Public Transportation, Subjective Experience and Influencing Events – Identifying the Impact of Everyday Situations on Personal Journeys

Marie Güntert[a], Stefan Pfeffer[a], Esther Bosch[b]

[a] *Faculty of Engineering and Technology, Furtwangen University, Kronenstraße 16, Tuttlingen, 78532, Germany*
[b] *Institute of Transportation Systems, German Aerospace Center (DLR), Lilienthalplatz 7, Braunschweig, 38108, Germany*

Abstract

The presented study investigates factors influencing public transportation experience in both urban (Hamburg) and rural (Tuttlingen) areas in Germany, with the aim of identifying events that affect travel experience and as a result sustainable travel behaviour. Using a mobile application, 21 participants in Tuttlingen tracked everyday trips, providing real-time evaluations of travel experiences along with demographic and situational data. Multi-level regression analyses were applied to assess the impact of events such as punctuality, capacity offer, information about public transportation and others on the ontrip experience. A previous collected dataset of Hamburg was used for comparison. Results indicate that a positive capacity offer has the strongest positive effect in Tuttlingen, whereas negative punctuality and low personal wellbeing have the strongest negative effects. In contrast, all event types significantly influence travel satisfaction in Hamburg, with negative punctuality and a negative information event having the largest impacts. This provides a foundation for decision-making and measures to improve local public transportation.

Keywords: public transportation, travel satisfaction, mobile data collection, sustainable behaviour, multi-level regression

1. Introduction

The climate crisis is currently one of the biggest social and environmental challenges of the 21st century. Numerous physical and mental health issues

have been associated with the presence of climate change, environmental degradation and the respective triggered negative emotions (Maslin et al., 2025; Cosh et al., 2024). While the European Climate Law states the goal of reaching climate neutrality by 2050 and reducing greenhouse gas emissions by at least 55% in 2030 (European Parliament and Council, 2021), current projections of established policies and measures indicate a reduction of only 47% (European Environment Agency, 2025). Hence, more ambitious policies and measures must be implemented to reach the agreed goal.

The transport sector of the European Union accounted for 21.5% of emissions in 2023 (Environmental Protection Agency, 2025), making it the largest emitting sector in that year (Agency, 2025). Although advances in technology have lead to more emission-efficient vehicles, the number of private vehicles has risen (Environmental Protection Agency, 2025). European cities such as Paris, Brussels and Zurich have a pioneering role in effective transport policy by passing multiple laws regarding the limitation of vehicles (Spiegel, 2025) and speed regulation in the city (Yannis and Michelaraki, 2024), motivating residents and tourists into using public transportation as sustainable alternative compared to private vehicles (Banister, 2008).

De Vos et al. (2021) argue that public transportation will be chosen more likely if satisfaction of the travel experience is given. The modelled circulatory effect, shown in Figure 1, in their *travel mode choice cycle* of travel satisfaction on *attitude*, *desire* and *intention* influences the *shown behaviour* and therefore the habit of choosing a travel mode, which continuously influences the *satisfaction*. By evaluating the current attitude of people towards public transportation and identifying influencing factors (e.g., experience of current trips or satisfaction of previous trips), improvements of these factors could result in a more robust attitude and therefore a higher probability of using public transportation as sustainable behaviour (Bosch et al., 2025).

Additionally, multiple publications have attended the theory of critical incidents as driving influence on travel satisfaction and emotional wellbeing. These incidents can be defined as particularly satisfying or dissatisfying encounters (Allen et al., 2020). Bitner et al. (1994); Friman (2004); Gremler (2004) show the immense effect critical incidents have on the remembered travel experience. Therefore, highly positive or negative experienced events could influence the travel satisfaction and as a result change the probability of showing sustainable behaviour (using public transportation instead of private vehicles).

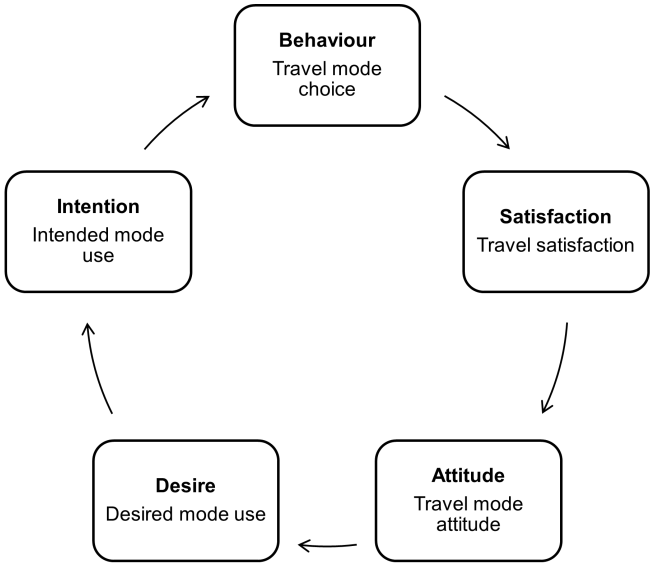

Figure 1: Simplified representation of the travel mode choice cycle by De Vos et al. (2021, p. 210).

Travel satisfaction as a research concept for the assessment of public transportation has been used since the 1960s (Susilo and Cats, 2014), evolved over time and is now frequently researched. Morfoulaki et al. (2010) define public transportation satisfaction as the overall experience compared to the associated expectations. Identified influencing factors include cleanliness, comfort, service, safety and punctuality (Van Lierop et al., 2018).

Measuring travel behaviour whilst using public transportation is a challenge Jariyasunant et al. (2015) investigated in the San Francisco Bay Area. An app collected movement and calculated personalized data such as costs or emitted greenhouse gases of the travel and visualized the effects for the participants. The results show that receiving specific, individualized feedback increased users' awareness and willingness to change their travel habits in favour of sustainability. Additionally, participants agreed to using their personal phone for data collection. A first approach for the design of such an application is the Future Mobility Survey published by Cottrill et al. (2013).

Two studies by Abou-Zeid and Ben-Akiva (2012) in Switzerland (Geneva airport, Université de Lausanne and Ecole Polytechnique Fédérale de Lausanne) and the United States (Massachusetts Institute of Technology) investigated car commuters, who were asked to use public transportation for two or three days in a week. All participants got a free transportation pass

for the period of the study. In retrospect, participants were asked whether they would continue to use public transportation. The identified influencing factors include "individual socio-demographic factors, travel attributes and institutional transportation policies, experiment context, social influences and psychological variables" (Abou-Zeid and Ben-Akiva, 2012, p. 48).

Research using experience sampling in body image studies shows that frequent self-reports do not systematically alter momentary body satisfaction or its associations with other variables, suggesting that self- and external measurements capture experiences without fundamentally reshaping them (Heron and Smyth, 2013). On the other hand, the study by Ariely (1998) on experience evaluation demonstrates that people's judgments are shaped by how and when they evaluate what they have experienced rather than by fixed, pre-existing preferences. When participants assessed pain after an experience, factors such as intensity patterns and the act of measuring continuously influenced their retrospective evaluations, showing that preferences are constructed during evaluation and are sensitive to the evaluation context. These two effects need to be taken into consideration when designing and analysing experience sampling studies.

Conclusively, using personal phones for data collection, including movement data and experience ratings, while recording influencing events such as travel attributes might be a promising way of identifying place-specific challenges of public transportation.

As part of the research project experience atlas (original: Erlebensatlas), the study design of this work has been previously tested in German cities, such as Hamburg, Berlin and Brunswick (Deutsches Zentrum für Luft- und Raumfahrt, 2025a). Influencing factors are based on a literature review and identified by analysing complaints issued to the Hamburg Transport Association as well as qualitative and statistical analysis of previous studies: driving behaviour, information, fellow travellers, personal wellbeing, capacity offer, staff behaviour, punctuality and infrastructure. The respective manuscript is currently under preparation.

Based on the previous mentioned theoretical considerations the following research questions can be defined:

1. Which events influence travel experience in Hamburg and Tuttlingen?
2. Does the influence of these events differ between the cities?

2. Method

Participants were recruited by addressing them directly at an university event and using the social media channels of Furtwangen University (hs.furtwangen, 2025) and the city of Tuttlingen (stadt_tuttlingen, 2025). They were then referred to a recruitment questionnaire, which included the contact details and demographic data. Participants had to be 18 years or older and were required to have access to an Android mobile phone. Additionally, previous collected data for Hamburg (manuscript under preparation) is being used for comparing the results. That dataset includes around 8188 data points, demographic data, event-types, evaluation of situation and journey and geolocations. The following chapter focusses on the method of data collection in Tuttlingen.

2.1. Sample

Overall $N = 21$ participants with a mean age of 29.24 years ($SD = 13.55$) took part. Gender distribution was almost balanced, with nine female and eleven male participants. One participant chose not to answer this question. 19 participants stated using public transportation regularly multiple times a week or daily while three participants use it once a week or once a month.

2.2. Study Procedure

After acquisition, participants were sent a subject agreement including informed consent. In return for completion, they received instructions to download the developed research application (Deutsches Zentrum für Luft- und Raumfahrt, 2025b) as well as a Q&A document. With downloading the app on their Android smartphone, participants were now instructed to track six trips with a minimum duration of 15 minutes. During their trip, they were reminded by vibration of their phone to complete a questionnaire about the current situation every five minutes. When they reached their final destination, an additional questionnaire regarding the overall trip was completed. The study was concluded with a retrospective questionnaire of the entire participation. This included stressors, positive and negative aspects of travelling, used apps and the potential willingness to share data for personalized routing. The study manager verified the number of trips and their completeness before paying out money as incentive. Overall participants could get up to 70€ which consisted of 20€ for the first three trips, 30€ after completion of all six trips, 10€ if at least 95% of questionnaires were answered and ten

times 1€ for each additional trip. This study procedure has been approved by the ethics committee of the German Aerospace Center (reference number 4/25).

2.3. Collected Data and Measures

Demographic data was collected though the recruitment questionnaire. The institute's research app *Keep Moving* recorded connection data, actual routes travelled, including the start and end point, and the used transport modes. Additionally, questionnaire evaluation data was saved with corresponding pseudonymous login data. The data was prepared before conducting the statistical analysis. First, all data was combined and filtered. Trips with no start or destination in county of Tuttlingen were sorted out. Evaluations during the trip (called 'ontrip' throughout the paper) were assigned to the associated post-trip evaluation and events. The ontrip questionnaire contained the following items. Items 1 to 3 were answered with a 5-point Likert-scale, items 4 to 12 could be answered positive or negative, no answer resulted in neutral. Item 13 contained an optional free text answer.

1. The journey at the moment is 1 (miserable) to 5 (excellent).
2. For achieving my goals, this journey is 1 (a hindrance) to 5 (favourable).
3. Based on my previous experience with travelling this journey is 1 (below average) to 5 (above average).
4. Punctuality and transfers, e.g. connection made or transport departed too early (positive or negative, not completed resulted in neutral)
5. Fellow passengers, e.g. pleasant fellow passengers or disruptive people
6. Capacity utilisation in the transport, e.g. full or plenty of space
7. Driving behaviour, e.g. rough or pleasant driving style
8. Infrastructure, e.g. clean means of transport or no weather protection available
9. Information, e.g. alternative routes in case of cancellation or lack of information
10. Wellbeing, e.g. nice view, music, temperature, or discomfort, need to hurry
11. Staff, e.g. nice or unfriendly ticket inspector
12. Capacity, e.g. good or poor frequency
13. Other

Collected data was analysed using RStudio with multi-level regressions. The mean ontrip experience was defined by calculating the mean value of items 1 to 3 and predicted by the events of items 4 to 12 as independent variables. A random intercept accounted for interpersonal differences of participants. No random slope or interaction effects were modelled.

3. Results

The following chapter presents a visual overview of the data and the results of each regression. Figure 2 represents an overview of the collected data with integrated mean ontrip experience and the collected events. For example, the village of Emmingen is visualized by mainly yellow, indicating few very bad or very good mean experience ratings.

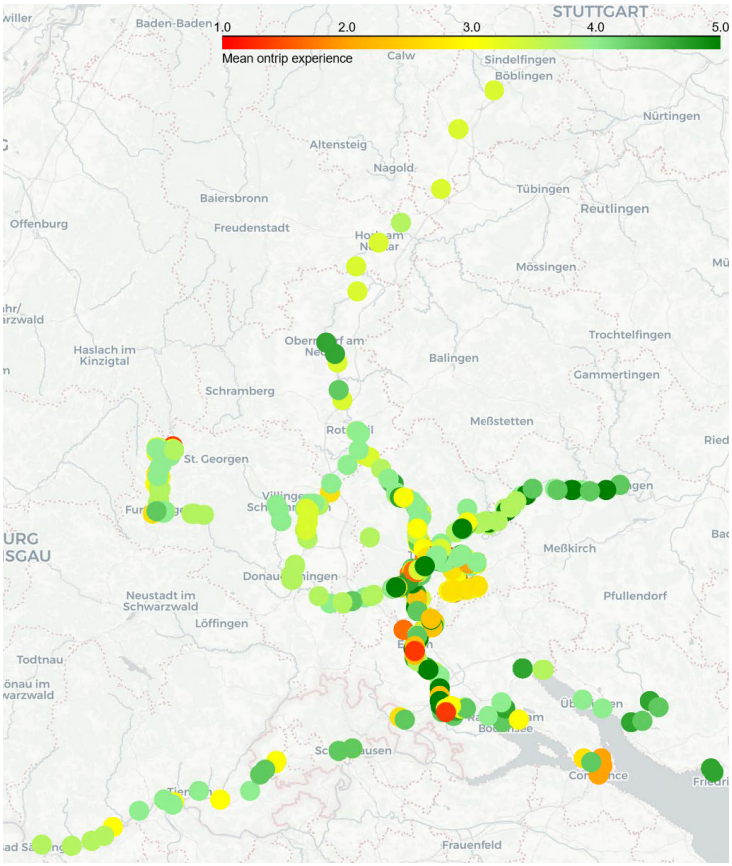

Figure 2: Location of collected data points coloured by the mean ontrip experience (1 = red, 5 = green).

Multi-level regression models with an AR(1) correlation structure are fitted to predict mean ontrip experience for each city. Residuals of the initial model without autocorrelation showed strong positive autocorrelation ($Durbin-Watson = 0.26, p \leq .001$), so a first-order autoregressive structure ($AR(1)\phi = 0.90$) was included. ACF and PACF plots of normalized residuals indicated that AR(1) adequately captured temporal dependence and a second-order AR structure did not improve fit ($\chi^2(1) = 0.58$, $p = .448$; $\Delta\text{AIC} = +1.40$). A series of model comparisons were conducted using likelihood-ratio tests and information criteria (AIC and BIC). If the likelihood-ratio test was non-significant, the more conservative model was preferred, particularly when supported by BIC. This approach was chosen due to the large sample size and the risk of detecting statistically significant but practically negligible effects. Table 1 presents the results of the fitted model, which shows the lowest AIC (821.08) and BIC (920.75) for the compared models with the excluded event *staff*. Including all collected events results in a slightly worse model fit ($\Delta\text{BIC} = +14.20$) with the likelihood-ratio being non-significant, $x^2(1) = 0.87, p = .646$.

Non-significant events include *negative driving behaviour*, *positive fellow travellers*, *positive personal wellbeing* and *negative infrastructure*. All negative coefficients are associated with lower experience ratings, while positive coefficients are associated with higher ratings. The strongest effects in Tuttlingen are caused by a *positive capacity offer* ($\beta = 0.31$), *negative punctuality* ($\beta = -0.26$), *negative wellbeing* ($\beta = -0.23$) as well as *negative* ($\beta = -0.22$) and *positive* ($\beta = -0.23$) *information*.

Table 1: Results of multi-level regression for Tuttlingen, non-significant events are highlighted. Neutral served as reference for the categorial event variables. $df = 1842$

Event		β	t	p
Intercept		3.17	28.33	$\leq .001$
Driving behaviour	negative	0.07	1.13	**.258**
	positive	0.18	4.46	$\leq .001$
Information	negative	- 0.22	- 3.67	$\leq .001$
	positive	- 0.23	- 4.44	$\leq .001$
Fellow travellers	negative	- 0.17	- 3.78	$\leq .001$
	positive	0.06	1.54	**.123**
Personal wellbeing	negative	- 0.23	- 5.14	$\leq .001$
	positive	0.06	1.66	**.097**
Capacity offer	negative	- 0.09	- 2.02	.044
	positive	0.31	6.15	$\leq .001$
Punctuality	negative	- 0.26	- 5.26	$\leq .001$
	positive	0.17	3.67	$\leq .001$
Infrastructure	negative	0.09	1.74	**.082**
	positive	0.20	4.21	$\leq .001$

The model for Hamburg includes all event-types with an AIC = 2088.50 and BIC = 2228.71 and uses an AR(1) correction as well. Excluding the event *staff* would result in a worse model fit (ΔBIC = +4.95) with a significant likelihood-ratio, $\chi^2(1) = 22.44, p \leq .001$.

Table 2: Results of multi-level regression for Hamburg. Neutral served as reference for the categorial event variables. $df = 8101$

Event		β	t	p
Intercept		3.36	76.01	$\leq .001$
Driving behaviour	negative	- 0.07	- 2.33	.020
	positive	0.13	7.75	$\leq .001$
Information	negative	- 0.30	- 11.34	$\leq .001$
	positive	0.08	4.26	$\leq .001$
Fellow travellers	negative	- 0.13	- 7.81	$\leq .001$
	positive	0.07	4.20	$\leq .001$
Personal wellbeing	negative	- 0.13	- 7.21	$\leq .001$
	positive	0.15	8.34	$\leq .001$
Capacity offer	negative	- 0.15	- 6.34	$\leq .001$
	positive	0.14	7.36	$\leq .001$
Staff	negative	- 0.15	- 2.66	.008
	positive	0.07	3.75	$\leq .001$
Punctuality	negative	- 0.50	- 21.38	$\leq .001$
	positive	0.07	3.73	$\leq .001$
Infrastructure	negative	- 0.07	- 2.79	.005
	positive	0.12	6.21	$\leq .001$

4. Discussion

This work presents a novel data set of the experienced public transportation in the county of Tuttlingen. A statistical analysis provides the influence of the defined events on the mean ontrip experience for the cities Tuttlingen and Hamburg as answer for research question 1. The visual presentation shows possible local hotspots (high data point density), e.g. the village Emmingen or city Konstanz, that could be investigated further.

For Tuttlingen the different coefficients can be interpreted as follows: A positive capacity offer seems to have the highest positive influence on the mean ontrip experience and could be explained by the rural nature of the county Tuttlingen, where sufficient or above-average experienced space is perhaps perceived and evaluated more positively than in urban areas. In contrast, negative events such as unpunctuality or low subjective wellbeing significantly impact the ontrip experience negatively. Interestingly both, the

absence of information, as well as the presence of information, have a negative impact. This phenomenon can be attributed to the quality of the displayed information, which suggests that the information received by the participants was generally perceived as unsatisfactory or inadequate. It is noteworthy that positive driving behaviour and infrastructure significantly enhance the experience, while negative driving behaviour or negative infrastructure have a negligible impact. Again, this could be attributed to the rural characteristic of Tuttlingen, where participants may not anticipate adequate behaviour or infrastructure and consequently experience positive surprise when such qualities are present. In contrast to this, fellow travellers and personal wellbeing have a sorely negative influence. This could indicate that in a public transport system with low overall usage, individual negative experiences become particularly salient, while positive or neutral behaviour is hardly noticed.

It has been demonstrated that all identified events based on previous work and literature (Morfoulaki et al., 2010; Van Lierop et al., 2018; Allen et al., 2020) do indeed have an influence in Hamburg, thus strengthening the findings of Bitner et al. (1994); Friman (2004); Gremler (2004) about positive and negative critical incidents. However, with the dataset including 8188 data points, the significance could be a consequence of the large sample size.

Research question 2 addresses the differences between the cities. With an intercept value of 3.17 for the mean ontrip experience in Tuttlingen, Hamburg has a slightly higher value of 3.36. This could potentially indicate a better fundamental experience in the public transportation of Hamburg, however, both values are relatively low and display only a marginal difference. In contrast to Hamburg the mean ontrip experience in Tuttlingen is not significantly predicted by each event. The event staff provided no significant explanation for variance in Tuttlingen and should be therefore verified of its importance. Due to the rural nature, it should be investigated further which additional events have an influential impact. It is possible that the low public transport offer of Tuttlingen leads to fewer staff presence. This could also be the reason why negative punctuality has the highest effect in Hamburg, whereas a positive capacity offer influences the strongest in Tuttlingen. Interestingly, the most influential events are the same in both cities. Although the order and intensity varies, *punctuality*, *capacity*, *wellbeing* and *information* are the important events, which could indicate city-unspecific, general influences. These differences between the cities highlight the importance of contextual factors, including urban density and transport system

characteristics, whereas the similarities show the fundamental problems of public transportation in Germany.

The ability to answer the research questions indicates the suitability of the study design, abbreviated from literature (Jariyasunant et al., 2015; Abou-Zeid and Ben-Akiva, 2012), which uses personal phones to collect movement and experience data. The influencing factors for major cities are identified and could now be validated with this study. Following the travel mode choice cycle (De Vos et al., 2021), a next step would be to define improvements of measures for these factors and evaluate the resulting probability of choosing public transportation as sustainable *behaviour* with the respective *satisfaction*.

These results provide a basis for influencing sustainable travel behaviour and can be seen as a small impulse in decision-making and drafting policies supporting the implementation of the European Climate Law.

5. Limitations

With every study limitations arise. Firstly, the rural characteristic of Tuttlingen made it difficult to recruit as much participants as in Hamburg. This is simply because not every resident has access to public transportation and is reliant on a personal car or car sharing. Together with the smaller population it results in a small sample size which further influences the statistical power and comparability of the dataset to Hamburg. Secondly, with a mean age of 29.24 the sample is rather young. Whether this is due to a younger population being more dependant on public transportation or because the usage of a phone application resulted in a technical barrier for elderly residents is currently unclear. However, an older population might be influenced in a different way by the identified factors. This has to be investigated further to guarantee solid research for inclusive measures for all.

Another potential limitation of the present analysis is the potentially inconsistent interpretation of individual event categories by participants. This is especially evident in the context of the *information* category, where the presence or absence of information, or its perceived quality, can be viewed as positive and negative which in turn influences the data in a contrary way. In future surveys, the ambiguity should be reduced through the implementation of more precise items and verified.

While prior evidence suggests that momentary measurement generally does not distort overall evaluations (Heron and Smyth, 2013), some studies

indicate that frequent reporting may amplify the salience of momentary fluctuations (Ariely, 1998). That effect does not necessarily has to be suppressed with an adapted study design, as it could rise the awareness of travellers using public transportation and result in a more reflected experience. However, it needs to be investigated in order to be able to answer this question with certainty. Furthermore, the retrospective evaluation might influence the satisfaction, as suggested by the peak-end rule of Kahneman et al. (1993). Additional analysis of the collected post-trip data could clarify, whether the experience could be improved with measures after the trip and to what extend.

Lastly, the explanations for the results discussed in chapter 4 are based on the statistical analysis of the data. No qualitative information served as foundation which should be subject to future analysis.

6. Declaring of generative AI and AI-assisted technologies in the writing process

Statement: During the preparation of this work, the author used ChatGPT to improve wording and optimise the readability of the text. DeepL was used for the translation of individual terms and passages and checked against specialist literature. DeepL Write was used to refine stylistic and linguistic nuances. Zotero was used to manage and organise the literature sources used in all chapters including the references. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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