering a sample and the research result. This effect prevents the interchangeability of the different samples, since different samples lead to different causalities. A possibility of addressing this circumstance is to model the selection process in order to account for the skewness created in the explanatory model. Further biases might occur when causality is not one-directional but bi-directional or measurement errors steal in when proxy variables are measured instead of the direct influencing factor. (Antonakis et al., 2010)

Social scientists study motives for participating in surveys for a long time. According to Poon et al. (2004) the most relevant theories are the following: The exchange theory by Dillman (1978) postulates that participating in surveys is a special case of social exchange and respondents are motivated by any kind of compensation. The outcome does not necessarily have to be financial, but in a way that makes it worthwhile to participate in the survey. Effects of incentives are further investigated by Toepeol (2012). The theory of cognitive dissonance (Furse and Stewart, 1984) is based on the fact that ignoring a request to participate in a survey may contradict one's perception of being, e.g., a helpful person. The decision process may not be straight forward, but the only way to reduce internal disharmony - caused by denying the request - is participating in the survey. The theory of self-perception (Bem, 1972) concludes that individuals develop attitudes and emotions by external factors, e.g. observing behaviors. These attitudes subsequently also influence response behavior. Allen (1982) specifies this theory with regard to mail survey response by adding the concepts of salience, favourability and availability. The theory of commitment/involvement suggests that people rather respond to surveys "if the topic, sponsor or researcher is relevant to them" (Poon et al., 2004). These different motives might all influence the respondents' behavior. An example in the context of SAMB research can be the study of Nordhoff et al. (2017), where a survey was conducted as part of an SAMB test trial on the EUREF Campus in

Berlin. Most participants studied or worked on campus and were consequently considered as tech-savvy. This was also reflected in a very positive assessment of the SAMB.

Further, it is also already known that different survey designs attract different respondents and weighting does not correct the result adequately. An example from the field of transport research is the study of Bayart and Bonnel (2015). The authors compare results of a telephone survey with the additional provided web survey. They conclude that combining different survey methods enhances the quality of data. However, researchers should be aware of different samples and different reported behavior. Households answering the web survey had more members, a higher monthly income and are more motorised as well as more active. Moreover, very young and old people were underrepresented in the web survey. This might be due to the higher flexibility of web-surveys as participants can decide by themselves and without further agreements when answering the questions. Even when weighting the two samples, the results obtained differ: Web-respondents report a different modal split and fewer trips. However, the reported trips take longer and they travel on average longer distances. Due to cost and efficiency reasons, however, the share of online surveys is rising in different fields of research (Keusch, 2015).

3. Method

3.1. Data Collection

This research uses datasets from two different surveys for the sample and result analysis. They both were designed and carried out to capture people's perception of SAMB and collect a variety of additional information on personal background, attitudes, travel behavior and spatial context. As the majority of questions coincides in both surveys, a comparison respectively a merge can be done to enrich the understanding of respondents' attitudes towards autonomous minibuses and to understand different results stemming from varying recruiting methods in different survey areas.

The first dataset originates from a Germany-wide survey conducted with an online access panel in summer of 2018. It consists of roughly 1,000 responses collected with a separated quotation of age, gender and community size of residence. Respondents were restricted to participate in the survey when quotas were reached leading to potential biases through having more fast answering respondents in the sample contrary to the other samples. It should be mentioned that respondents got paid a small amount for participating in the survey and that a majority participates regularly in comparable surveys. It took respondents on average 14 minutes to answer the questionnaire. About 89.5 % of all respondents that opened the survey and fitted into the quotation completed the whole questionnaire. A response rate cannot be given as the number of persons to whom the survey was sent is unknown.

The second dataset was collected at different fairs in the context of an education center for autonomous mobility. These fairs can be differentiated into more technical fairs and garden shows and took place in late 2018 and 2019. Within the education center, visitors could get information on autonomous technology and their field of application medial simply prepared by illustrative objects, demonstrations of sensors and videos. The range was designed for young and old. Within this education center, visitors were asked to answer a reduced version of the questionnaire - in comparison to the first questionnaire - on-site at prepared tablets or afterwards on their own devices, which took them on average 15 minutes. Respondents didn't receive a designated incentive, but were motivated by a conversation with a contact person at the education center. As these contact persons provided technical assistance for respondents who were insecure about answering the tablet-based questionnaire, the possibility to participate was given to all visitors. Of all respondents starting the survey, about 55.5 % completed the whole survey. Again, a response rate cannot be given as the number of persons contacted was not collected. All fairs are embedded in a particular catchment area. They all took place in the state of Baden-Württemberg and attracted predominantly visitors within a radius of up to 100 kilometers varying from fair to fair (cf. Messe Stuttgart (2019)). Especially the national garden show attracted a more national public.

For the further study, the German-wide survey is labeled GWS, the data from the garden show are labeled GSS and the data originating from technical fairs are labeled TFS.

When analyzing the sample distributions, major differences in the size and composition of the samples arise (see Table 1). As a reference, the corresponding distributions based on the German census of 2016 are given (Statistisches Bundesamt, 2017). The on-site surveys (GSS and TFS) at the education center contain a substantially smaller sample

than the GWS. This is due to the voluntary participation and the more elaborate recruiting at the fair. As a quotation was used for the collection of the GWS sample, no extreme rates occur within the sample. Only the share of respondents above an age of 75 is lower than expected due to a more aggregated quotation. Still, it should be mentioned that there hasn't been a combined quotation. Both the GSS sample and the TFS sample reveal a substantially higher share of male respondents, GSS a slightly and TFS a substantially younger sample and both fair samples a higher share of respondents living in smaller cities and communities. An evaluation of occupation distributions found all three samples to miss homekeepers and to contain a substantially higher share of employees. A smaller share of retirees and higher share of students in the GSS and TFS sample correspond to the findings in the age distribution. For one of the technical fairs, a visitor analysis was conducted and found a higher share of male visitors of about 60 % and a lower share of visitors older than 60 with about 18 % (Messe Stuttgart, 2019). Still, the received sample from the technical fairs even has a stronger expression of the described effects.

Table 1. Sample distribution

Attribute		Germany-wide	Technical fair	Garden show	German census 2016
	total	1078	169	181	
Gender	female	51.1 %	19.5 %	30.2 %	51.1%
	male	48.9%	80.5 %	69.2 %	48.9%
	divers	-	-	0.6 %	-
Age	0-17	-	11.2%	5.5 %	16.3%
	18-30	19.2 %	24.9%	23.6 %	15.5%
	31-45	22.2 %	21.3%	17.0 %	18.4%
	46-60	27.8 %	28.4%	24.7 %	23.6%
	61-65	8.0 %	2.4 %	11.0 %	6.2%
	66-75	21.3%	7.1 %	8.8 %	9.9%
	76 +	1.5 %	3.6 %	8.8 %	10.1%
Community size	over 500 thous.	22.4 %	14.4 %	9.9 %	16.7%
	100-500 thous.	36.5 %	19.6 %	14.9 %	14.8%
	20-100 thous.	23.3 %	24.8 %	30.9 %	27.5%
	under 20 thous.	17.9 %	41.2 %	44.2 %	40.9%

Looking closer at the completion times of respondents multiple effects can be observed (see Figure 1). Due to the shorter questionnaire a large share of the fair samples has a lower completion time than the access panel survey. Still, there exist very long completion times up to three hours as the respondents were able to pause the participation when answering on an own device. One might expect that respondents started the survey on-site but finished it later at home. Further, the authors assume the respondents on-site to generally answer more cautious leading to longer completion times. It is worth noting that in all surveys respondents were able to decide the time of participation. In general, the range of completion time is lower for the access panel than for the fair surveys indicating that respondents are accustomed to participate in survey and that the system promotes to answer questionnaires quickly.

It is difficult to differentiate between effects of recruitment and environment of the survey on the survey results. The GWS sample was collected impersonally and in a private surrounding, whereas the GSS and TFS samples were collected with direct interaction with a contact person and the possibility to choose between on-site and at-home response. Results being described hereafter are influenced of this two-dimensional difference.

For the reason of different compositions of samples regarding age, gender and city size and small sample sizes, the samples are weighted to match the composition of one of the small samples (cf. Bayart and Bonnel (2015)). We chose the GSS sample as it is between the other samples in terms of age and gender distribution. None of the samples is representative and for the aim of comparing the samples appropriately, we aim to at least have similar compositions regarding gender and age as we found them to be the most unbalanced variables. City size serves as an independent variable within the descriptive analysis whereas it is not considered in the weighting. Respondents with an age below 18 years are exempt from the further analysis to receive equal age ranges in all samples. It should be taken into account

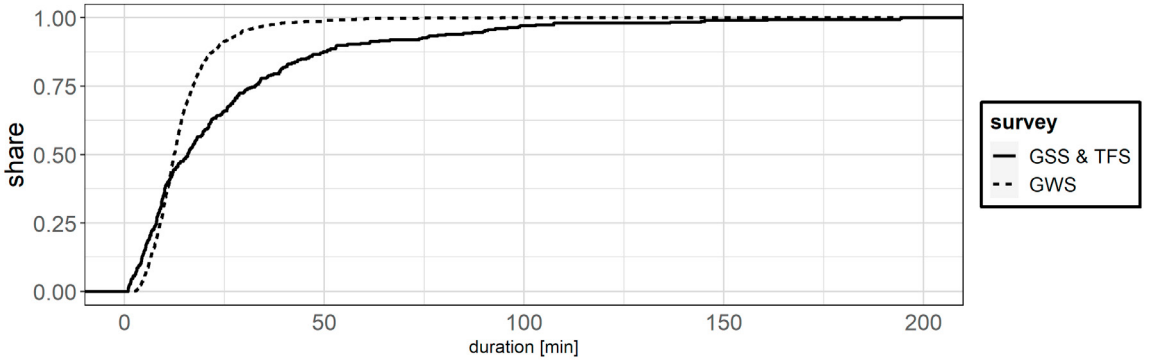

Fig. 1. Cumulative distribution of completion times in surveys

that the resulting weighted sample composition results in a highly male dominated sample. The resulting distribution is comparable to the GSS sample shown in Table 1. For the further analysis, the weighted database is used.

3.2. Data Comparison

Whether a fair respectively a survey attracts similar respondents within a defined spatial area (i.e. city size) is subject of the following section. The participation in the GWS is highly dependent on the characteristics of people being a member of a panel database, whereas the participation in the TFS and GSS depends on the interest in certain topics (i.e. gardening, landscape, model making or mobility) and therefore the visit of mentioned fairs. Further, the willingness to participate in the survey depends on the interest in autonomous minibuses and the situational possibility to participate. For visitors of a fair, it might be more important to see as many parts of the exhibit than to participate in a survey. Other distracting factors - even for interested visitors- are for example children, who distract their parents and prevent them from participating in the survey. Situational possibility is a minor factor for participants in an access panel.

Looking at the current usage of travel modes, different effects appear in different city sizes. For cities with more than 100,000 inhabitants both the GSS as well as the TFS sample contain more respondents with a less frequent car usage (see Figure 2). This goes in hand with more frequent bicycle and public transportation usage within these cities. In contrast, a slightly higher use of the private car appears in cities with less than 20,000 inhabitants combined with a lower bicycle and public transportation usage. These results are in line with the availability of a private car reported in the samples which reveal a higher proportion of non-availability in the GSS and TFS samples.

This behavioral difference can only in some parts be explained by a regional differences in travel behavior. Small area estimates of the German national household travel survey Mobility in Germany 2017 reveal especially a high share of public transportation usage within the cities of the region with more than 500,000 inhabitants (Bräumer et al., 2018). Still, this does not count for bicycle usage, which is low within the whole region. The majority of municipalities above 50,000 inhabitants in the region profits of a well-established public transportation network. Car ownership and usage is of higher importance in smaller municipalities. Still, the share of private car usage among all trips is high in all sizes of municipalities.

The samples of the education center further tend to have more respondents that are already informed about autonomous minibuses. This is mainly due to the fact that a majority of respondents visited the education center before participating in the survey which was counted as a kind of previous information in the survey. The share of respondents having used SAMB already is slightly higher than in the GWS sample. This might be partly explained by the later collection of the sample and a therefore broader supply of autonomous minibuses in test cases. Still, the share of respondents taking part in a test case is at most 5.5% in the GSS sample. There is no clear indication that this is influenced by the city size of residence.

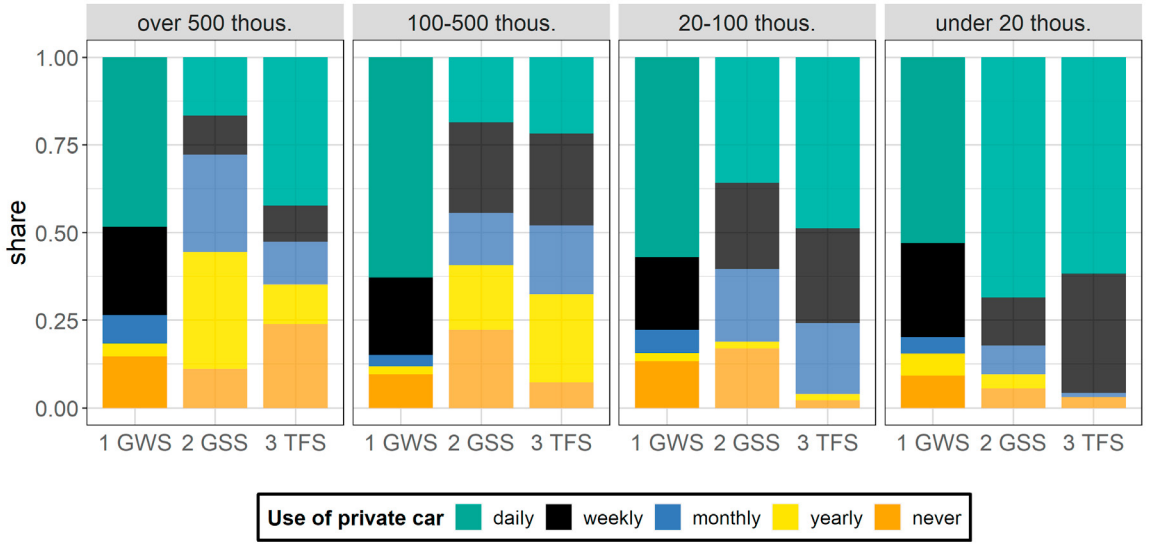

Fig. 2. Car usage by municipality size of residence and sample, weighted

4. Results

The interest of surveys like the ones presented in the sections before is to analyze aspects of future mobility services in the context of existing travel behavior. As shown above, problems regarding sample composition, sample size and potentially different levels of motivation arise in more specific contexts of sample collection. The examples presented could also have been conducted in the form of a household travel survey, both a personal interview or a pen and paper questionnaire, which would lead to a less biased sample. But other contexts require a selection of respondents on site, as they need to have certain experiences. Especially, when respondents should get experiences with new mobility services or new means of transportation. For the example of SAMB, this means a sample collection during or after a ride in a test case. Dealing with a non-representative user group can be inevitable, if no complex test setup and recruiting is affordable. Referring to the education center, it can be of further interest to specifically investigate attitudes of informed persons. For this reason, an understanding of possible biases and a selection of useful findings within this setting is required.

4.1. Intention to use SAMB

Respondents within all surveys were asked, under which circumstances they would use a SAMB service. The item set covered questions regarding the spatial area of use, which travel modes could possibly be replaced and for what trip purposes respondents could imagine to use SAMB.

Generally, it is noticeable, that the intention to use an SAMB service - not specifying the operation area or the type of operation - is higher within the GSS and the TFS sample (see Figure 3). The analysis differentiates agreement on an imaginable use and disagreement combined with an uncertain opinion (”other”). This suggests a higher self-selection of people being interested in SAMB to participate in the survey. A greater difference of intention to use an SAMB among the samples can be observed in larger cities above 100,000 inhabitants.

The higher intention of SAMB use does not concern the replacement of all existing travel modes: among the respondents of the GSS and TFS samples, a higher tendency towards an SAMB use instead of public transportation, taxi and the private car - especially as a passenger - is observable. On the contrary, the substitution of riding a bicycle or walking is less popular.

A general higher importance of SAMB use in these samples can also be observed across all spatial operation areas. But especially the importance of services in rural areas is valued as higher by these respondents living in larger cities.

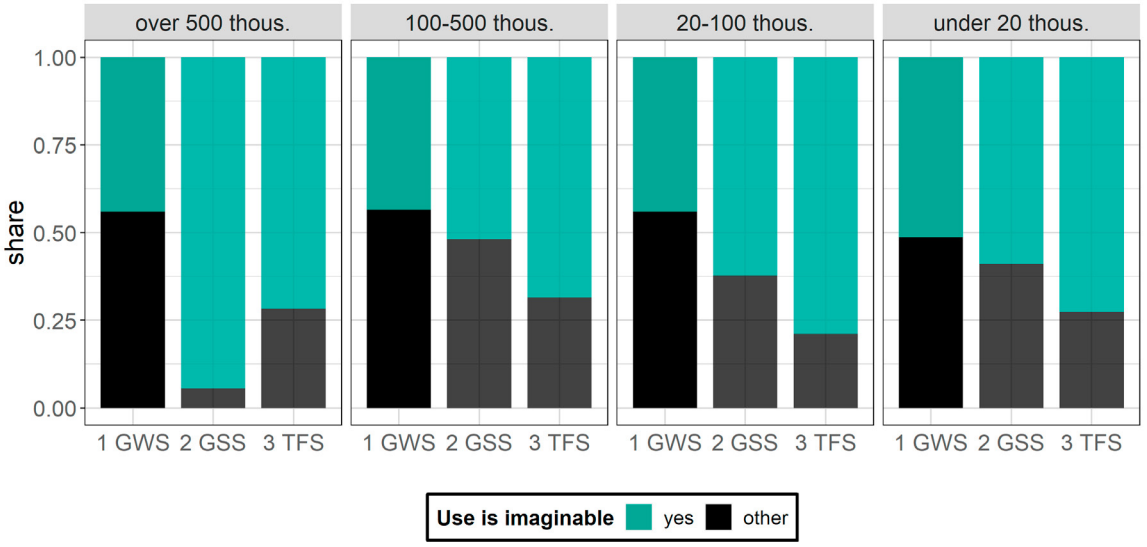

Fig. 3. Intention to use SAMB by municipality size of residence and sample, weighted

These respondents seem to consider SAMB to be most valuable for rural areas as their local supply is well-established and satisfying.

As we found a greater difference in travel behavior among the samples as well, the question arises whether the higher intention of SAMB usage is due to the differing existing behavior. Especially a more frequent use of public transportation can be expected to lead to a higher intention of SAMB usage, as they were presented in the survey as an integrated part of public transportation.

A further analysis of behavioral patterns (i.e. frequencies of use of certain travel modes) reveals that people with a similar reported behavior do not state comparable intentions in different subsamples. The general intention of SAMB usage in the GSS and TFS sample is substantially higher for all respondents independent from the usage of public transportation with a larger difference when the usage is on a daily or weekly level. Also, respondents from the GSS and the TFS samples would rather substitute previous public transportation trips by SAMB, again independent from public transportation usage (see Figure 4). Further investigations differentiating by current bicycle use also confirm a general higher usage intention among the GSS and TFS samples. However, frequent cyclists would less likely substitute a bicycle trip with an SAMB with an increasing tendency for less-frequent users. The results suggest more motivated bicycle users in the TFS and GSS sample. Further, the intention is less sensitive to the existing behavior in the GWS sample.

All these observations indicate that respondents from different samples have a different intention to use SAMB, which cannot only be explained by different socio-demographics, spatial areas of residence or behavior of respondents in the samples.

4.2. Attitudes towards SAMB usage

The intention to use SAMB services varies among the samples stemming from different travel behavior and different attitudes. Therefore, respondents' perceptions of SAMB use and attitudes towards SAMB use are compared.

The analysis of the sample in section 3.2 shows a higher degree of previous information on SAMB within the GSS and TFS sample. This is expected to influence the precision of answers as stated above and the perception of SAMB. In the questionnaire, respondents were asked whether they expect the usage of an SAMB to be hard to understand. It appears that less respondents share this fear in these samples (see Figure 5). They further do not consider the loss of the driver to cause problems.

On the other hand, respondents in these samples are more proud in front of others to use an SAMB, expect to experience a higher degree of fun and have a higher motivation to use an SAMB service to protect the environment

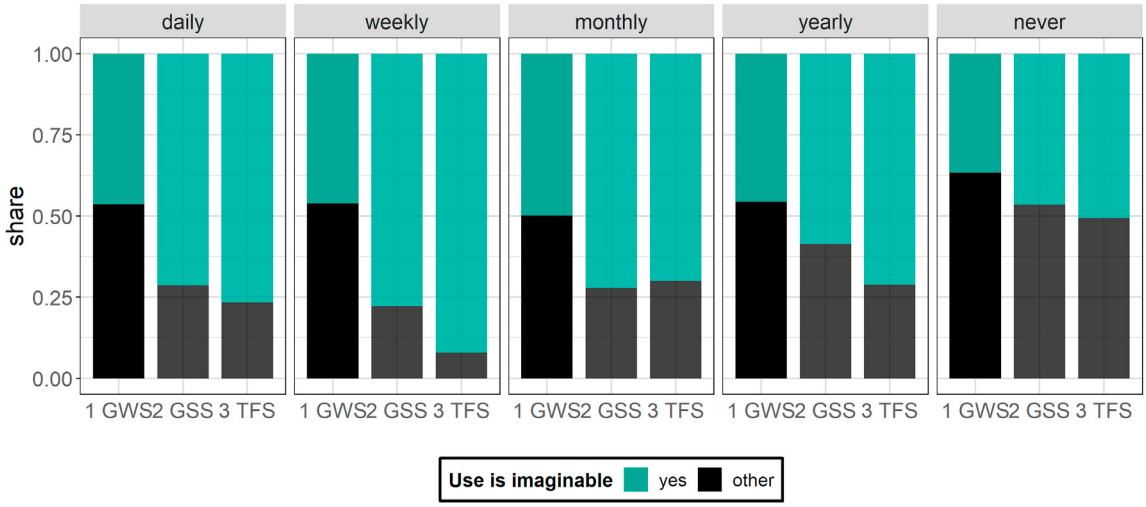

Fig. 4. Intention to use SAMB by existing use of public transportation and sample, weighted

(see Figure 5). The latter is in line with a higher usage of bicycle and public transportation in these samples. In total, they expect public transportation to become to a higher degree more attractive by integrating SAMB.

It should be mentioned that the items described in this subsection were not mandatory in the questionnaire whereas a substantial share of respondents chose not to answer leading to potential biases.

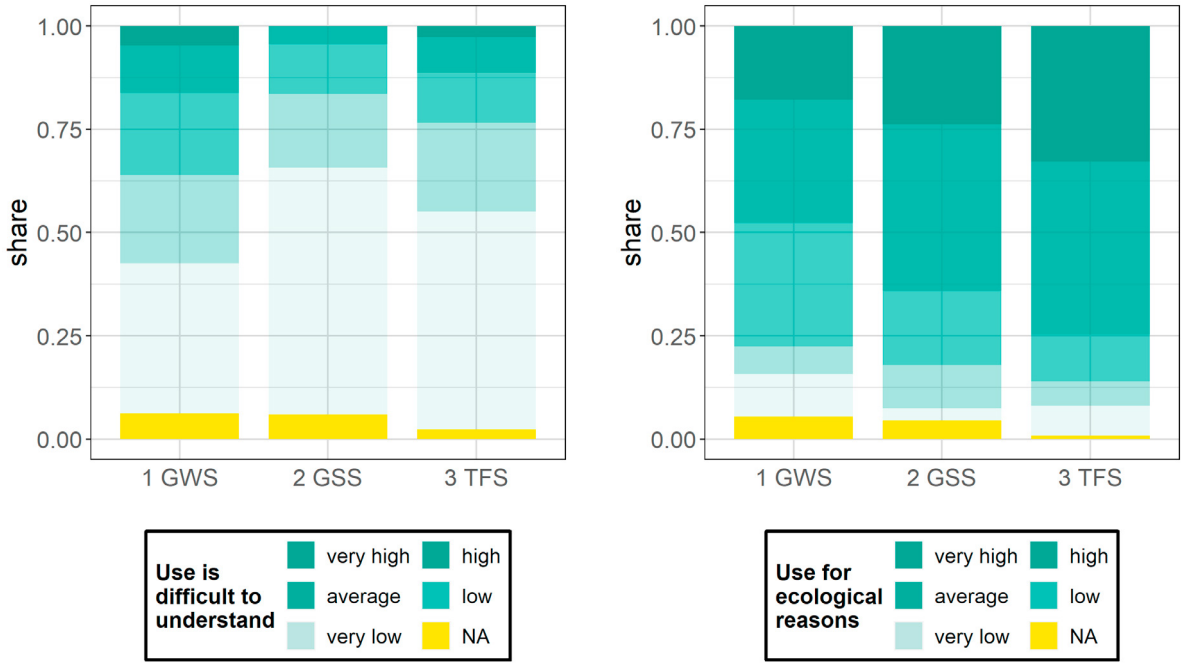

Fig. 5. Agreement on a difficult usage of SAMB (left) and a usage for ecological reasons (right) by sample, weighted

It further stands out that respondents in the GWS sample more often report an average intention to use SAMB. This may have a cause in the type of sample collection: panelists are compensated for their participation regardless of the data quality. Moreover, when being recruited for the panel, they do not need particular knowledge on the survey topic. Hence, it is conceivable that their motivation comes from the incentive instead of the research topic (cf. Dillman

(1978)). On the contrary, respondents taking part in the education centers have invested a certain time into the topic by informing themselves, trying autonomous functionalities and discussing with the staff. Further, assistance while answering the survey enables a broader access to the survey and helps especially respondents who are not familiar with computer-assisted surveys. They only provide guidance on request and do not interpret the questions which can be the case when conducting a personal interview. Consequently, respondents are able to report their intention more precisely. On the other hand, respondents may feel obliged to participate (see theory of cognitive dissonance) in the survey, which can reduce the precision of the answers. To sum up, the authors interpret the answers to be more honest and potentially more extreme.

Still, the positive effects cannot be assuredly traced back to the education center. It is merely a combination of more interested visitors at the fairs, an increased participation of interested visitors and the positive effects described above, corresponding to motives resulting from the theory of commitment/involvement (Poon et al., 2004). It cannot be observed that a larger part of respondents in either of the samples is highly critical regarding SAMB.

5. Implications from different perspectives

The investigation of the different samples stemming from an access panel and on-site surveys as part of an education center regarding their representativeness points out that it is problematic to derive generalized results regarding the acceptance of SAMB. Both, the analysis of sample composition and the analysis of the reported typical travel behavior reveal substantial differences in the survey samples. Still, considering only personal attributes and reported travel behavior is not sufficient to explain the different levels of intention to use SAMB, their perception and the motivation behind the use. Instead, survey formats and sampling methods influence respondents participating in the surveys.

On the one hand, on-site surveys lead to a more cautious responding and a more positive result regarding the acceptance of SAMB. The latter is in line with findings from Nordhoff et al. (2017) observing with an SAMB test case a more open sample ”towards sustainable innovations in mobility sector” (p.8). On the other hand, only the perception of a more interested an motivated group of person is surveyed. The GWS sample suspects more indifferent responses, but covers more socio-demographic groups due to a larger sample and a German-wide collection.

To not only rely on biased results of a single survey it is reasonable to get as many perspectives as possible: the selection of different samples may lower this risk. In this context it is important to not only bet on voluntary responses, but also on appropriate incentives.

For specific insights it can be useful to analyze item sets only within certain samples. If a sample occurs to be comparatively critical of mobility services, this can be useful to understand doubts and fears in detail.

Statistical methods are used in other fields of research to address selection bias. As an example, Heckman models are applied to model the probability of participation in a survey. Still, Certo et al. (2016) suggest to value other sources of endogeneity more than sample selection bias.

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