The Influence of Citizen Involvement on the Intention to Use Smart Traffic Management Applications

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Completed Research Paper

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Abstract

Smart traffic management initiatives are a growing trend in many cities. While they have the potential to fundamentally improve traffic in urban areas, their success is determined by the citizens' use of the applications developed in related projects. However, citizens are rarely involved in the requirements elicitation or development process encompassed within such initiatives, even despite research showing the high potential of user-centric software development. In a multiple-methods approach combining focus group discussions and a quantitative survey, we investigate how citizens can be integrated in the specification process of data-driven traffic management applications and whether their involvement can influence the intention to use those applications in the future. With our findings, we contribute to the field of user-centric software design in information systems research applied to smart cities and offer insights into citizen involvement in that context.

Keywords: Smart city, smart mobility, citizen involvement, user centricity, technology acceptance

Introduction

In view of the current era's complex challenges with overpopulation, demographic change, globalization, shortages in living space, traffic congestion, and climate change, today's cities aim to remain attractive to their citizens by providing livable environments (Chen et al., 2022; Morabito, 2015). In that context, so-called smart cities aspire to leverage the advantages of digitalization and advanced technology to support municipal management and create public value for citizens (Al Nuaimi et al., 2015; Dameri, 2017; Jonathan, 2020; Van Veldhoven and Vanthienen, 2022).

However, research on smart cities during their evolution in the past decade has focused on technical solutions without considering the human factor (Balakrishna, 2012; Law and Lynch, 2019; Murphy, 2010).

Only recently, have researchers begun to also consider the citizens' role and impacts in such initiatives despite their relevance and potential for better smart city solutions (Cardullo and Kitchin, 2019; Lee et al., 2022; Patel and Doshi, 2019). Such research has shown that involving citizens in the software development process of smart city initiatives can lead to more inclusive, and resilient solutions.

In Germany, the midsized city of Wetzlar, with approximately 54,000 citizens, is currently pursuing one such digital transformation towards becoming a smart city, namely in a process focused on data-driven traffic management applications. To that end, the VLUID project has been initiated to mitigate the negative effects of extension construction, which will take several years and highly affect mobility both in and around the city. [1] The project aims to maintain, if not improve, citizens' quality of life by seizing opportunities for digitalization in smart mobility while relying on the citizens and their use of the data-driven applications that will be developed during the project. Such applications may offer traffic-dependent routing, recommendations for other modes of transport, parking space assistants, or traffic light assistants. In that context, one question has arisen: What can municipalities do to make citizens willing to use those applications and adopt their recommendations?

Factor influencing the acceptance and adoption of information systems (IS) have been widely studied and, in research of IS, are primarily defined by the Unified Theory of Acceptance and Use of Technology (UTAUT; Davis et al., 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2003). However, the potential of involving citizens as co-creators in public projects, though shown to be high, has remained underexplored in IS research (Gascó, 2017; Mergel et al., 2018; Weinhardt et al., 2020). Thus, in our study, we sought to combine the well-explored theory of user acceptance with approaches for citizen involvement and apply them in the context of smart traffic management.

Therefore, in this paper we address the following research questions (RQ):

> RQ 1: How can citizens be involved into the specification process of data-driven applications for traffic management?
> RQ 2: How does involving citizens in those processes affect their likelihood to use the data-driven applications?

Our study builds on our previous research concerning methods of evaluating data-driven applications for traffic management (Lorenz et al., 2022). It prioritizes the concept of citizen centricity by conducting focus groups and evaluating whether citizen involvement changes the citizens' likelihood of using the data-driven applications. In that way, we performed a quantitative study in a qualitative research setting. In this paper, we use *citizen centricity* synonymously with *human centricity* and *user centricity*. Although those terms are not usually used interchangeably, in our study's context they refer to the same idea, because humans in that context are both citizens and end users of future software.

With our findings, we aim to provide insights into how citizen involvement and co-creation can shape the success of public digitalization projects. We also stress taking advantage of the opportunities afforded by citizen-centric approaches in IS as a means to increase citizens' likelihood of using data-driven applications. Given the outstanding potential of user-centric software development and the need for citizen-centric smart city initiatives, we aim to contribute to the field of user-centric requirements elicitation in smart traffic management. Our findings stand to pave the way for more user-centric software design in public smart traffic management projects and, in turn, more suitable, widely accepted solutions for livable smart cities.

To answer our research questions and verify the hypotheses, we have structured this paper as follows. First, we discuss relevant literature on smart cities, user acceptance, and approaches to realizing citizen centricity. Second, we articulate and justify our hypotheses, as well as explain our methods and research process in detail. Third, we present the results of our study and probe the observed effects as well as participants' qualitative feedback in considerable depth. Last, we discuss the limitations and implications of our study and offer an outlook for future research.

[1] The VLUID project, named after a German term that translates to "traffic management solutions for complex reconstruction scenarios based on intelligent data analysis", is an interdisciplinary project led by six project partners. In this paper, we refer to "us" as the scientific research team of the project. We also refer to the "project team" as the whole project team in general, consisting of all six partners and 15 individuals in total.

Theoretical Background

Smart Cities and Smart Traffic Management

Despite limited space and resources, today's cities are becoming more and more populated as a result of population growth and increased urbanization (General Assembly of the United Nations, 2017). In parallel, smart city initiatives have evolved in recent years with the goal of contributing to those challenges and, in turn, ensuring livability in urban areas. Such initiatives aspire to positively impact society as well as nature by using opportunities afforded by technology, software, and data while considering sustainability, resilience, governance, and the intelligent management of natural resources, all to enhance the quality of life in cities (Al Nuaimi et al., 2015).

The concept of smart mobility, as one building block of smart cities, focuses on using information and communications technology (ICT) to improve mobility in cities. Smart mobility is defined as "a set of coordinated actions addressed at improving the efficiency, the effectiveness and the environmental sustainability in cities" by using ICT in the context of mobility (Benevolo et al., 2016). While administrators can focus on improving traffic management, route planning and data-based development, citizens can reap the benefits of those advances in terms of improved traffic, alternative routes, and cost-efficiency (Paiva et al., 2021). That relationship clearly captures the relevance of citizens as users of the developed applications and consequently stresses that smart mobility approaches should aim to generate advantages for administrators and citizens alike. However, though the deployment of technology and digital infrastructure are prerequisites for smart cities and smart mobility, they are merely the foundation and cannot generate value without usage.

User Acceptance

In IS research, the Technology Acceptance Model (TAM) and UTAUT model offer guidance for analyzing and measuring users' acceptance and adoption of IS (Venkatesh and Davis, 2000; Venkatesh et al., 2003). TAM explains several stages of users' acceptance of technology whereby attitudes toward using a technology indicate actual system use and later influence continued use and adoption (Venkatesh and Davis, 2000). Derived from the TAM, the UTAUT model identifies four key constructs of user acceptance—performance expectancy, effort expectancy, social influence, and facilitating conditions—each influenced by the user's gender, age, experience, and the voluntariness of use (Venkatesh and Davis, 2000; Venkatesh et al., 2003). Combined, they influence the behavioral intention and usage behavior as well as each other.

Beyond those two models, a recent study has revealed factors that influence the intention to use and actual use of web applications in smart cities (Popova and Zagulova, 2022). The authors characterize citizens of smart cities as both the collective source for change and the object of all target activities and suggest increasing the population's involvement in using the applications (ibid). Along similar lines, other authors have also called for more user-centric approaches and the involvement of citizens in smart city initiatives—for instance, by empowering them and using bottom-up approaches (Cardullo and Kitchin, 2019). Taken together, the studies have indicated that people living in cities play a key role in smart city initiatives because their adoption of the systems determines the initiatives' success or failure. However, despite those calls for end users' involvement and other studies on user-centric design, research on smart cities has continued to focus on technical solutions (Balakrishna, 2012; Law and Lynch, 2019).

User Centricity and Citizen Centricity

For years, user-centric design has been studied both in product and in software development. In this paper, we define user centricity as a form of participation and involvement in which alternatives are evaluated and shared with interested parties beyond a project team in order to agree upon and implement solutions that are supported by the entire group (Vroom and Jago, 1988). In software development, research has shown that user-centric design and requirements elicitation stands in direct relation to user acceptance (Grundy et al., 2020) and improved product usefulness and usability (Mao et al., 2005). Involving users early in software development can also promote a system's success and user satisfaction as well as improve the quality of requirements (Kujala, 2003). For users themselves, being involved in development and/or building processes also generally drives feelings of ownership, the fulfillment of personal needs, and better understandings of the systems being used (Barki and Hartwick, 1994). Research has additionally shown

that user involvement throughout the software development process can be vital for the success of software systems (Alvertis et al., 2016).

Despite their clear implications for user-centric software design, the cited studies have focused on software that helps users to perform their tasks better in the workplace. By contrast, smart city applications are support systems offered to end users for voluntary use in public environments. Because smart cities are transformed for the benefit of their inhabitants, combining user-centric and data-driven approaches has the potential to improve the development of applications as well as their usability (Qi and Shen, 2019). User-centric software development involving requirements elicitation with citizens has already been explored in governmental contexts, including e-government services (van Velsen et al., 2009). Another initiative categorized citizens as democratic participants, co-creators and ICT users and derived a participation dashboard that reflects citizen involvement on multiple levels (Simonofski et al., 2019). Beyond that, other initiatives promoting citizen involvement have included citizens in designing plans, providing data, or making decisions (Przeybilovicz et al., 2022). In those roles, however, they are mostly providers of feedback and seldom encouraged to shape plans (Cardullo and Kitchin, 2019). Other researchers have pointed out that to become smart, cities require a long process for development and transformation, in which they have to align different influential factors while respecting diverse human needs (Levy and Germonprez, 2017). Citizens do not benefit from technology itself but from its usefulness. Although organizations often have an understanding of what citizens require, only by casting citizens in the role of end users can they provide certain knowledge of their needs (Becker et al., 2023). It has also been highlighted that citizens' involvement in smart city initiatives is highly complex, differs from initiative to initiative, and should be studied in the long term owing to the current lack of evidence about their roles in such initiatives (Przeybilovicz et al., 2022).

In sum, the literature discussed shows that user-centric software design has been successfully applied to influence acceptance among end users. Researchers have also identified the influence of citizens as being entangled with the success of smart cities but called for more involvement because the practice remains underexplored. Beyond that, most research on citizen involvement in smart cities has been conducted in the context of smart governance, thereby leaving room for research on the matter in the context of smart mobility. Due to the growing relevance of smart traffic management, we recognize the potential of citizen-centric software design and aimed to explore its potential in our research.

Research Approach

Research Model and Hypotheses

The terms *citizen involvement*, *citizen engagement* and *citizen participation* are closely related and often used interchangeably. Nevertheless, in the following, we use the original wording from the literature in order to remain true to the meaning expressed in the sources. Prior research has revealed a notable relationship between citizen participation in various phases of software development and the level of their acceptance of related systems (Grundy et al., 2020; Mao et al., 2005). Researchers have also identified the positive impact of user engagement on IS acceptance throughout the analysis, design, and implementation of the systems as they are being developed (Foster and Franz, 1999). Moreover, at least one study has emphasized that citizen engagement in the initial phases of analysis and design can significantly influence citizens' eventual acceptance of the system (Franz and Robey, 1986). The link between higher levels of user involvement and higher levels of perceived usefulness has also been evidenced and explained by the notion that a user's involvement enhances their understanding of a system's functionalities and problem-solving capabilities (Franz and Robey, 1986; Hunton, 1996). Added to that, research has demonstrated a strong association between user involvement and system success, with success defined by the variable of attitude, including perceived success, accuracy, reliability, and IS quality (Pettingell et al., 1988).

In sum, studies have highlighted correlations between user involvement at various stages of IS development and end users' attitude toward and acceptance of systems, as well as the system's overall success. Considering those aspects in our study's context of application, we identified potential areas for further research that currently seem to be underexplored and to which our study could contribute. On that count, our study diverges from previous investigations in three primary ways. First, the mentioned studies have been conducted within closed organizational settings. They often involved employees as end users and (internal) software development teams as representatives of companies' goals. By contrast, we focused on

interactions between citizens as end users and a municipal authority in a relationship that presents different dynamics. Second, our study was conducted in the specific context of applying smart traffic management solutions, which represent a specialized type of software that is nevertheless highly important in the daily lives of citizens. Third, whereas most previous studies have evaluated users' attitudes, acceptance, and adoption after a system's implementation, we evaluated the possible effects of user involvement on the intention and likelihood of usage of IS in the early stage of requirements elicitation in a project whose final product has yet to be developed.

By extension, our hypotheses generally expected that involving citizens in the process of requirements elicitation in the context of smart traffic management in a city ultimately increases their intention to use said applications. We explored those hypotheses in light of our research model shown in Figure 1. The model captures how citizens identify and discuss software requirements, which we understand as a form of citizen involvement. We hypothesized that such involvement influences citizens' intention to use the applications and might later predict their actual use and acceptance of the same applications. However, that last aspect will be part of a future study within our longitudinal research design.

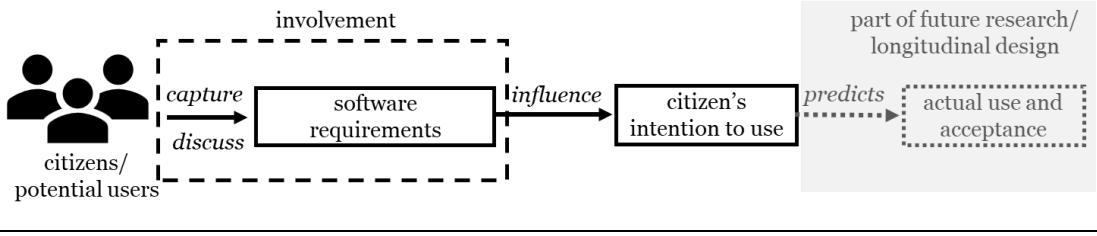

Figure 1. Research Model

In the study reported in this paper, we investigated the following three hypotheses:

> H1: Citizens are more willing to use data-driven applications for traffic management in general after being involved in focus groups for requirements elicitation.
>
> H2: Citizens are willing to use data-driven applications for traffic management more often after being involved in focus groups for requirements elicitation.
>
> H3: After citizens are involved in focus groups for requirements elicitation, their attitude toward the applications addressed in the groups changes.

Although H1 and H2 may appear to be similar, they differ in an important aspect. With H1, we sought to analyze whether involving citizens affects their willingness to use the applications in question; however, with H2, we sought to analyze whether their intended frequency of using the applications changes as a result of their involvement. We differentiated those hypotheses because the frequent use of the applications may drive their adoption as well as exert broader effects on traffic in the city in general. Beyond that, in the long term, a higher intention to use the applications could also lead to their actual use and improve their acceptance as soon as they are introduced. However, that will be the focus of future research, for we currently cannot capture trends in actual use at such an early phase of the project. Last, H3 focused on general attitudes toward using the applications after the focus groups. To investigate all three hypotheses, we devised a research process based on a multiple-methods approach that we describe in what follows.

Research Process

This paper focuses on the first part of a larger study designed to explore opportunities for using focus groups as a method of citizen involvement in the context of a city's transformation towards a smart city. In the study reported here, we aimed to answer our research questions by following a quantitative research approach and to enhance the results with additional findings from a qualitative analysis. Although we also gained more in-depth findings about detailed requirements from the qualitative part of our study, they are not reported here. Figure 2 illustrates our two-pronged research process.

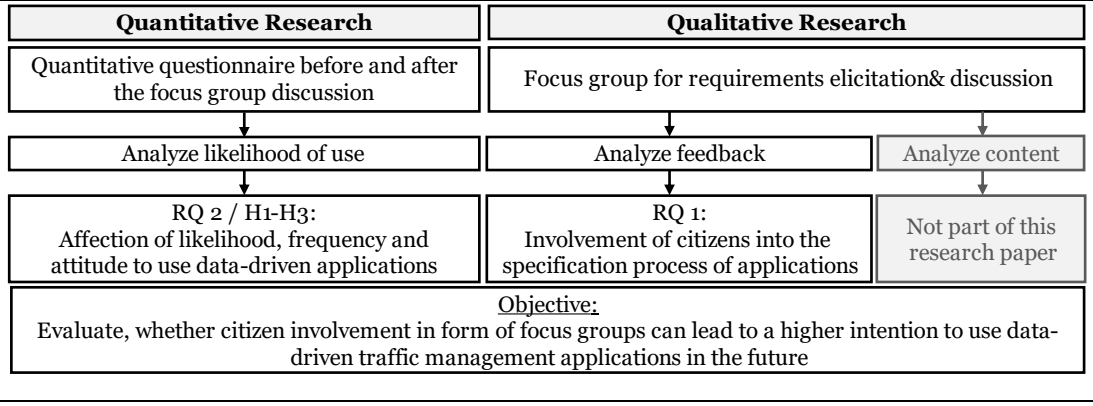

Figure 2. Research Process

First, we explored methods of involving citizens in the process of requirements elicitation, which is typically the first step in the process of system development (Dick et al., 2017) and which has succeeded in other areas of software development. We also investigated whether involving citizens in that process leads to their higher acceptance and likelihood of using the applications in question. To those ends, we adopted an approach for driving citizen involvement and evaluated it by using quantitative methods. In so doing, we measured changes, if any, in citizens' likelihood of using the applications after the requirements elicitation process compared with before. We sought to answer our two research questions by conducting focus groups with citizens of Wetzlar and providing them a questionnaire before and after their discussions. For that purpose, we determined that following a convergent multiple-methods design would be the most fitting for our research because it would allow evaluating the focus group design and measuring the format's influence on participants (Creswell and Creswell, 2018). Whereas the quantitative part of our study concerned identifying whether involving citizens positively affects their intention to use the data-driven applications in question, the qualitative part afforded us more insights into the reasons that might drive such intentions. By following that approach, we sought a stronger understanding of insights gained from our quantitative findings. Furthermore, by virtue of the design, we were able to collect data on the process being studied and its outcomes, both of which are crucial parts of our research questions.

Focus groups are defined as group discussions organized to explore a specific set of issues with special emphasis on the participants' views and experiences during their involvement in a shared activity (Kitzinger, 1994). They are also used to gather information on current or past experiences, feelings, and beliefs and for gaining in-depth understanding of topics (Krueger and Casey, 2009). Because traffic and livability are both highly personal areas of interest, focus groups were considered to be particularly apt for exploring individual understandings and perceptions within a diverse group of citizens. Last, focus groups are a highly interactive, participatory form of citizen involvement, and because more engaging forms of citizen involvement have been associated with more positive effects, we decided that the approach would be fitting for our study (Hunton, 1996).

In our study, we combined focus group discussions with a requirements elicitation exercise in which participants, despite being diverse, were expected to reach a mutual understanding. We sought to form heterogeneous groups in order to bring together perspectives from citizens who differed in preferred modes of transport, age, and gender. At the same time, we wanted the groups to be highly interactive, to stimulate the exchange of different perspectives and to encourage all participants to consider views other than their own. In past research on user-centric software design, the focus group approach has been found to be appropriate for exploring underlying factors such as emotions, accessibility, and acceptance that influence the software development process (Grundy et al., 2020). Because we were interested not only in the requirements elicitation process but also whether our approach to involve citizens would change their likelihood of using yet-to-be-developed applications, we opted to also integrate a complementary quantitative approach in the form of a survey. In so doing, we aimed to gain additional data about citizens' preferences both before and after the focus group discussions. Although we could not measure the actual use of the applications, that part of the study allowed us to empirically evaluate whether involving citizens in requirements elicitation would increase their likelihood of using the applications.

Study Design

For our study, we recruited participants via a registration form that asked citizens of Wetzlar to voluntarily provide information about their residence, age, and gender as well as modal split, meaning the types of transportation used on a regular basis (e.g., car, public transport, and bicycle). We distributed the registration form via several online and offline channels operated by the project's partners, local administrations, and private organizations. To moderate possible selection bias resulting from applications from people with a preexisting interest in traffic, we raffled three vouchers worth €50–150 among all participants as an incentive for participation. Citizens were recruited for both the qualitative and quantitative parts of the study because both were interlinked and conducted in the same setting. Therefore, we set the lower limit of our sample size to 30 participants, which is both the recommended total sample size for focus groups (Creswell and Creswell, 2018) and considered to be sufficient for the Wilcoxon signed-rank test (Cleff, 2019). Our registration form was accessed over 500 times and 12,6% of visitors completed the form, for a total of more than 60 forms. From those forms, we selected only participants who lived in Wetzlar or in areas up to 5 km from the city's border or who worked or studied in the city. By applying those criteria, we wanted to ensure a focus on citizens who were directly connected to the city and who would be affected by the construction sites in the future.

Next, we formed focus groups that were as diverse as possible, especially in terms of participants' reported modal split, age group, and gender. We selected 52 participants and organized seven focus groups with 5–8 participants each. We did not select all 60 participants for two reasons. First, considering our aim to fill each focus group with diverse participants, we had to exclude some participants whose profiles were too similar to the profiles of other participants. Second, because participants could choose from nine timeslots for the focus groups, their availability sometimes did not align with the dates of the focus groups. Ultimately, 37 citizens participated in the study; thus, our lower sample size limit of 30 participants was achieved. On average, participants were 53 years old (median = 55 years); the youngest was 14, whereas the oldest was 74. Nearly two-thirds of participants were men (n = 24) and approximately one-third were women (n = 13). The primary form of transport most used was cars (22), while the secondary form of transport most used was bicycles (17). The distribution of the participants regarding the criteria for our focus groups appears in Table 1.

Citizens' characteristics	**Mean**	**Median**	**Count**	**Percentage**
Age	53.14	55	-	-
Gender				
Man	-	-	24	65
Woman	-	-	13	35
Residence				
City (center)	-	-	11	30
City district	-	-	14	38
Surrounding areas	-	-	12	32
Primary form of transport				
Car	-	-	22	59
Public transport	-	-	3	8
Bicycle	-	-	8	22
Foot	-	-	4	11
Secondary form of transport (multiple choices possible)				
Car	-	-	16	43
Public transport	-	-	9	24
Bicycle	-	-	17	46
Foot	-	-	9	34
Distance to occupation (km)	11.3	6	-	-

Table 1. Descriptive Statistics of the Study's Participants

For the quantitative part of our study, we designed two questionnaires to assess possible changes in the perceptions of citizens regarding different factors and, more importantly, in their likelihood to use the data-driven applications. When interacting with participants, we changed the term "data-driven applications" to "digital information services" because the latter term is more user-friendly and easier to comprehend. One questionnaire was designed to be distributed before the focus group workshop and the other after the workshop. Both questionnaires contained mostly the same questions. The first questionnaire consisted of three questions, whereas the second contained three additional questions as a means to identify changes in greater detail. The questions were designed as self-assessments to be rated on a 5-point Likert scale as recommended by literature (Chomeya, 2010). We also allowed participants to answer the questions per use case in anticipation that they might feel differently regarding the different modes of transport. The use cases were developed with multiple partners, practitioners from the City of Wetzlar, and other stakeholders of the project in the preceding phase of the project; they were developed in multiple workshops and iterations, which resulted in 17 use cases overall that were subsequently sorted and condensed into five categories of cases. The complete questionnaire with the related categories of use cases is displayed in Table 2.

Q	Time of evaluation	Question	Response options	Rationale
1	Pre- and post-discussion	How personally relevant to you is each of the following use cases? a) Recommendations for individual car traffic b) Informative overview of construction sites c) Environmental data d) Informative overview of public transport e) Information for cyclists and pedestrians	(5) Very relevant (4) Somewhat relevant (3) Undecided (2) Not especially relevant (1) Not relevant	To identify whether the participants' focus on mobility had shifted after the discussion
2	Pre- and post-discussion	How likely are you to use information services for the related use cases in the future? a) Recommendations for individual car traffic b) Informative overview of construction sites c) Environmental data d) Informative overview of public transport e) Information for cyclists and pedestrians	(5) Very likely (4) Somewhat likely (3) Undecided (2) Somewhat unlikely (1) Very unlikely	To identify usage intention before and after the discussion
3	Pre- and post-discussion	How often would you use information services for the related use cases in the future? a) Recommendations for individual car traffic b) Informative overview of construction sites c) Environmental data d) Informative overview of public transport e) Information for cyclists and pedestrians	(5) Daily (4) Several times per week (3) Several times per month (2) Once per month (1) Only on occasion	To identify usage intention before and after the discussion
4	Post-discussion	To what extent has your attitude toward the information services changed following the discussion?	(5) Strongly (4) Slightly (3) Undecided (2) Mostly unchanged (1) Unchanged	To identify concrete changes, if any, in attitude toward the applications
5	Post-discussion	If your attitude toward the information services has changed, then how has it changed and why?	Free text box	Identify underlying reasons for possible changes in usage intention
6	Post-discussion	Since the discussion, are you more or less likely to use the information services? a) Recommendations for individual car traffic b) Informative overview of construction sites c) Environmental data d) Informative overview of public transport e) Information for cyclists and pedestrians	(5) Far more likely (4) More likely (3) Unchanged (2) Less likely (1) Far less likely	To identify concrete changes in the likelihood to use the applications

Table 2. Questionnaire Design

Procedure

The focus group workshops were set to last 3 hours, with 1 hour for the introduction and completing both questionnaires before and after the discussion. The focus group discussion was set to last approximately 2 hours, with 1.5 hours dedicated to collecting participants' requirements and approximately 30 minutes for sorting the requirements and reaching consensus. Figure 3 shows the design of the focus group workshops in detail.

Stage		Rationale
1	Introduction of project and use cases	▪ Familiarize participants with the topic and problem description ▪ Introduce participants to use cases which reflect potential areas for implementing data-driven applications
2	First questionnaire	▪ Determine the as-is state by asking participants a) for their opinion on the importance of each of the presented use cases and b) for their likeliness to use data-driven applications associated with each use case
3	Discussion	▪ Determine the participants potential agenda and their mobility patterns and preferences ▪ Collect requirements raised by participants and observe their attitude towards them as well as the importance of each requirement
4	Second questionnaire	▪ Determine the participants opinions after the discussion ▪ Find out whether the discussion or the involvement changed their a) perception of certain use cases and b) their likeliness to use the data-driven applications
5	Feedback	▪ Get participants feedback on the session, the method and their perception of the atmosphere to identify potential for improvement ▪ Give participants the opportunity to mention or stress aspects that are particularly important to them

Figure 3: Focus Group Workshop Design

Each workshop commenced with an introduction of the project and a presentation of the use cases defined within the project team as a means to familiarize participants with the topic and describe the problem being studied. We presented five use cases with the following topics: a) recommendations for individual car traffic; b) informative overview of construction sites; c) environmental data; d) informative overview of public transport; and e) information for cyclists and pedestrians. Presented without any ranking, the use cases summarized possible data-driven applications and how they could improve traffic in the city. The participants were next asked to complete the first questionnaire based on the information presented in the introduction. Afterward, the focus group discussion was led by a moderator chosen from the researchers involved and supported by two assistants who summarized the participants' ideas on a pin board. The discussion began with two introductory questions and six primary questions. The introductory questions, focused on the purpose of the participants' involvement and their mobility patterns in relation to their mobility needs, expanded our understanding of each participant's preferences. By contrast, the primary questions were designed with the UTAUT model in mind, starting with the broadest question, followed by increasingly granular questions. Although the UTAUT model is often used to design quantitative studies, we opted for a different approach by using qualitative questions to determine which factors would influence the participants' likelihood of using the applications.

The aim of each focus group discussion was to gather requirements mentioned by the participants while also determining their individual preferences and mobility patterns. We also asked the participants to reach a consensus within their groups regarding all mentioned requirements and to label each requirement as either "required" or "optional"; we defined "required" requirements as criteria that the applications need to meet in order for citizens to be willing to use the applications, whereas the "optional" requirements were defined as ones that would be preferred but that if unmet would not stop citizens from using the applications. After that categorization, the participants were asked to complete the second questionnaire. In that step, we wanted to analyze whether their perceptions had changed as a result of the focus group discussions. We ended the focus groups with a round of feedback to gather potential ways to improve the workshops and evaluate participants' attitudes toward the study's design.

Results

Quantitative Results

In this section, we focus on the quantitative results of our study. Although we do not focus on the content or themes of the focus group discussions, we include qualitative feedback from participants that contributes to enriching our results in relation to the research questions.

Because we used a 5-point Likert scale in our questionnaires, we were able to easily translate the participants' responses into values for analysis. Referring to our hypotheses, we performed statistical tests for each of the questions, hereafter designated as "Q1," "Q2," and so on, from the questionnaire for two reasons. First, we wanted to determine whether any changes emerged in the measured values from before versus after the focus group discussions and, if so, then how large they were. Second, we wanted to test the statistical significance of our results. For most of our questions, we collected two samples of answers (i.e., before and after the focus group discussions), which made our samples dependent. Although most questionnaires had been filled out correctly, we were forced to exclude one questionnaire in its entirety and two others when it came to Q6 due to errors in completion and missing values.

We conducted tests with two samples in order to compare the central tendencies of the two dependent samples that we measured on an ordinal scale. We used the Wilcoxon signed-rank test with one and two samples, depending on the hypothesis and data set, which is used for ordinally scaled variables that do not have to be normally distributed (Cleff, 2019). The requirement of having two repeated measurements was therefore met. We used the test with two samples for Q1–Q3 due to the availability of response before and after the focus group discussions. For Q4 and Q6, which were asked exclusively on the second questionnaire, we used the same test with one sample tested against an expected median of 3. In so doing, we were able to test whether H_0, the null hypothesis (i.e., "There is no difference between scores from before and after the focus group discussions" for two samples and "There is no difference to the expected median of 3 after the focus group discussions" for one sample), could be rejected, which would indicate a significant result.

We applied a significance level (α) of .05 and calculated the following values (Cleff, 2019; Cohen, 1988):

- W+, the sum of positive ranks, and W−, the sum of negative ranks;
- The median (Mdn), in the case of the two-sample test before (Mdn_1) and after the focus group discussions (Mdn_2), and which in the case of the one-sample test was assumed to be 3;
- *Z*, which represents the test statistic of the Wilcoxon signed-rank test;
- *p*, or the probability of H_0 being correct; and
- *r*, the effect size, calculated by dividing *Z* with the square root of *n* times 2. The effect size can vary from 0 to close to 1, with from 0 to less than .1 indicating a very small effect, from .1 to less than .3 indicating a small effect, from .3 to less than .5 indicating a medium effect, and .5 or more indicating a large effect (Cohen, 1988).

Q1 addressed the relevance of each use case to the participants. In asking Q1 before and after the focus group discussions, we sought to rule out any changes in attitudes toward the applications due to changes in relevance. As Table 3 shows, the effects were very small and, except for Q1(c), were non-significant, meaning that the personal relevance of the use cases did not change for the participants.

Wilcoxon signed-rank test in two samples (n = 36, α = .05)								
Q1: How personally relevant to you is each of the following use cases?								
Subquestion	**W+**	**W−**	**Mdn_1**	**Mdn_2**	***Z***	***P***	***r***	**Difference**
(a) Car	48.0	30.0	4.0	5.0	−0.775	.439	−.091	Very small, non-significant
(b) Construction site	28.0	8.0	5.0	5.0	−1.508	.132	−.178	Small, non-significant
(c) Environment	5.5	60.5	3.0	3.0	−2.673	.008	−.315	Medium, significant
(d) Public transport	24.0	42.0	4.0	4.0	−0.905	.366	−.107	Small, non-significant
(e) Foot/bicycle	35.5	84.5	4.5	4.0	−1.507	.132	−.178	Small, non-significant

Table 3. Results of the Wilcoxon Signed-Rank Test on the Relevance of the Use Cases

H1 expected that citizens would be more likely to use data-driven applications for traffic management in general after their involvement in the focus group discussions and the requirements elicitation process. Q2 related to H1. According to the results in Table 4, H1 had to be rejected for all use cases.

Wilcoxon signed-rank test in two samples (n = 36, α = .05)								
Q2: How likely are you to use information services for the related use cases in the future?								
Subquestion	**W+**	**W−**	**Mdn_1**	**Mdn_2**	***Z***	***p***	***r***	**Difference**
(a) Car	37.0	8.0	5.0	5.0	−1.811	.070	−.213	Small, non-significant
(b) Construction site	10.5	10.5	5.0	5.0	0.000	1.000	.000	None, non-significant
(c) Environment	24.0	42.0	3.0	3.0	−0.905	.366	−.107	Small, non-significant
(d) Public transport	33.5	44.5	4.0	4.0	−0.462	.644	−.054	Very small, non-significant
(e) Foot/bicycle	10.0	45.0	5.0	4.0	−1.941	.052	−.229	Small, non-significant

Table 4. Results of the Wilcoxon Signed-Rank Test for Likelihood of Use

H2, by contrast, expected that citizens would estimate their frequency of using the data-driven applications as being higher after their involvement than before. Q3 related to H2 and was again not supported by the data, as Table 5 shows. We thus conclude that citizen involvement does not change the estimated frequency of using the applications. The mean values of responses to Q3 show that most citizens would use such applications several times per month to several times per week.

Wilcoxon signed-rank test in two samples (n = 36, α = .05)								
Q3: How often would you use information services for the related use cases in the future?								
Subquestion	**W+**	**W−**	**Mdn_1**	**Mdn_2**	***Z***	***p***	***r***	**Difference**
(a) Car	37.0	8.0	4.0	4.0	−1.755	.079	−.207	Small, non-significant
(b) Construction site	88.0	48.0	4.0	4.0	−1.147	.251	−.135	Small, non-significant
(c) Environment	33.0	45.0	2.0	2.0	−0.489	.625	−.058	Very small, non-significant
(d) Public transport	36.0	42.0	3.0	3.0	−0.247	.805	−.029	Very small, non-significant
(e) Foot/bicycle	104.5	85.5	4.0	4.0	−0.426	.670	−.050	Very small, non-significant

Table 5. Results of the Wilcoxon Signed-Rank Test on Frequency of Using the Information Services

Last, H3 expected that the involvement of citizens would affect their attitude toward the applications. We asked the participants in Q4 whether their attitude toward the information services had changed following the focus group discussion. Because we asked Q4 only after the discussion, we compared our results to an expected median value of 3, derived from our 5-point Likert scale, and used the Wilcoxon signed-rank test with one sample to analyze the results. Again, the data did not support our hypothesis, as displayed in Table 6. However, we observed in Q1–Q3 that the reported relevance, willingness to use, and frequency of use were often higher than the expected median of 3. Therefore, a reason for the lack of change in attitude might have been that the citizens' overall attitude toward the information services was already positive.

Wilcoxon signed-rank test in one sample (n = 36, α = .05)				
Q4: How has your attitude toward the information services changed since the focus group discussion?				
Mdn	***Z***	***P***	***r***	**Difference**
3.5	−0.714	.475	−.0841	Very small, non-significant

Table 6. Results of the Wilcoxon Signed-Rank Test on Attitude Change

To identify possible reasons for changes in attitude, we offered a text box in our questionnaire (i.e., Q5) where participants could report how their attitude had changed and why. Twenty-two participants seized that opportunity and shared their reasons. In Table 7, we display an excerpt of those answers that we translated from German. Clearly, citizens felt more informed after the focus group discussions and had

gained additional insights from the discussions. Furthermore, the responses indicate that an explanation of possible solutions as well as diverse perspectives led to changes in attitude. Altogether, those results support our approach for citizen involvement.

Q5: If your attitude toward the information services has changed, then how has it changed and why?
- "Regarding the construction sites, the traffic information became more transparent."
- "I could see all of the possibilities that I didn't know about before."
- "I now have a better picture of the potential of a digital platform."
- "Certain use cases became clearer."
- "My attitude changed following the intensive discussion and the breadth of information shared."
- "The options are diverse and provide many opportunities."
- "My attitude changed when I saw the possibilities of using the data in the information services and its beneficial impacts."
- "The personal advantages for me became clearer."
- "I gained many new perspectives."
- "Seeing different possibilities for each traffic participant and related ideas led me to reprioritize the relevance of the use cases."
- "Through the discussion I gained new perspectives and views."

Table 7. Reasons for Changes in Attitude

Added to Q2, which asked participants before and after the focus group discussions to assess their likelihood of using the data-driven applications, we asked Q6 on the second questionnaire to gauge whether participants would be more or less likely after the discussions to use the information services. In contrast to Q2, Q6 focused on the relative change in the likelihood of use. Because participants were asked to complete the questionnaires intuitively and did not have access to their answers from the first questionnaire, we used Q6 to rule out any errors in self-assessment. As with Q4, we did not have values for Q6 to compare and therefore assumed that their attitude had not changed, for an expected median value of 3 (*unchanged*). Results of the one-sample Wilcoxon signed-rank test showed a large, significant effect for the use case on car traffic and medium, significant effects for the use cases on construction sites, public transport, and pedestrian/bicycle traffic. We could not prove effects for the use case regarding the environment. Therefore, phrasing Q6 differently than Q2 exerted a different effect (Table 8). The results for the use cases (a), (b), (d), and (e) therefore support H1 that citizens are more likely to use the information services after the focus group discussions. We were surprised by those results, which raise the question of whether actual use and adoption will be higher after citizen involvement.

Wilcoxon signed-rank test in one sample (n = 34, α = .05)					
Q6: After the focus group discussion, are you more or less likely to use the information services?					
Subquestion	**Mdn**	***Z***	***P***	***r***	**Difference**
(a) Car	4.0	4.132	.00004	.501	Large, significant
(b) Construction site	4.0	4.013	.00006	.487	Medium, significant
(c) Environment	3.0	1.129	.197	.137	Small, non-significant
(d) Public transport	4.0	3.141	.002	.381	Medium, significant
(e) Foot/bicycle	4.0	3.507	.00045	.425	Medium, significant

Table 8. Results of the Wilcoxon Signed-Rank Test on Likelihood of Use

We further explored the responses of Q6 in more depth after the statistical tests. The detailed responses to Q6 show that 22 of the participants (65%) rated their use of information services regarding car traffic and bicycle/pedestrian traffic as more likely or much more likely after the focus group discussions. Furthermore, 21 participants (61%) rated their intention to use information services regarding construction sites as more or much more likely, while 18 participants (53%) were more likely to use public transport information services. The information services regarding the environment were rated lowest, which might

partly explain why the likelihood of use did not change. Nevertheless, nine participants still found it more likely that they would use such applications in the future. This shows that for four of the five use cases, more than half of the participants reported a positive change in their likelihood to use the information services in the future after the focus group discussions. Our results indicate that if we phrased a question in absolute values, then no changes could be tracked. However, if we asked participants to report changes, then we could measure an effect. One explanation could be that most information services were already rated quite highly and that changes in attitude toward them were not as high as when reported intuitively. As a result, H1—that citizen involvement can lead to a higher usage intention—was supported.

Insights from Focus Groups

After the focus groups, we distributed a hyperlink to a website soliciting anonymous feedback where we asked the participants what they liked about the focus groups, what they disliked, how they perceived the format of the groups, and what we could do improve the focus groups in the future. Table 9 shows the feedback that 12 participants gave after the discussions. Although the statements have been translated, we did not change important keywords to stay true to the original meaning. We do not include results from the questions about what participants disliked and what we could do to improve because the answers were either unrelated to our study or format or already covered in the other responses (e.g., focus group size). As the results show, most participants liked the format primarily because of the exchange between the participants and the open discussion. Furthermore, the size of the groups seemed fitting to the participants. Therefore, a group size of 6–8 participants could provide a suitable setting for exchange.

Regarding areas for improvement, most participants mentioned organizational aspects (e.g., size of the room where the study was conducted), the time slots available, and requests for the results after analysis. Some participants from two of the relatively homogeneous groups also requested that future groups could be slightly more diverse in terms of gender and preferred modes of transportation.

Group	Online form feedback after focus groups
1	- "I liked the mixed composition of the group in terms of age but also in terms of our interests. Everyone was very open, and the interactions were pleasant. The format of the small groups was nice." - "The discussion was constructive, and the focus group setting was successful." - "I liked the small, diverse group. Everybody had the chance to speak, and the interactions were respectful. The size of the group was nice, and everybody could participate. The groups shouldn't be bigger." - "I liked the structure of the workshop and that it was well-prepared. I also liked the format because the conversation in the small group was easy and casual."
3	- "I liked the professionalism of initiating a project by listening to different opinions, collecting ideas, recognizing different aspects, and then making an informed decision. I liked the small groups." - "I liked the open discussion, but I think that the group could have been bigger."
4	- "I liked the constructive exchange in the small groups and that we had sufficient time and space to develop ideas. I liked the group size a lot." - "I liked the open discussion, and I got the impression that the contributions were treated confidentially. Regarding the group size, I think that 8–10 people per group would be better."
5	- "It was a very nice, open discussion. The small groups were very good because everybody had the opportunity to speak and share their perspective." - "The target-oriented selection of participants was very good. The open discussion was optimal because the different requirements and perspectives within the group could be presented and discussed. The size of the group was considerate, and the composition was very balanced."
6	- "The small size of the group and the diverse participants with different emphases allowed new, thought-provoking impulses. There were many different perspectives represented despite the group's small size. We were very productive in the small group."
7	- "I liked the structured process, the thoughtful preparation, and the visualizations. I think that the group size was good and constructive."

Table 9: Focus Group Participants Feedback

During the focus group discussions, we additionally perceived that the participants felt uninformed about construction measures in the past and welcomed the idea of digital information services. They further reported feeling that their voices had been heard by the project team as a result of the focus groups. In all

groups, participants were able to reach a consensus rather quickly and expressed their surprise that doing so was possible despite their different backgrounds and preferred modes of transportation. Although those qualitative results extend further, they are not discussed in this paper but will be in future publications.

With those results, we can also answer our first research question regarding how citizens could be involved in the specification process for data-driven applications. Our focus group approach provided an open, diverse environment for exchange as well as the opportunity for citizens to give voice to their requirements. They were also able to familiarize themselves with possible solutions and ask questions. As our quantitative results indicate, that approach led to a higher intention to use the applications in question later. In all, we conclude that the focus group workshop format was successful.

Implications and Limitations

In this paper, we have presented an approach for including citizens in the requirements elicitation process for data-driven traffic management applications for a smart city and shown that the involvement of citizens can lead to a higher intention to use the applications. Our results have several practical implications for citizen-centric design and citizen involvement in smart city initiatives. Above all, according to an internal analysis, more than 130 cities in Germany are of a size comparable to Wetzlar and might face similar challenges in the future, especially with further urbanization and shortages of living space. Therefore, the need for smart traffic management and approaches to developing solutions therein applies to other cases. Aside from traffic management, similar workshops could also be applied in other aspects of smart city initiatives in which the perspective of citizens could be fruitful.

Our theoretical contributions especially pertain to citizen involvement when used to influence changes in attitude. We have confirmed that involving citizens exerts effects on their intention to use applications similar to the effects of involving end users in private organizations. Moreover, our multiple-methods approach has shown promising results demonstrating that the method could be similarly used in other areas of research. Regarding our quantitative results, we are especially interested in further analyzing the reasons for changes in the willingness to use data-driven applications and which parts of the focus groups prompted those changes. We therefore see great potential in further pursuing such research in order to contribute to understandings and theory of technology acceptance. As shown, our study took two perspectives on similar research questions. In this paper, we have covered our quantitative research as well as parts of our qualitative analysis. In the future, we will further analyze the results from the focus group discussions to identify themes in the requirements and their implications. By doing so, we will show additional perspectives on specific requirements and highlight the advantages of the method of focus group workshops. Beyond that, we see potential for further research that explores the qualitative aspects of such initiatives as well as possibilities for involving citizens in smart city projects.

While the strengths of our study lie in our method of data collection in the field via focus groups as well as in its practical relevance, our study and its findings have some limitations. For one, although we aimed for a sufficient basis of empirical data, the sample size had shortcomings due to our bilateral approach of merging both qualitative and quantitative research. Therefore, our results might be less generalizable than in studies with larger samples. For the same reason, our quantitative study might have a relatively qualitative character, an assumption that we will test in other studies during subsequent phases of our project. Furthermore, we conducted our study in the context of a specific country and city. Along those lines, it might be interesting to reproduce our concept in more cities and/or countries to determine whether context alters the results. Another limitation derives from our sampling of participants. Despite our best efforts to diversify the focus groups, we had short-notice cancelations, mostly by younger women, which created a relatively high average age and an overrepresentation of men. In the qualitative part of the study, men and women reported different mobility-related needs, which might have affected aspects of our results. We also recognize that the focus groups might have influenced the survey, and vice versa. That limitation stems from our study design, even if it also served as a strength, as described in this paper's "Research Approach" section. Furthermore, in our quantitative study, we measured the attitude of citizens, which can be understood as a long-term construct. Therefore, it is possible that we did not detect significant changes in focus group workshops lasting only 3 hours. Yet another limitation stems from our questionnaire design. Despite our best efforts to formulate questions for the questionnaires that were straightforward, not complex, and oriented toward answering the research questions, that strategy may have affected which questions we asked and how we asked them. Self-assessment bias could have also affected how participants

answered the questions. Added to that, other formats of participation could result in changes in attitude or usage intention unlike those facilitated by focus groups. For that reason, future research should involve comparing different workshop formats or types of involvement.

Last, usage intention, even if likely, does not equal actual use. Therefore, the question again arises as to whether potential users' involvement in developing systems leads to their adoption of those systems. To determine whether involving citizens results in actual use, further tests are necessary. On that count, our study was only the first part of a larger, 3-year longitudinal study in which we will measure actual use in order to determine the effect of our workshops and other initiatives on actual use and adoption. Despite those limitations, we are confident that our results are relevant for both research and practice and provide a basis for further research and projects in smart cities of the future.

Summary and Outlook

In this paper, we have addressed the questions of how citizens can be involved in the specification of data-driven applications for traffic management and how their involvement affects their likelihood of using those applications. In our study, following a multiple-methods approach, we combined focus group discussions with a quantitative survey to explore opportunities for involving citizens and indications of factors that change their likelihood of using the applications discussed in the future. As a result, we were able to answer both of our research questions.

Our first hypothesis, H1, received mixed results. When we asked participants about their likelihood to use the applications before versus after the workshops, their answers were unchanged. However, when we asked about the change in their likelihood to use the applications, they reported a change that was significant. We therefore showed that citizens are more willing to use data-driven applications after their involvement in focus groups that solicit input about the applications. Even so, our data did not support H2 or H3, which focused on the intended frequency of use and possible changes in attitude. We suspect that those changes did not occur because the likelihood of use was already high before the focus groups.

In sum, our results show that that involving citizens in developing applications can positively impact their likelihood of using the applications in the future. The qualitative analysis of participants' feedback also showed that the participants felt engaged by the focus group format, that they enjoyed the small group size, and were able to give voice to their requirements for future applications. Based on those insights, smart traffic management projects and smart city initiatives in general may be able to positively affect citizens' likelihood of using new technology by involving them in the projects designed to develop such technology. If the likelihood of use also translates into actual use, then the potential of our results becomes especially relevant. Although our research approach had limitations, we are confident that our data provide a sufficient basis for that conclusion and light a clear path toward putting it into practice. With our findings, we contribute to the field of user-centric software design and technology acceptance in relation to smart cities and stress the relevance of involving citizens in public digitalization initiatives. Our findings underscore the great potential for knowledge transfer and synergies for future smart traffic initiatives, as well as for future research, by involving citizens in the development of those initiatives. We will continue such research in our project and in other research on smart cities in general and, in the future, look forward to presenting new findings from our longitudinal study.

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