Attitudes Towards Autonomous Public Transportation

Henrik Detjen
henrik.detjen@hs-ruhrwest.de
Positive Computing Institute, Univ. of Appl. Sciences Ruhr West
Bottrop, Germany

Irawan Nurhas
irawan.nurhas@hs-ruhrwest.de
Positive Computing Institute, Univ. of Appl. Sciences Ruhr West
Bottrop, Germany

Stefan Geisler
stefan.geisler@hs-ruhrwest.de
Positive Computing Institute, Univ. of Appl. Sciences Ruhr West
Bottrop, Germany

ABSTRACT

Public transportation will become highly automated in the future, and at some point, human drivers are no longer necessary. Today many people are skeptical about such scenarios of autonomous public transport (abbr.: APT). In this paper, we assess users' subjective priority of different factors that lead to personal acceptance or rejection of APT using an adapted online version of the Q-Methodology with 44 participants. We found four prototypical attitudes to which subgroups of participants relate: 1) technical enthusiasts, 2) social skeptics, 3) service-oriented non-enthusiasts, and 4) technology-oriented non-enthusiasts. We provide an unconventional perspective on APT acceptance that helps practitioners prioritize design requirements and communicate, targeting users' specific attitudes.

CCS CONCEPTS

• Human-centered computing → User studies; **• Social and professional topics → User characteristics**.

KEYWORDS

autonomous public transport, autonomous vehicles, automated vehicles, technology acceptance, attitudes, Q-methodology.

ACM Reference Format:
Henrik Detjen, Irawan Nurhas, and Stefan Geisler. 2021. Attitudes Towards Autonomous Public Transportation. In *13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct), September 9–14, 2021, Leeds, United Kingdom.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3473682.3480265

1 INTRODUCTION

Autonomous vehicles will become available soon and profoundly impact people's mobility. While many research projects focus on private transportation scenarios, the public transportation sector will transform, too: From autonomous trains, over autonomous cable cars and busses, to autonomous shuttle busses for the last mile. Highly automated and autonomous vehicles (cf., SAE levels 4 and 5 [16]) are expected to increase road safety by avoiding human errors and reduce environmental pollution through optimized traffic flows. However, studies [18] show that many of the potential users do not perceive a potential safety gain from automated driving and would reject a driverless public transport system. Therefore, it is essential for a successful adoption to understand what motivates people to accept or reject this technology by targeting specific concerns or highlighting potentials.

In this paper, we use an adapted online version of the Q-methodology [7, 12, 21], a method that can provide empirical results by revealing grouped similarities and differences of subjective perspectives. Thereby, we contribute to the understanding of user attitudes towards autonomous public transportation (abbr.: APT). In specific, we 1) provide a brief overview of acceptance factors for APT, 2) explore how potential users value and relate these factors to each other, and 3) find polarizing clusters of personal beliefs that help to identify attitude conflicts between potential users. We discuss how researchers can use these insights to improve future models of user acceptance of APT and how practitioners can prioritize design requirements and use content-specific communication.

2 METHOD

Because we aim at exploring user attitudes and the structural patterns and nuances of user acceptance of APT, we apply the Q-Method. The method originates from research in the social sciences and is also helpful to identify technological affordances and system requirements [10, 12]. The pattern analysis might serve as input for two kinds of follow-up considerations. First, "Likert attitude scales could be structured around the factors revealed by a Q-sort study" [17]. Second, the found patterns might serve as input for content-specific design and communication "since products, brands, and organizations are usually not expected to have one overall image, but multiple images in different stakeholder groups. A distinction of audience segments based on their own perspectives [...] may be an important step toward targeted interventions" [17]. Figure 1 shows the outline of our following Q-method approach.

2.1 Construction of the Statement Set

To identify different user attitudes, we constructed a set of statements that will serve as a base for the pattern analysis. Each statement represents a theoretical concept, mostly factors of user acceptance. We included concepts that we expect to *differ in APT from standard public transportation*, mainly the mobility habits, technical differences, and the absence of a human driver. The construction was based on a three-step procedure. We first looked into literature on technology acceptance and extracted concepts from general technology acceptance models [2, 19, 20], as well as domain-specific research on autonomous (public) transportation [5, 9, 13–15], e.g., "I think driverless public transportation would be useful." to indicate the performance expectancy of autonomous public transportation. Second, we analyzed research on user needs during automated driving [3] such as the need for competence, autonomy, and stimulation. For instance, for the need for autonomy, we created a statement that

AutomotiveUI '21 Adjunct, September 9–14, 2021, Leeds, United Kingdom

ACM ISBN 978-1-4503-8641-8/21/09.
https://doi.org/10.1145/3473682.3480265

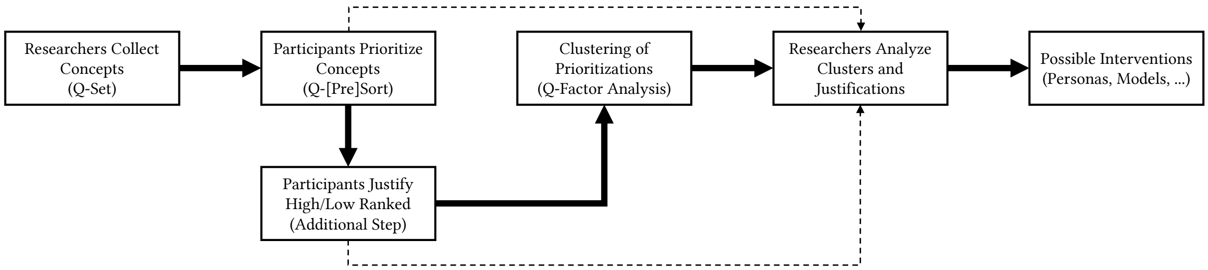

Figure 1: Overall procedure of the Q-Methodology, participants additionally explained high/low priority rankings in our study.

Table 1: The Q-Set – Statements used for investigating user attitudes were derived from technology acceptance models, user needs, and discussion.

#	Concept	Statement
s1	Performance Expectancy	*I think driverless public transportation would be useful.*
s2	Effort Expectancy	*I think driverless public transportation would be complicated to use.*
s3	Social Influence	*I will likely use driverless public transportation options if they are recommended by people or institutions that I trust.*
s4	Hedonic Motivation	*I think that driverless public transportation would be fun to use.*
s5	Price Value	*I hope that driverless public transportation will be less expensive than modern public transportation.*
s6	Mobility Habits	*I think that public transportation works just fine already and should stay the way it is.*
s7	Attitude Toward Using	*I am eager to try driverless public transportation.*
s8	Attitude Toward Using	*I think that it is a good idea to introduce driverless public transportation.*
s9	Ethics	*I am afraid that driverless public transportation will be unethical.*
s10	Self-Efficacy	*I have the skills and knowledge necessary to use driverless public transportation systems.*
s11	Anxiety	*I would feel insecure using driverless public transportation (because of the potential for theft, sexual harassment, etc.).*
s12	Perceived Safety	*I am afraid that driverless public transportation would lead to more accidents.*
s13	Transparency	*The display of ride-related information (e.g., speed) would help me to feel safe in driverless public transport.*
s14	Empathy	*I believe that driverless public transportation has no tolerance for mistakes.*
s15	Social Control	*I worry that, without a human driver, public transportation units will become unclean.*
s16	Transparency	*I think that a driverless public transportation system should provide real-time information to passengers (e.g., route changes, connections, delays).*
s17	Autonomy	*I expect driverless public transportation to be more flexible.*
s18	System's Empathy / Trust	*I am afraid that, without a human driver, the vehicle could start moving before I sit down.*
s19	Social Control / Security	*I think that driverless public transportation will lead to more disturbing behavior among other passengers.*
s20	System's Empathy / Trust	*I think school-age children should be accompanied by adults when using driverless public transportation.*
s21	Privacy / Security	*I think that driverless public transportation units should have observation cameras.*
s22	Service Quality	*Without a driver, I think that I could still get the same information in an autonomous public transportation unit.*
s23	Connectedness	*The contact with a human driver is important to me.*
s24	Comfort	*Ordering driverless public transportation pick-ups through an app seems complicated.*

confronts participants with their expectations if autonomous public transportation leads to more or less flexibility. Further, we utilized the Positive Computing framework [1], respectively, the Positive Computing determinants, which are related to human well-being (competence, autonomy, positive emotions, meaning, engagement, relatedness). Last, all authors discussed the concepts so far and added new ones if not already listed, e.g., that older persons might be afraid that with automation, the service quality would decrease because no bus driver will be around to help them out if they have a problem finding the right pieces of information during the journey. Table 1 shows the whole list of the statements (Q-Set) used in this study.

Table 2: Scenario used for the study

"In the future, public transportation will not require human drivers. Buses, shuttles, cabs, and cable cars will operate autonomously. To take advantage of driverless public transportation and find the most suitable connections, passengers will need to type their desired destination into an app. Buses or cable cars will be implemented for highly frequented lines, while less-frequented lines will operate using smaller, on-demand vehicles. Every action that people need to perform today to get from one place to another—driving, buying tickets, providing information, will be done by or through a system".

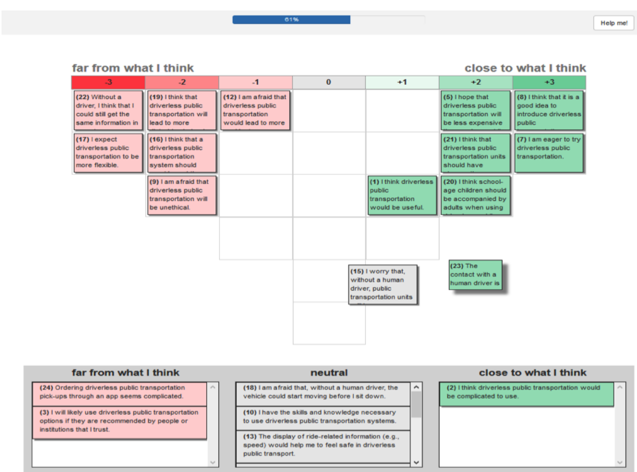

Figure 2: Example of the used online Q-Sort tool. *Best seen in color.*

2.2 Q-Sort Study

We conducted the study online with the help of a Browser-based Q-sort tool[1] (see Figure 2). Metaphorically referring to the offline Q-methodology, we visualized the statements on virtual cards. At first, we presented a scenario description to participants (cf. Table 2). The subsequent study consisted of three main parts: 1) the statement cards' presorting, where participants categorized statements to be neutral, positive, or negative, 2) the main Q-sorting, a precise sorting of the cards along the Q-pyramid (cf. Figure 2), assigning ranks from -3 to +3, and 3) the explanation phase where participants named reasons for putting statements in the highest/lowest ranks (-3/+3). In the end, participants answered demographic questions related to age groups and gender.

The whole procedure took between 15 min and 30 min. We selected 44 participants ($m = 21$, $f = 23$) of different age groups (18-25: 9.09 %, 26-40: 47.72 %, 41-55: 34.09 %, >56: 9.09 %) from a technologically developed country (USA) via Amazon Mechanical Turk[2]. Following concourse theory and abductive reasoning as part of the Q method process, a large number of participants (more than 44 as the collected data) is not required to conduct a successful Q method; furthermore, there is no consensus on the appropriate percentage of study participants because the focus is not on the participant population as in a typical quantitative study, but on the Q set that represents the population of subjective opinions [6, 8, 10, 12].

2.3 Analysis

We performed a Q-factor analysis to identify clusters of participants' card placements (similarities and differences in the cart sorting). Thereby, we minimized the number of factors while keeping a minimum of 60% of the explained variance [4] between participants. Next, we used a centroid-analysis to identify the initial number of clusters to be included in statistical rotation [21] and used the following criteria for the selected number of factors: scree plot, Eigenvalue >= 1, and the minimum amount of explained variance [21]. The subsequent flagging process assigned participants to a specific cluster based on Z-scores [21]. The factor analysis reveals four different clusters, with 64 % of the cumulative explained variance. The composite reliability of the four clusters is excellent (>.9): only two participants do not belong to a specific cluster. Table 3 shows the characteristics of the factor analysis results.

Table 3: Characteristics of the Factor Analysis.

	Cluster			
	1	2	3	4
No. of participants	25	10	4	3
Avg. rel. coef.	0.80	0.80	0.80	0.80
Composite reliability	0.99	0.98	0.94	0.92
S.E. of Factor Z-scores	0.10	0.16	0.24	0.28
% Explained variance (EV)	35	13	9	7
Cumulative % EV	35	48	57	64
No. of confounded P-Set	2 (P-1, P-35)			
Cluster Correlations				
Cluster 1	1	-	-	-
Cluster 2	-0.06	1	-	-
Cluster 3	-0.01	0.52	1	-
Cluster 4	0.32	0.13	0.07	1

3 RESULTS AND DISCUSSION

The factors from the Q-Sort analysis contain a cluster of participants which made similar sorting of statements. These clustered views

[1] https://github.com/aproxima/htmlq

[2] https://www.mturk.com

Table 4: Attitudes and their distinguishing statements (strong opinions with Rank ≤-2 or ≥+2 that are unique to that attitude).

Attitude #	Contrasting Statements	Rank
1	Technical Enthusiasts	
	I think driverless public transportation would be useful.	+3
	I think that it is a good idea to introduce driverless public transportation.	+2
	I think that public transportation works just fine already and should stay the way it is.	-2
	The contact with a human driver is important to me.	-2
2	Social Skeptics	
	I would feel insecure using driverless public transportation (because of the potentialfor theft, sexual harassment, etc.).	+2
	I believe that driverless public transportation has no tolerance for mistakes.	-2
	Ordering driverless public transportation pick-ups through an app seems complicated.	-3
3	Service-Oriented Non-Enthusiasts	
	I am afraid that, without a human driver, the vehicle could start moving before I sit down.	+2
	I expect driverless public transportation to be more flexible.	-2
	I will likely use driverless public transportation options if they are recommended by people or institutions that I trust.	-3
4	Technology-Oriented Non-Enthusiasts	
	The display of ride-related information (e.g., speed) would help me to feel safe in driverless public transport.	+2
	I expect driverless public transportation to be more flexible.	+2
	I think school-age children should be accompanied by adults when using driverless public transportation.	-2
	I worry that, without a human driver, public transportation units will become unclean.	-3
	I am afraid that, without a human driver, the vehicle could start moving before I sit down.	-3

can be seen as a supra-individual opinion or a type of attitude in our context. From all relative rankings, the distinguishing statements are most important because they show the contrast between attitude clusters (cf., Table 4).

We found a small number of meaningful, statistically significant attitudes towards APT. Notably, we see that the found attitudes have different personal motivations: The largest cluster of participants belonging to Attitude 1 is based on a positivist attitude and enthusiasm towards the new technologies and thus called *Technical Enthusiasts*, while participants sharing Attitude 2 focus on the negative sides and barriers related to social consequences and therefore called *Social Skeptics*. Further, the remaining participants share a more neutral attitude focusing on public transportation service as in Attitude 3, thus called *Service-Oriented Non-Enthusiasts*, or technology benefits as in Attitude 4 thus called *Technology-Oriented Non-Enthusiasts*.

The clusters of user attitudes factors provide an overview for researchers to understand the expectations of users. Some of these expectations compete with each other among potential users. For example, the statement "I am afraid that, without a human driver, the vehicle could start moving before I sit down." is important (+2) for *Service-Oriented Non-Enthusiasts* (Attitude 3) but very unimportant (-3) for *Technology-Oriented Non-Enthusiasts* (Attitude 4), and found to be neutral within the other attitudes (*1*: -1, *2*: 0). These contrasting views are hard to integrate into a one-fits-all perspective, which is the primary aim of a technology acceptance model. Moreover, such a factor would possibly result in the omission of the factor because of overall neutral prediction quality. The more conflicting attitudes there are, the less generalization we can make in a specific domain. Nevertheless, using a Q-method approach as demonstrated might help to understand some of these conflicts.

From the attitude clusters, practitioners can prioritize design requirements according to the subjective relevance of users. Further, they can derive communication strategies to increase group-specific acceptance of autonomous public transportation, e.g., through the creation of user personas [11] An example: For *Technical Enthusiasts* (Attitude 1), communication should focus on performance-oriented benefits of autonomous public transport, e.g., improved timing of autonomous public transport and efficient travel time use. For *Social Skeptics* (Attitude 2), communication should tackle the barriers of the technology, argue, and provide facts about why the safety in autonomous public transportation will not be decreased through the absence of human authority, e.g., through the experience gained in pilot studies or through the offer to try the technology. Overall, the detection of attitudes clusters seems helpful to get fast insights into diverging user attitudes.

ACKNOWLEDGMENTS

Henrik Detjen's work is supported by the European Regional Development Fund (EFRE) at the Center for Automated Mobility. Irawan Nurhas' work is supported trough internal funding of the University of Applied Sciences at the Positive Computing Institute.

REFERENCES

[1] Rafael A. Calvo and Dorian Peters. 2014. *Positive computing: Technology for wellbeing and human potential.* The MIT Press, Cambridge, Mass.

[2] Fred D. Davis. 1985. *A technology acceptance model for empirically testing new end-user information systems: Theory and results.* Doctoral dissertation, Massachusetts Institute of Technology, Cambridge, MA, USA.

[3] Anna-Katharina Frison, Philipp Wintersberger, and Andreas Riener. 2019. Resurrecting the ghost in the shell: A need-centered development approach for optimizing user experience in highly automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour* 65 (2019), 439–456. https://doi.org/10.1016/j.trf.2019.08.001

[4] Joseph F. Hair, William C. Black, Barry J. Babin, Rolph E. Anderson, Ronald L. Tatham, et al. 1998. *Multivariate data analysis*. Vol. 5. Prentice hall, Upper Saddle River, NJ, USA.

[5] Charlie Hewitt, Ioannis Politis, Theocharis Amanatidis, and Advait Sarkar. 2019. Assessing public perception of self-driving cars. In *Proceedings of the 24th International Conference on Intelligent User Interfaces*, Wai-Tat Fu, Shimei Pan, Oliver Brdiczka, Polo Chau, and Gaelle Calvary (Eds.). ACM, New York, NY, USA, 518–527. https://doi.org/10.1145/3301275.3302268

[6] Pouyan Jahanbin, Stephen Wingreen, and Ravishankar Sharma. 2019. A Blockchain Traceability Information System for Trust Improvement in Agricultural Supply Chain. https://aisel.aisnet.org/ecis2019_rip/10

[7] Bruce McKeown and Dan B. Thomas. 2013. *Q methodology*. Vol. 66. Sage publications, Washington, DC, USA.

[8] Tobias Mettler, Michaela Sprenger, and Robert Winter. 2017. Service robots in hospitals: new perspectives on niche evolution and technology affordances. *European Journal of Information Systems* 26, 5 (2017), 451–468.

[9] Sina Nordhoff, Miltos Kyriakidis, Bart van Arem, and Riender Happee. 2019. A multi-level model on automated vehicle acceptance (MAVA): a review-based study. *Theoretical Issues in Ergonomics Science* 20, 6 (2019), 682–710. https://doi.org/10.1080/1463922X.2019.1621406

[10] Irawan Nurhas, Stefan Geisler, and Jan M. Pawlowski. 2019. Why Should the Q-Method be Integrated into the Design Science Research? A Systematic Mapping Study. https://aisel.aisnet.org/scis2019/9/

[11] Irawan Nurhas, Jan M. Pawlowski, and Stefan Geisler. 2019. Towards humane digitization: a wellbeing-driven process of personas creation. , 24–31 pages. https://doi.org/10.1145/3328243.3328247

[12] Kathleen O'Leary, Jacob O. Wobbrock, and Eve A. Riskin. 2013. Q-methodology as a research and design tool for HCI. In *CHI 2019*, Wendy E. Mackay, Stephen Brewster, and Susanne Bødker (Eds.). ACM, New York, NY, 1941. https://doi.org/10.1145/2470654.2466256

[13] Sebastian Osswald, Daniela Wurhofer, Sandra Trösterer, Elke Beck, and Manfred Tscheligi. 2012. Predicting information technology usage in the car. In *Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Andrew L. Kun (Ed.). ACM, New York, NY, 51. https://doi.org/10.1145/2390256.2390264

[14] William Payre, Julien Cestac, and Patricia Delhomme. 2014. Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation Research Part F: Traffic Psychology and Behaviour* 27 (2014), 252–263. https://doi.org/10.1016/j.trf.2014.04.009

[15] Christina Rödel, Susanne Stadler, Alexander Meschtscherjakov, and Manfred Tscheligi. 2014. Towards Autonomous Cars. In *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Erika Miller (Ed.). ACM, New York, NY, 1–8. https://doi.org/10.1145/2667317.2667330

[16] SAE International. 2018. J3016-201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. https://www.sae.org/standards/content/j3016_201806/

[17] Peter M. ten Klooster, Martijn Visser, and Menno D.T. de Jong. 2008. Comparing two image research instruments: The Q-sort method versus the Likert attitude questionnaire. *Food Quality and Preference* 19, 5 (2008), 511–518. https://doi.org/10.1016/j.foodqual.2008.02.007

[18] VDI. 2019. Automatisiertes Fahren in der Smart City. https://www.vdi.de/ueber-uns/presse/publikationen/details/vdi-studie-automatisiertes-fahren-in-der-smart-city

[19] Venkatesh, Morris, and Davis. 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly* 27, 3 (2003), 425. https://doi.org/10.2307/30036540

[20] Venkatesh, Thong, and Xu. 2012. Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly* 36, 1 (2012), 157. https://doi.org/10.2307/41410412

[21] Simon Watts and Paul Stenner. 2005. Doing Q methodology: theory, method and interpretation. *Qualitative Research in Psychology* 2, 1 (2005), 67–91. https://doi.org/10.1191/1478088705qp022oa