Usability Evaluation of Mobile Passenger Information Systems

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Abstract. Public transportation becomes increasingly diverse because of innovation in transport modalities and a large number of service providers. For facilitating passengers' comfort, intermodal passenger information systems are required, which combine data of different providers and transport modes. Therefore, context sensitive mobile applications are promising solutions to supporting passengers at every stage of their trip. Crucial for the success of these applications is their usability. In this paper, a prototype of an intermodal passenger information system is investigated in a usability evaluation and tested in comparison to the leading mobility application in Germany. Both iOS apps were evaluated with a questionnaire using the system usability scale (SUS) in a lab setting (n=20) and in a field test (n=20). Additionally, participants of the field test were interviewed retrospectively about app and setting. The user feedback was beneficial in learning about users' expectations towards information retrieval procedure in and functionalities of a passenger information system. The usability evaluation basically revealed easy to improve usability problems, but also a trust issue and the need for a participatory component in public transportation, probably by integrating social media.

Keywords: mobile applications, smartphone app, travel information, passenger information system, usability, evaluation methods.

1 Innovating Public Transportation

Current trends in urbanism foster sustainable and green city designs for enhancing dwellers' quality of life [1]. In this context, transportation plays a notably role because emissions still grow in this industrial sector [2]. One strategy of mitigating the pollution is to enlarge public transportation and simultaneously reduce the number of rides with personal vehicles. To achieve this hoped-for emission decrease, the ridership in public transportation must be raised significantly [3].

For providing public transportation across an urban region, three levels of activity must be considered according to the transportation expert Paul Mees [4]: (a) On the *strategic level* system objectives are set, for instance funding sources, transportation modes etc. (b) On the *tactical level* the objectives are transferred into system-wide service strategies, for example defining the route network, drives, timetables etc. (c) Then, the tactic is translated to the *operational level*. There, day-to-day-operations are carried out such as training personnel, selling tickets, designing and distributing passenger information.

The image of public transportation emerges by the interaction of multiple factors; but predominantly by passengers' experience of consuming public transportation services. Therefore, even slight improvements on the operational level can contribute to accomplish a higher customer satisfaction. For this, it is necessary to identify shortcomings, which impair their comfort.

According to [5] and [6], passengers are highly frustrated when using public transportation because of lacking information provided by transit agencies. Travel information often seems incomprehensible to passengers; for instance understanding timetables overtaxes many people. Furthermore, they have no real-time information about the actual position of the vehicle they are waiting for. As a consequence, they do not know about its progress on its route and also not about delays, which causes frustration. Hence, introducing interactive information systems with real-time passenger information is a promising solution and a common passenger request. They can be realized using information and communication technologies (ICT). In particular, the proliferation of mobile Wi-Fi and the increasing prevalence of smartphones shift the focus strongly on mobile passenger information systems (PIS) realized as smartphone apps [3]. They can offer passengers the opportunity of easy and rapid information access and will advance to the position of passengers' daily companions [7].

Crucial for the success of these services are two factors: a) the quality of the provided information in terms of comprehensiveness and completeness and b) the systems' usability. For achieving this comfort improvement, passengers must award a "perceived usefulness" to these apps (according to the technology acceptance model of [8]). Hence, passengers' perspective must be thoroughly integrated during the iterative development of a passenger information system for accomplishing the best possible user experience.

2   Related Work

Recent work about passenger information systems is wide-ranging because various disciplines grapple with these services: Engineers address technical issues such as the development of primary-context models and ontologies [9] or dynamic personalization in multi-channel data dissemination environments [10]. Mobility experts deal with generic models of transport management systems including components for traffic regulation support and user information [11]. Especially, real-time data consideration is of major importance for assisting passengers en-route [12].

In the last decade, many pilot projects have presented their prototypes: One example is the TUTPIS application, which accompanies passengers at every stage of their trip and offers them personalized, real time information services (e.g. timetables, connection search, electronic ticketing) [13]. Another promising initiative is the UbiBus project, in which an ubiquitous system for public transport assistance uses context information [14]. Its core is an intelligent transportation system application, which supplies travel information on onboard displays, is available on the web and as a smart phone app. The latter delivers information about the current location of a bus or its progress on its route respectively.

Besides information distribution for public vehicle use, attention is also drawn to pedestrian navigation in multimodal routing services. For instance, Yu and Lu [15] created an initial prototype considering walking as a transport mode, which assesses travel modes by a defined criteria set. Their approach uses dynamic information about real-time and historic traffic data to facilitate precise estimations. In addition, Baus et al. [16] present a pedestrian navigation system for indoor and outdoor use, which can automatically adapt to location changes and display directions on different devices. Creating an intermodal information system also requires indoor navigation features. While passengers change modes at transit points, they often must route themselves through buildings in a short time period. Rehrl et al. [17] are aware of this problem and, therefore, propose an electronic guide, which generates a hierarchical model of the transit point complex and gives user instructions using visual aids (e.g. maps). According to a study investigating pedestrians' informational requirements, landmarks are the most valuable navigation cues and are way more important than street names or distance information [18]. Chowaw-Liebman et al. [19] and Heiniz et al. [20] have used this finding as a basis for developing a turn-by-turn approach for navigation inside large complexes of buildings (e.g. airports).

When surveying the latest research on passenger information systems, the majority of research initiatives focuses on technical aspects. Only few research activities were dedicated to HCI topics. Human factors experts work on user-centered application concepts: they study user behavior to design intuitively usable passenger information systems (see [21]). Especially, displaying travel information on mobile (small screen) devices is challenging why evaluating different presentation formats is necessary, for instance with paper prototyping [22]. In [4] and [23], Wirtz et al. conduct user tests to evaluate a passenger information system. The collected data was analyzed to investigate patterns and reference objects for gaining a deeper understanding of the media net surrounding a lately launched application.

Regarding user diversity, few empirical studies have been carried out on user groups' particularities. The ongoing demographic change shifts attention on elderly who are increasingly considered in the development of electronic devices and services (see [24]). Schaar and Ziefle [25] found that age is a notable factor in the acceptance of passenger information systems. This age effect underlies travel expertise and also technology experience. Another relevant user group are passengers with restricted mobility. Heck et al. [26] propose a concept for providing information about handicapped accessible routing using a hotline and a website. In this approach, most types of disabilities are considered; user profiles can be personalized.

Still missing are user test studies with passenger information systems to collect authentic user feedback. For this, an evaluation with a lab setting seems insufficient because it does not represent realistic using conditions. Therefore, an additional field test is necessary.

3   Empirical Study

The presented study deals with the usability evaluation of an exemplary intermodal passenger information system, which emphasizes guiding passengers in intermodal scenarios throughout the whole journey.

3.1   Evaluated Application[1]

A passenger information system is created following the guiding principle of gamification. The main conceptual idea is to design passenger information similarly to navigation aids in complex video games (e.g. World of Warcraft). There, the information provision is portioned according to situation-specific gamer needs (cascading information), which supports keeping gamers' actions focused on the objective, for instance completing the current level [27].

An intermodal trip is regarded as a quest game conceptualized as a chain of single tasks, which is displayed in a turn-by-turn-like user aid. Passengers gradually solve these tasks (get on bus, change mode etc.) until they reach their destination. Information is only given in order to reach the next intermediate target. The prototype is realized as an iOS 6 app, whose GUI basically consists of three different views: planning, selecting and assisting (see Figure 1).
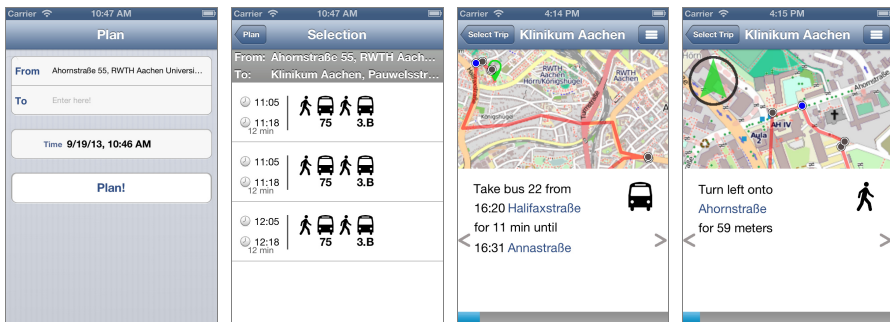
Fig. 1. Screenshots of views displayed in the prototype during an intermodal journey: a) plan view, b) selection view, c) assistance view (bus), d) assistance view (pedestrian)

The *plan view* displays a search mask for entering a trip's starting point (*From*), destination (*To*), a date selector (*Time*), and a search button (*Plan!*) (see Fig. 1,

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[1] For more information about the approach (e.g. functions, view design, back-end realization, implementing etc.) see [27].

screenshot a). Using the virtual keyboard passengers can insert, for example, an address for start and/or destination. Furthermore, the current geolocation can be used as a starting by tapping a green position icon, which appears while interacting with the *From* text field. Two scenarios can be serviced: planning a route or rescheduling an active trip. The actions in the former lead to the selection view, in which feasible itineraries are listed; the ones in the latter to the first listed itinerary implying that this is the optimum route.

The *selection view* is displayed as a table (see Fig. 1, screenshot b). On top of it, starting and destination are described. Subsequently, the possible itineraries are listed; each providing time of departure and arrival, trip duration, required transportation modes (icon-based visualization), vehicle /route identifier (e.g. bus number).

On the *assistance view* the trip is segmented into steps, which are drawn in a map (see Fig. 1, screenshot c). Progress on the route is visualized as well as starting points of each step (position markers). When walking is the proposed transportation mode, a *compass* functionality – inspired by quest games – gives passengers information about the direction of their destination (rotatable green arrow). The displayed text refers to the actual transport mode: While walking, the turn-by-turn assistance is provided. The name of the road the pedestrian is supposed to walk down is given as well as the distance this step covers. Moreover, the absolute and the relative direction are presented via map. While being on a transit stage, the current mode depicted by an icon and informational labels are shown. They incorporate details such as vehicle type, transit route, departure and arrival time, starting point as well as destination of step. Finally, a progress bar conveys information regarding time about the total progress on the chosen route.

3.2   Evaluation Methodology

The described prototype was tested in comparison to the DB Navigator, which is the most popular mobility application in Germany [28]. The test covered a leading scenario and three tasks which test participants had to tackle by interacting with the apps. The scenario was used to communicate participants the nature of the test and to give the tasks an overall framing (participant is a student with an iPhone owning a student ticket and using public transportation frequently).

After reading the scenario, the task processing began. All tasks focused on the apps' primary functionality routing. For lowering the cognitive load, task instructions were handed over only after completing or terminating the previous task.

Task 1 required a routing from the actual position to a bus stop: *It is 09:18 a.m. at the 3rd of August 2013. You are running through an unknown street. You have to go to the Audimax, a university building, to write an exam. The exam will start at 10:00 a.m. Use your app to find information about a bus ride to your exam. Use the integrated functionality to find your actual location.*

Task 2 was about routing from a bus stop to an address: *It is 03:03 p.m. at the 3rd of August 2013. Your performance during the exam was more or less successful. You are having a late lunch with your girlfriend Claudia and have to plan a trip from the Pontstrasse, Aachen to the home improvement store because you have to buy material*

for fixing a shelf for Claudia. The home improvement store is located in Roermonder Strasse 177, Aachen. You are again pressed for time because later you have an important appointment. Use your app to reach your destination by bus as quickly as possible.

Task 3 was dedicated to routing between two addresses: *It is 17:13 p.m. at the 3rd of August 2013. After you have carried out all tasks you have promised to Claudia you must rush to your family to help them preparing a birthday party. At the moment, you are at Claudia's place in Oppenhoffallee 143, Aachen. Your parents live in Burtscheid, a suburb of Aachen, in the street Birkengrund 10, Aachen. You have to be there at 06:00 p.m. to set up a pavilion for the guests. You have to hurry because the weather forecast has announced 88% brollability. Use your app to reach your destination by bus as quickly as possible.*

All participants had to execute all tasks on both apps. The experimental design considered position effects: 50% of the test participants started with the prototype and used afterwards the DB Navigator, the other 50% vice versa.

Experimental Setting. Both applications were evaluated using an iPhone 4s. The test was carried out in two conditions: The first was an indoor laboratory setting in which participants were sitting at a desk in an office. The second was a field setting in which participants had to solve the test outdoor while walking (see Figure 2).

Fig. 2. Left: Test participant interacting with the prototype in the lab setting. Study manager documents the interaction using a screen camera, video camera, and a stopwatch. *Right:* Test participant interacting with the prototype in the field test. Only voice is recorded.

The latter condition refers to a current societal phenomenon: Many people deal with ICT-related multi-tasks in their everyday life. For instance, they interact almost all the time and everywhere with their smartphones, even while walking on the road. Passenger information systems foster this behavior because they are frequently consulted when information about public transportation is urgently needed, e. g. when immediately re-scheduling a trip. In such stressful situations, moving (rushing) to an entry of the public transportation system (bus stop etc.) often happens.

During the test, participants were instructed to "think aloud" (spontaneous commenting on interaction). Verbal comments were digitally recorded. In the lab, the interaction was additionally recorded with a screen record software. Due to technical restrictions this was not applicable for the field setting. For compensating this,

additional retrospective interviews were carried out with field test participants. After all, participants' feedback was collected with a questionnaire consisting of six sections: (1) demographic data, (2) mobility profile, (3) technology use, (4) assessment of DB Navigator, (5) assessment of the prototype, (6) overall rating.

The usability of both apps was measured with a questionnaire using the System Usability Scale (SUS) [29]. It is an easy-to-apply ten-item scale, in which users are asked to indicate the degree of (dis)agreement to several statements on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"). The overall scale gives a global view of subjective usability assessments. The maximum score on the SUS is 100 points. For avoiding any biases, the items are alternated between positive and negative ones (see Table 1):

Table 1. System Usability Scale (SUS) [29]

System Usability Scale
1   I think that I would like to use this system frequently.
2   I found the system unnecessarily complex.
3   I thought the system was easy to use.
4   I think that I would need the support of a technical person to be able to use this system.
5   I found the various functions in this system were well integrated.
6   I thought there was too much inconsistency in this system.
7   I would imagine that most people would learn to use this system very quickly.
8   I found the system very cumbersome to use.
9   I felt very confident using the system.
10   I needed to learn a lot of things before I could get going with this system.

Sample. 40 test participants took part in the user test (20 lab condition: Table 2; 20 in field test: Table 3). In total, the sample consisted of young adults (20-32 years old, 50% male/ 50% female). All test persons were well educated (university students, university graduates) and predominantly worked in technology-related professions.

Table 2. Sample description of the laboratory setting n = 20

Age	Gender	Profession
M = 23.9	Male = 11	20 students (mostly technology-related/
SD = 2.7	Female = 9	technical study programs)

**Table 3.** Sample description of the field setting n = 20

Age[2]	Gender	Profession
M = 26.1	Male = 9	14 students (mostly technical study programs)
SD = 3.8	Female = 11	6 university graduates (scientific staff)

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[2] One participant did not specify his/her age.

About their daily mobility they stated to be multimodal and use public transportation often (19 using bus daily). 34 test persons were using smartphones (no use: 2, missing data: 4). Concerning mobility apps, 38 stated to know the DB Navigator and 30 to use it (in addition: 8 Öffi users, 7 Navigon users, 37 Google Maps users[3]). The DB navigator's popularity was regarded as a problem because user experience influenced the results of performance tests. However, this experience had also a positive effect on assessing the prototype's quality by eliciting focused improvement suggestions.

3.3   Results

Participants' overall SUS rating of the evaluated apps differs in 3.9 points. The DB Navigator gained averagely 79.6 points out of 100 possible (SD = 14.9). In comparison, the prototype received a rating of 75.7 points (SD = 14.7). Carrying out the test with the prototype took 14 seconds longer compared to the DB Navigator. When working with the prototype, participants spent averagely 103 seconds on completing one task during the lab condition, 117s in the field. When interacting with the DB Navigator, 90 seconds were required in the mean to solve one task at the lab and 102s in the field (for details, see Figure 3).
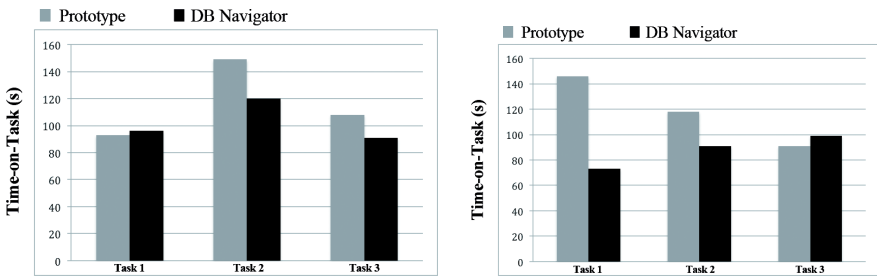
Fig. 3. Left: Time-on-task of lab setting (s). *Right:* Time-on-task of field setting (s).

Regarding the average duration for processing a task (time-on-task), a wide difference between lab and field condition becomes apparent: participants were dealing longer with the tasks during the field condition.

Besides the usability assessment using the SUS, participants gave a detailed feedback on prototype's visualization and features by writing down comments in the questionnaire and uttering them during the interviews. Many positive comments were made on the prototype in general. It was simply structured, minimalistic designed and quickly to learn. One participant stated: *"I really liked that the app was designed so minimalistic: only two [text] fields and a button. This means I just start this widget and have no access barrier at all." (DB_5_23_m).* In addition, they acknowledged the door-to-door routing, the icon-based choice of transportation mode, the integrated map and the step-by-step support during the journey. One participant identified a

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[3] Many participants stated they did not differentiate between app and website Google Maps.

disadvantage of the latter: *"You can zoom in [the map], this was nice. But you could not enlarge the map to see the whole route in a glance. There was also no list view of all steps, which had to be tackled successively. It would be nice to add this [overview] function. [...] Maybe just [... display] what I need, but I want to have the option [at least]."* Further negative comments addressed missing features or information. Test participants criticized the lacking comfort when mentioning that a tool to set arrival/departure time was missing, no auto-complete was offered in the text fields, no selection of surrounding bus stops was automatically provided or that a default setting of the territory was lacking (e.g. displayed data related to actual position, not to whole country). One female said: *"I had the impression that [the DB Navigator] retrieves more [results] with less information than the prototype. It suffices to insert a street name and it detects the street in the correct city [automatically]."* (QBMI_6_30_f)

Regarding the *size of the map,* participants were pleased. The majority stated it was sufficient and useful for maintaining orientation during the trip. However, problems while scrolling were observed because a swiping functionality was accidentally activated which opened a superior menu. Also zooming (pinch-to-zoom) was reported as a little challenging. The *quality of icons* was rated as comprehensive, except for two icons (train and bus), which appeared too similarly. Marking icons was intuitively usable, but its meaning was unclear. Finally, the color code was criticized: a dark blue marking on a black icon fully covers the icon. Participants also liked the idea of having *information about the overall progress* during their trip. The majority opted for implementing a progress bar. Some people reported that it was not obvious to them, which progress was visualized in the prototype – distance, time, or number of turns within the turn-by-turn assistance.

Moreover, difficulties were mentioned which are common for small screen device applications, for example a too large proximity of (navigation) elements. Besides, the interaction was assessed as too slow because reactions evoked by tipping on interactive elements (e.g. buttons) occurred comparing to other apps relatively late. Deleting text from the text fields did not work as in other iOS apps. Concerning the transportation mode choice, participants could not intuitively understand the meaning of the marker ('chosen' or 'excluded'?). Many error reports occurred. Technical problems of the location-based service were mentioned.

4   Discussion and Conclusion

Both apps received relative similar scores on the SUS, which is amazing because the prototype is only a demonstrator, and by far not as sophisticated as the DB Navigator is. This rating could result from the composition of the sample, which is not representative for the whole workforce. The young participants showed according to their study programs/jobs a high technology-affinity. They might have overlooked technical problems and less serious design problems. For a sound assessment of the prototype, further studies should involve older people with lower technology-affinity. Besides, the prototype needs to be improved with regard to system reliability (e.g. wheel to set time/date not working properly) and arrangement of navigation elements (e.g. too close proximity of buttons).

Interestingly participants uttered requirements concerning the information retrieval procedure. They were expecting an intelligent, context aware passenger information system, which would offer assistance, not only information. For instance, they supposed the app to consider their actual position and the surrounding region when proposing routes, in best case all alternatives within one list. Concerning the turn-by-turn assistance of the prototype, participants highly appreciated the small amount of information including the visual aids given in each step, but opted for an additional overview functionality, probably a large map and/or a list view. They uttered this request, but could not give a comprehensible reasoning. This raises the question to which extent users trust the displayed information and which features a passenger information system must offer to be the ideal daily mobility broker.

Finally, all these presented endeavors tend to enhance passengers' comfort and, finally, to increase ridership in public transportation. However, the overall impact of passenger information systems should be examined. A study on decision-making reveals that innovating passenger information does not lead to a "substantial behaviour change (certainly in terms of mode choice)" [31]. Therefore, the perceived usefulness of public transportation must be increased, probably by adding a participatory component. Foth and Schroeter [32] investigated the daily journey of commuters and envisioned a "digitally augmenting of the public transport environment" in terms of using electronic devices and interactive services for creating a unique, enjoyable and meaningful user experience. Similarly, Camacho, Foth and Rakotonirainy [3] are aiming at an image modernization of public transportation. They propose extending the service portfolio, for instance providing free Wi-Fi access or location-based services (tour guides). Passengers can consume these new services, but can also become active themselves, for example when sharing information about seat availability via social media.

In conclusion, passenger information systems can contribute to a modernized image of public transportation and enhance passengers' comfort. Thus, system designers must identify and consider user requirements concerning interaction design, layout and range of functions at an early stage within the design cycle. They must take trust-related aspects into account as well as innovative participatory components such as social media features. Finally, user experience must be generated and communicated early to empower passengers' confidence in any novel application.

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