Case Study

A User-Centered Design Approach to Self-Service Ticket Vending Machines

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***Abstract*—*Since their introduction, self-service ticket vending machines (TVMs) have become an increasingly important distribution channel in the public transport sector, progressively replacing the traditional ticket counter. In a public transport setting, where ticket counter closures have left different groups of people dependent on TVM to meet their mobility needs, a single, effective system is required.* **Research questions:** *(1) Which barriers do currently hinder the usage of TVM? (2) Which requirements should a barrier-free TVM fulfill? (3) How can we design a new self-service TVM for a nationwide public railway company? (4) How can we ensure that the usability and user experience (UX) is high for all users, especially for those with low levels of technological affinity?* **Situating the case:** *Most other studies on the use and usability of TVMs were conducted as post-hoc evaluations. In contrast, our case study presents a user-centered design (UCD) approach that takes the needs of the different target groups into account throughout the whole development process. Theories and concepts that guided the case included UCD, which involves alternating test and evaluation loops that actively involve users to create a usable product and UX, which describes the quality of the experience a person has when interacting with a specific computer system using a specific interaction technique.* **Methodology:** *More than 250 participants were involved in focus groups, observations, interviews, and experiments from the very first stages of development. Interface designs were presented to the future end users to obtain their feedback, with the results fed back into the design process.* **About the case:** *A prototype for a novel generation of TVM was developed in three phases: First, the context of use was analyzed. In the second phase, we conducted a requirements analysis. Third, different hardware and software interaction designs were iteratively tested and evaluated. The resulting prototype met the requirements of most user groups, though further adjustments are necessary.* **Conclusions:** *The UCD approach proved to be a valuable framework for the development and design of self-service systems.*

***Index Terms*—*Self-service technologies, senior user, ticket vending machines (TVMs), user-centered design (UCD), user experience (UX).*

INTRODUCTION

There is an observable trend across Europe to continuously reduce the number and opening hours of serviced ticketing for public transport. This forces passengers to use self-service ticketing channels like the internet, mobile ticketing, or—as in the case of this study—ticket vending machines (TVMs).

These self-service channels pose a barrier—especially to older passengers [1]–[4]. Why is this the case? The current generation of ticket machines in Europe (often developed around 15 years ago) mainly displays "machine-generated logic" at the interface to the customer. No focus was placed on user friendliness and the user experience (UX) during their development. As a consequence, people with low technological affinity have difficulties in using these machines. Given that transport policies seek to encourage the increased use of public transport by the broad population, reducing these access barriers will be one of the major tasks facing technical communicators when developing such systems.

This paper presents a case study on the development of a prototype for a new generation of user-friendly self-service TVMs, the INNOMAT project. This prototype will be the basis for the industrial development of the new TVM for the Austrian Federal Railway [Österreichische Bundesbahnen (ÖBB)]. The project itself serves as a showcase for a user-centered design (UCD) process for self-service systems. When service providers develop a self-service system intended for use by the broad public, users should be included throughout the entire development process—right from its early beginning. The aim of such a development process should not only be to develop a system which is usable by most users, but to develop a system which leaves *all* passengers with a positive feeling after use. Accordingly, the INNOMAT project

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focused not only on usability, but also on the UX of different user groups.

The research questions of the case study were:

- Which barriers do currently hinder the usage of TVM?
- Which requirements should a barrier-free TVM fulfill?
- How can we design a new self-service TVM for a nationwide public railway company?
- How can we ensure that the usability and UX is high for all users, especially for those with low levels of technological affinity?

In this paper, we situate our case study in the context of other research on barriers in self-service ticketing and discuss relevant theoretical concepts, namely, UCD and UX. We then describe how this case was studied and how we applied the UCD process. Next, we present our case, outlining each step of the UCD process with its main results. In the final conclusions section, we discuss how the UCD approach helped us to reach our aims and examine those factors which proved to promote or hinder the development of a novel, self-service TVM.

SITUATING THE CASE

This section situates our case study. First, we outline the barriers to the use of self-service TVM already identified in prior case studies. We then describe UCD in its context as a methodology which allows user needs to be addressed during the entire design process. Finally, we discuss UX as a factor which can promote a positive experience with TVM and lead to their repeated use.

How Literature Was Selected TVMs have not been a subject of major research interest until now. We therefore conducted a broader literature review and searched not only for prior research on our specific target technology (TVM), but also on other self-service technologies—for public transport or other services. In doing so, we tried to identify existing barriers to the use of TVM and success factors in existing design solutions and effective development processes.

Self-service technologies and UCD cannot be reduced to one single discipline. Likewise, a literature review of this topic cannot be reduced to one single database. We therefore conducted a broad literature search in databases on computer sciences, engineering, and social sciences, but also a more open search on cross-disciplinary databases like Google Scholar.

Barriers to the Use of Self-Service TVMs Many subgroups in today's society are not skilled at using new technologies. Based on their negative experiences with technology in everyday life, they often develop a tendency to avoid new technologies. The resulting lack of technological expertise can build barriers that affect mobility and lifestyle. This certainly holds true for the elderly and other socioeconomic groups disadvantaged by the digital divide, since they rely, in particular, on public transport [1].

Prior negative experiences with everyday technologies represent one of the strongest barriers to the use of self-service TVM. Research into ticket queues at 12 major railway stations in Great Britain supports this assertion. Passengers who could have bought their tickets from a TVM confirmed that their decision to purchase at the ticket counter was driven by a lack of confidence in their ability to use the machine as well as a lack of confidence in their "ability to select a ticket at the appropriate price with the necessary validity or relevant route" [2, p. 4].

Subasi et al. [3] come to a similar conclusion in their study of usage barriers and perceptions of an online ticketing service for a nationwide public railway company in Austria. With regard to the optimization of an online system, they conclude that:

> it is necessary to develop a system which is not only universally accessible, but also satisfies the specific expectations of senior users in terms of usage patterns and their specific needs as well as different perception models.

To overcome the lack of confidence among older passengers, the ALISA project [4] added training modules to a TVM. The training helped users learn how to use the machine and increased their technological self-efficacy—independent of age.

These case studies on self-service TVM were conducted as post-hoc evaluations [2]–[4]. None of them goes through the entire design process—a gap which our case study can close by using a UCD approach. The main benefit of such an approach is that the design can already be aligned with the needs of many different user groups at an early stage, removing the need for post-hoc adaptations as in the ALISA project [4].

UCD Approach In the UCD approach, the development of the design process is planned in alternating test and evaluating loops which actively involve users [5, p. 588]. More specifically (and according to the ISO 13407 standard on human-centered design), this includes five essential steps:

- Plan the human-centered design process
- Understand and specify the context of use
- Specify the user and organizational requirements
- Produce design and prototypes
- Carry out user-based assessment including formative evaluation

To ensure that a self-service system like a TVM meets the demands of a system intended for use by the general public (a broad target group), the UCD principles [5] should be adapted as follows:

- Interdisciplinarity: The conceptual construction and design of a self-service system as well as the functional aspects of the user interface should be developed by an interdisciplinary team of engineers and specialists for ergonomics and accessibility, media design, and hardware/software development.
- User-oriented design: To guarantee the design of a user-oriented system (both hardware and software), the target groups should be involved from the very first stages of development. The needs and requirements of different target groups should already be taken into account during the development stage; for example, to accommodate experienced users who want fast processing with few steps as well as inexperienced users who need comprehensive, intuitive prompting via audio-visual information channels.
- Iteration of design solutions: Design approaches and solutions should be presented to the future end users to generate feedback and the results fed back into the design process. User studies should systematically involve users from the beginning to the end of the project—from paper mockups of initial designs, through early clickable prototypes to a working prototype of an actual TVM.
- Allocation of function between the user and the system: A self-service system for the broad public should adapt to the user wherever possible. Any input required by the user should be kept to the necessary minimum. At the same time, the system has to provide the user with as much feedback as necessary to ensure he/she is aware of the selections he/she has made.

By translating the UCD principles to (the development of) self-service TVM, these assumptions all essentially relate to the quality of use of such machines. How quickly can I get a ticket? How complicated is the process? How confident am I that I will be able to get the best value ticket from this machine and pay the correct price? To what extent does the system's purchase process correspond to the mental models the different target groups have of such a process? To what extent can the design of the TVM support a purchase process with positive connotations? These questions, in turn, emphasize the importance of research into UX for self-service technology systems.

User Experience (UX) UX describes the quality of the experience a person has when interacting with a specific computer system using a specific interaction technique [6]. According to Hassenzahl and Tractinsky, UX incorporates different aspects like social experience, ambient conditions, joy of use and aesthetics, as well as factors like perceived privacy, security, and trust:

> UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc...), the characteristics of the designed system (such as complexity, purpose, usability, and functionality) and the context (or environment) within which the interaction occurs. [7, p. 95]

In the TVM context, factors like social experience and ambient conditions would seem to be particularly important. In this respect, technology aversion is caused or intensified at least to a certain extent by negative social experiences. It is not surprising that elderly users, in particular, often find themselves confronted during the purchase process with impatient reactions and social pressure from the other people waiting in line.

In general, there is an increasing demand for public self-service systems like TVM (such as e-government or e-health systems), and their prevalence will increase in the future. In the following sections, we present a multifaceted case study that describes how a new generation of TVM was designed to best meet the needs of different user groups. The findings of this study can serve as indicators for future research and design questions on the relations between self-service technologies and UX.

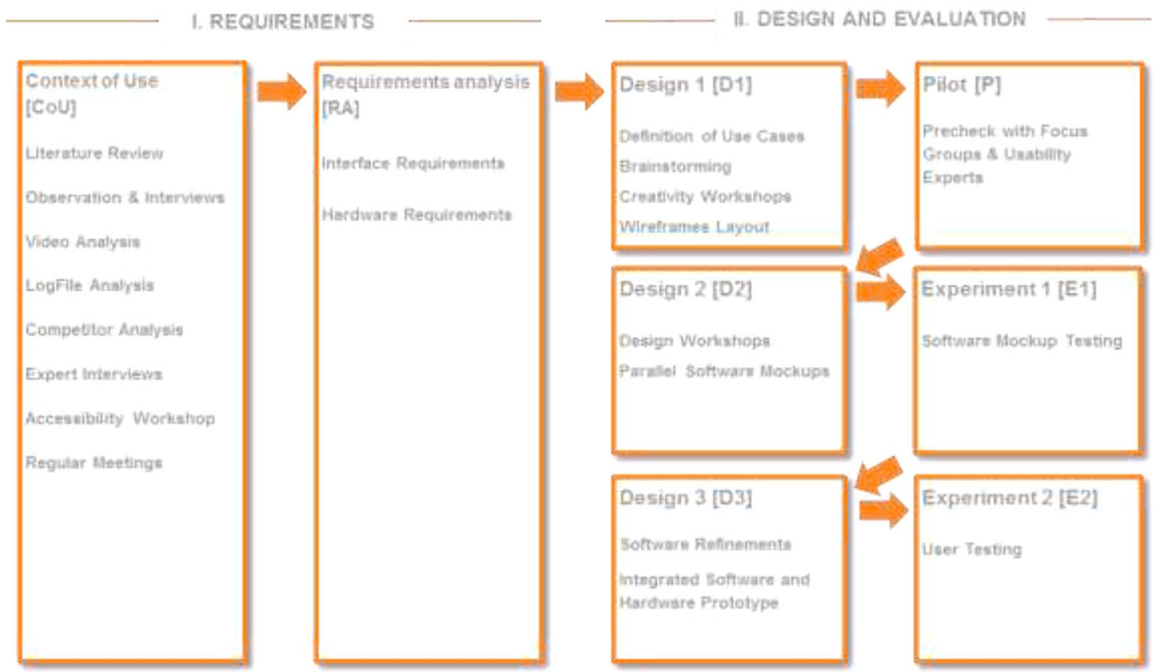

Fig. 1. Applied UCD process.

How This Case Was Studied

In this section, we present the methodology used in our case study: First, we discuss our choice of research methodology. We then describe the participants in the case study, explain how data were collected and analyzed in the UCD process, and demonstrate how we ensured credibility and trustworthiness.

Choice of Research Methodology Fig. 1 provides a general description of our UCD approach, the individual phases and steps in the project, and the methods used.[1] As can be seen, we used a wide set of different methodologies in the course of the project to best inform the next design phases and answer the relevant research questions in each phase.

In the first project phase (Requirements), our research focused on (1) looking into existing barriers to the usage of TVM, and (2) identifying requirements for a barrier-free TVM. To identify as many existing barriers as possible (CoU), we decided not to restrict ourselves to one single methodology (a procedure often necessary in economic contexts, when resources are more limited), but instead used different methodologies with different aims. Accordingly, we reviewed existing literature on the use of technology by people with special needs

[1]A detailed description of each phase, including its methodology, will be given in the section “About the Case.”

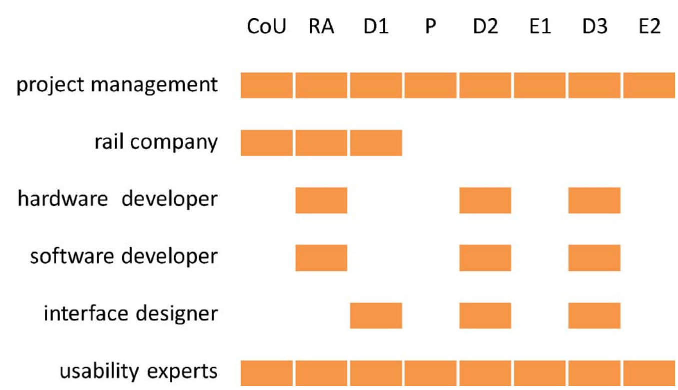

Fig. 2. Project team.

(vision impaired, mobility impaired, the elderly) and their requirements for using a TVM. In addition, we invited experts and stakeholders to participate in a focus group to add their experiences to the material gathered. To identify interaction problems and barriers to the use of the existing TVM in Austria, we conducted observations (*in situ*, video analysis, logfile analysis) and interviews at railway stations. To gather ideas on how to overcome these existing barriers, we carried out a competitor analysis of other TVM and self-service technologies through a literature survey and physical observations at railway stations across Europe. Regular meetings with the project consortium were used to collate all the information collected into a list of interface and hardware requirements [RA].

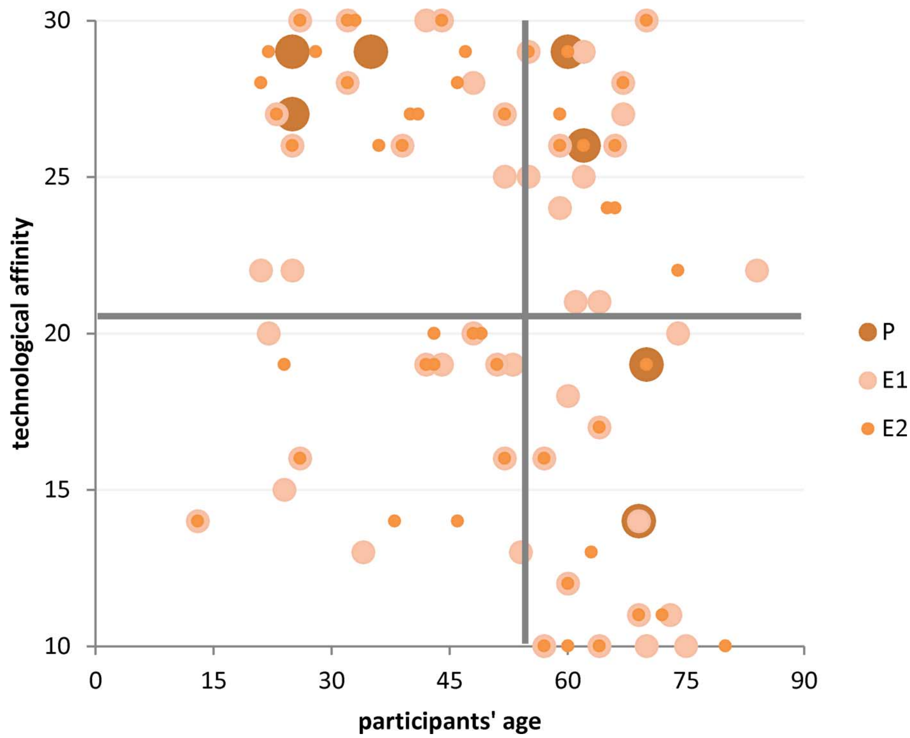

Fig. 3. Distribution of age and technological affinity among participants. Cutoff scores depicted as lines separate the participants into four experimental groups.

In the second project phase (Design and Evaluation), the research focus lay on (3) designing a new self-service TVM system for the ÖBB, and (4) ensuring that the usability and UX of this new TVM was high for all users, especially for those with low levels of technological affinity. After defining the use cases, we conducted brainstorming and creativity sessions to design first wireframe layouts [D1] and gained user feedback on these designs at a very early stage in the design process from focus groups and experts [P]. Although we were not able to conduct an experiment or any observations at this stage, this early feedback on the designs allowed us to avoid cost-intensive development activities in the wrong direction. In later stages, we tested three different software mockups [D2] in an experiment [E1] and developed the most usable of these mockups for inclusion in an integrated hardware and software prototype [D3] for the last round of user testing [E2].

Participants Two key principles of UCD are (1) involving the users throughout the whole process, and (2) working in an interdisciplinary team. Accordingly, a number of different people were involved in this design process. The regular project team in the INNOMAT consortium was made up of an interdisciplinary group of hardware and software developers, media designers, usability experts, and representatives of the ÖBB. (See Fig. 2.) During the different phases, we called in external experts and stakeholders to complement the know-how of the project team, for example, on UX, accessibility, and the needs of different target groups.

For user testing, we strived for two different characteristics in our participant sample: (1) diversity in age, and (2) diversity in technological self-efficacy (SE). Since public transport passengers range in age from the very young to the very old, we also strived to include a wide age range in our participants (13 to 84 years, see Fig. 3). We sought, in particular, to ensure that half of our participants fell into the older age bracket (above 55 years), thus including those people who had been identified as having problems with TVM in the past. Another group that had been identified as having problems (though often overlapping with the elderly group) was people with low technological affinity. We therefore sought to include participants who scored high as well as participants who scored low on our technological affinity scale.

We used different strategies to recruit test participants: In the railway station setting [observations and interviews (CoU)], we used a time sampling method: We observed TVM users on four occasions (weekday–weekend, urban–rural stations) and categorized them with respect to their age and how they approached the TVM (cautious—targeted fast interaction).

For the studies in our usability laboratory, we invited local participants using different strategies: First, we used our own database of test participants, which turned out to contain mainly young people with high technological affinity. To combat this bias, we used alternative strategies like newspaper adverts and requests to mailing lists announcements. We also contacted local retirement homes. Each potential participant answered a short screening questionnaire on technological affinity: Only those with either high or low technological affinity were included in the studies. Some people participated in both experiments 1 and 2, but this number was restricted to 45%. Participants received a payment of 25 Euros to cover their expenses.

Ethics approval was required neither by our own institution nor by our funding agency.

How Data Were Collected Wherever possible, we collected data in a standardized manner to allow us to analyze them efficiently and conduct statistical analysis to produce a generalization of results. To gain a more complete picture, we collected qualitative data that were not included in the structured recording protocols.

- We conducted pretests and created observation protocols from the behavioral patterns observed for any observations carried out. Additional behavioral patterns observed during the main tests were recorded in a free format. Similarly, we created structured protocols of features of interest for the competitor analysis. To illustrate these protocols, we took pictures of the different TVM and their features of interest.
- We created structured guidelines and protocol sheets to use in the interviews. We also recorded the interviews to allow us to transcribe important sequences and amend the protocols if necessary.
- Focus groups were conducted in the usability laboratory and video recorded with two dome cameras and audio recorded with two microphones. Two members of our research team led the group in line with a predefined structure. Another two observed the discussion in an adjacent room, took down notes, and documented major results.
- For experiments 1 and 2, participants were randomized to the different experimental conditions. Experiments were conducted in the usability laboratory and lasted between one and two hours. Participant interaction with the TVM (mockup) was logged, behavior was observed, and think-aloud-protocols were recorded digitally. Two members of the experiment team were present to instruct the participants and note down any observations and important statements.
- Logfile analysis from the train station and from experiment 2 was conducted by the software partner in the project.

How Data Were Analyzed We input quantitative data into Excel and SPSS and analyzed these data statistically. In essence, we computed frequencies to gain an overview of the distribution of features, interaction problems, and successful interactions. To generalize our findings, we computed statistical tests of mean comparisons (ANOVA) between participants in the elderly and young age groups and those with high and low technological affinity.

We conducted content analyses of qualitative data. We bundled the answers to specific questions and searched for common topics as well as common behavioral patterns or features.

Ensuring Credibility and Trustworthiness To ensure high reliability, we strived to collect and analyze data in an objective way. First, where possible, we structured data collection and used standardized protocols (see section “How data was collected”). Second, we recorded data where possible to allow us to review the ratings of observation, focus groups, and interview protocols. In those cases where data recording was not possible, we used two independent observers (the direct versus cautious approach to the old TVM was rated, for example, by two independent observers at the railway station, yielding an agreement of more than 90%). Third, we conducted an internal training session for the experiment team, observers, and for the coding team to ensure that instructions were always given in a similar manner, that protocols were understood in a similar way, and that data were coded in the same way. Fourth, we selected and negotiated all methodological decisions in our group of four to five usability experts to look for potential pitfalls and problems.

About the Case

In the following section, we will provide a step-by-step account of how we proceeded in the INNOMAT project to develop a prototype for a novel, barrier-free TVM for the ÖBB. In doing so, we will

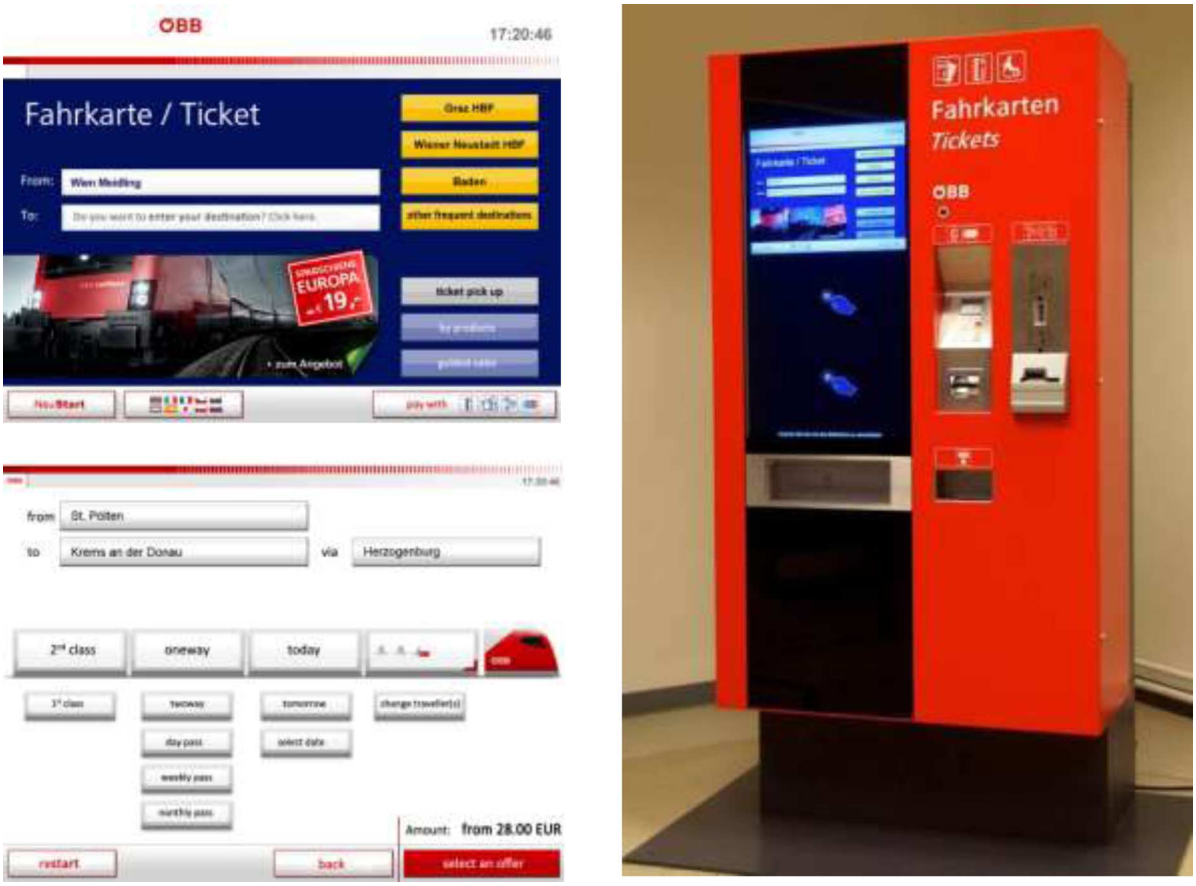

Fig. 4. Final design of the new TVM interface (left) and hardware (right).

present the problem, our solution, and how we developed it.

Problem Current TVMs do not meet the requirements of many of their users. In the public transport context, they tend to be aligned with business processes and mirror the thinking of IT specialists rather than the thinking of travelers. In the past, users were not involved in the development process for TVM. User studies were only conducted after the design was completed, and major redesigns were not possible at such a late stage.

To involve the users from the very start of the development process, this case study was not an industrial development, but was instead proposed and funded as a research project—with all of the associated constraints that come with such a project. In our case, the funding was cut, and we were therefore not able to conduct a final evaluation *in situ* in a railway station setting.

Solution In an iterative process, we developed a novel barrier-free TVM using a UCD approach. The TVM was aligned with the requirements and the thinking of the broad public who use such machines, especially the elderly and people with low technological self-efficacy.

The main screen of the resulting TVM only has a small number of buttons, which are clustered using different colors for different functions [Fig. 4, (top left)]. A "search engine-like" destination input bar is the most salient element on the screen. The purchase process interface narratively maps a train journey and by resembling the cognitive script of travelling is intuitive for many people and many different user groups [Fig. 4, (bottom left)]. Where possible, the TVM hardware reacts to user input in a smart way: It automatically adjusts to the user's height, activates relevant areas, and uses lighting to direct the user to these areas [Fig. 4, (right)]. Novel features have been included if they make the purchase process easier, but no cutting-edge technologies have been used that are of no benefit to the users.

Budget:	1.1 million euros, approx. 60 % funded by the FFG, Austria
Length of time needed to complete the project:	3 years
Skills used in the project:	Usability, creativity, interface design, software development, hardware development, project management
Software used:	Partly proprietary, especially for lower layers of the software; Flash and Tomcat (SSI) for the GUI (presented on Mozilla Firefox v3.4-v3.6)
Other resources used:	Off-the-shelf hardware components (such as touchscreen, barcode scanner)

Fig. 5. INNOMAT project facts about the solution.

Fig. 5 provides an overview of the key facts and figures regarding the INNOMAT project.

Process for Developing the Solution The process for developing the solution involved many phases. Fig. 1 identified the key phases in this process, which we followed when developing this project. The following sections describe our process in detail.

Context of Use (CoU)

All good design processes begin by examining the context of use, and the INNOMAT project was no different. In our case, this examination had to focus on the current situation at railway stations in Austria, the way people used the existing systems available at these stations, and their attitude towards these machines. We also aimed to identify other good and bad examples of TVM in Europe and to determine whether any other work had been carried out elsewhere to design a user interface that better accommodates the broad needs of the target groups (in particular, nontechnical railway users, persons with reduced mobility). In order to shed light on these issues, we used a variety of methods to ensure we obtained a holistic evaluation of the status quo.

Literature Review: In a first step, we collected the special needs and requirements of different target groups already identified in prior research. The findings of this literature review established links between the context of use (the railway station) and the users of the public transport network. From existing research dealing with the particular needs of the disabled, we were able to identify and incorporate a number of specific design requirements that have to be taken into consideration to allow people with vision impairments or wheelchair users to actually use (a new generation of barrier-free) TVM in the first place. In addition, our literature review included preparatory work to accommodate the special needs of the elderly, which frequently result from the changes to their cognitive abilities experienced by people in this age group. A detailed description of the findings of this phase can be found in [8].

Observations and Interviews: In order to specify and understand the target users, we conducted a field study in which we observed 50 people at two railway stations and interviewed an additional 50 people: 25 as they used TVM and the other 25 in front of the ticket counter. Our aim here was to identify user groups who had problems using the machines and determine where these problems lay. To assess their experiences, we asked these people about their levels of satisfaction with and reasons for choosing or avoiding a TVM.

Our observations and interviews showed no occurrence of “typical accessibility or usability problems” like font size, contrast, or button size, even among elderly users. In contrast, most people were able to use the TVM without encountering such problems. However, to ensure an all-round positive UX, we felt it was important to focus on the problems encountered by those people who did not succeed in using the machines.

The observations and interviews revealed a number of serious barriers to the use of TVM, above all among older and middle-aged passengers. They often approached the TVM with great caution and sometimes had to cancel their purchase process. Some customers in these age groups, in particular, had little confidence in their ability to successfully buy a ticket at a self-service terminal. When asked why they avoided the machines, they referred to bad experiences, doubt in their own abilities, and mistrust in the technology. (For more details, see [9].) They lack positive experiences of using everyday technologies.

Social Cognitive Theory offers an explanation for the underlying emotional and motivational factor responsible for avoiding everyday technologies: Self-efficacy (SE) is the belief “in one’s capabilities to organize and execute the courses of action required to produce given attainments” [10, p. 3]. In Czaja et al. [11], computer SE was an important predictor for the use of technical devices, and was mediated by computer anxiety. Czaja et al. (ibid.) noted that people with a low level of SE had a lower probability of using a technology. Since senior citizens are frequently represented in this group, the authors stressed the importance of using technology that allows senior citizens to experience success and build up their confidence in their own abilities. Consequently, low levels of technological literacy and the underlying emotional factor of avoiding the terminals—low levels of computer SE—were subsequently taken into consideration in the creation of the new interface.

Video Analysis: Analyzing anonymous video recordings of ticket purchase scenarios at a large railway station in Vienna provided us with further important insights into the location of TVM, the distance between machines, the layout of hardware elements (such as payment elements and dispensing drawers), as well as the behavior of customers during the purchase process. In the analysis of these videos, particular focus was given to the general behavior exhibited by customers when standing in line or selecting a machine: In general, they tried to maintain a social distance to other customers by selecting the machine that was farthest away from other customers. When a group of customers used one TVM, the adjacent machine was also blocked due to the narrow layout of the machines. Another problem observed was that people had to bend down to retrieve their tickets from the dispenser. This was a particular problem for elderly and mobility-impaired customers.

Log File Analysis: Purchase process logs for ÖBB TVM at the Vienna South railway station (*Südbahnhof*) were used to analyze the current system and current configuration of the purchase process. Logs of 144 purchase processes (on October 14, 2008 from 06:24 to 10:56 am) were analyzed. Of these, 61 were cancelled prior to completion of the actual purchase, with 54% of processes cancelled on the initial start screen and 20% on the selection screen. The start screen displays around 25 buttons, which seems to overwhelm customers in their search for the right product. The selection screen also required that ticket specifications be input in a predefined order that was not transparent to the customers. These observations led us to the conclusion that a great deal of emphasis had to be placed on the redesign of the start and selection screens.

Competitor Analysis: Important information on current state-of-the-art TVM was also obtained from our broad competitor analysis. The analysis data were gathered between December 2008 and April 2009 at railway stations in Austria (such as Vienna, Linz, and Bregenz) and nine other European cities (Munich, Frankfurt, Zurich, Brussels, Amsterdam, Strasbourg, Lille, Mikkeli, and Barcelona), and the US (New York and Boston). These locations were selected based on preliminary research and recommendations. The site analysis focused on the location/position of TVM in stations (ease of identification, accessibility factors), hardware design (such as height adjustability and options for use by the visually impaired), and user interface design (such as purchase process and accessibility factors). The data were supplemented by material provided on request by the respective transport operators or published on the internet.

One particularly interesting TVM was identified in the Netherlands. It displays the entire purchase process on one screen, thereby providing the customer with a good overview. It also provides direct visual feedback on any selections made. Interestingly, the development of this TVM was accompanied by user tests and aligned with gestalt principles [12].

Accessibility Workshop: A special accessibility workshop was held on March 23, 2009 at the Danube University Krems in Austria. This workshop was attended by accessibility experts, representatives of the various target groups (such as organizations for the visually impaired or organizations for people with mobility restrictions), and representatives of the ÖBB in its capacity both as project leader and largest current deployer of self-service TVM in Austria. Its aim was to establish the specific requirements, needs, and context of use of the different target groups. In the course of the workshop, the TVM’s importance as a sales channel for different target groups was discussed along with the major hardware and software design problems and possible solutions. In addition, the different systems identified in the competitor analysis were assessed.

An important outcome that stemmed from this workshop was the decision not to focus on developing a TVM for blind users: This user group prefers other sales channels where they can use their personal assistant technologies. Thus, the costs of developing an interface for the blind would be too high in relation to the benefits.

Regular Meetings: During regular project meetings, the results of the analyses to specify the context of use were discussed within the project team and implications derived for the requirements specification. At these meetings, the project team worked not only on developing its ideas and visions, but also on issues of technical feasibility, maintenance, and organizational implications.

REQUIREMENTS ANALYSES (RA)

The results of the first phase (context of use) were condensated into a list of requirements for a barrier-free TVM. Specific tasks of this phase included identifying interface and hardware requirements.

Interface Requirements: As far as the interface design was concerned, it quickly became evident that the biggest challenge would lie in reducing the complexity (such as establishing a purchase process that would be understandable to all users without requiring high computer literacy and knowledge of fare structures).

Some of the requirements encountered actually contradicted one another [8]. While users with little technological literacy argued for a step-by-step system that guides users through the whole process, expert users (such as commuters who arrive shortly before their train is due to depart and want to buy their tickets quickly) also have to be taken into consideration. Potential solutions to this dilemma could include a personalized system (such as offering cardholders the opportunity to simply insert their cards and buy frequently purchased tickets in a single step).

In the workshops and interviews with target group representatives, the question arose as to whether the TVM actually must/could meet all of the requirements or whether some of these could be better provided and served using other sales channels. People with mobility restrictions frequently require assistance to board a train and, therefore, generally buy their tickets at the ticket counter, since they have to request this assistance at the station in any case. However, ticket counters are the only alternative sales channel available to nontechnical customers (in our case, primarily senior citizens). As a result, a readily accessible, easy-to-use interface is important for this target group.

Hardware Requirements: The way the terminals are embedded into the station infrastructure is a further important point that became particularly apparent in the best practice analysis. The key elements that need to be considered here are the position and accessibility of the TVM in the station and the ability to purchase a ticket without impediment, such as by enabling users to maintain a proper social distance and preventing glare. Existing accessibility guidelines provided information on positioning machines to provide adequate clearance and accessibility for wheelchair users and emphasized the need to mark or indicate these features.

While the layout of hardware elements is, of course, affected by the technical framework and applicable norms, the layout itself also has a significant influence on usability. Our video analysis showed that the dispensing drawer on the current ÖBB TVM was very low, and that a large number of people had to bend down to get their tickets. Other requirements, which have received surprisingly little attention to date, relate to the context of use, such as facilities for people with luggage, prams, and pushchairs. The use of clear symbols to identify specific hardware elements is a further important hardware and layout aspect, in particular, when it comes to tailoring the system to the needs of visually impaired users.

While current self-service terminals often have a smaller sibling to allow wheelchair access, this rather expensive strategy fails to account for the various heights needed by users and is not a financially viable solution for general use at all railway stations in the future. In UCD process terms, the requirements analyses (RA) corresponds to the step “Specify the user and organizational requirements.” In the INNOMAT project, the specific requirements of the individual target groups were assessed for technical feasibility and maintainability. From a software design perspective, the results of this assessment showed that the purchase process had to be made as flexible as possible. From a hardware perspective, the results of the study also produced recommendations for system maintenance and addressed other aspects like burglar-proof construction, cleaning options, and other maintenance issues.

The results of the RA, together with the analyses of the context of use (TVM in railway stations) (CoU) and the different user groups, were used to create a detailed catalog of requirements. In addition to accessibility and usability factors, this catalog also contained some UX aspects, relating, in particular, to the issue of support for the different target groups.

DESIGN AND EVALUATION

The next steps in the project were UCD steps four and five ("Produce design and prototypes" and "Carry out user-based assessment"). The goal here was to identify and develop new approaches and designs for the TVM's hardware and software. The methods employed—from the initial creativity workshops and wireframes layouts in the early stages of the project, through to the clickable prototypes and subsequent integrated prototype—were all aimed at systematically involving the users. Solutions were presented to, tried out by and discussed with the future target groups, with the results fed back into the design process.

Definition of Use Cases: To structure and subsequently test the purchase process, four use cases were defined in cooperation with representatives of the ÖBB. While these cases were all based on current ÖBB ticket sales statistics, care was also taken to include a more complex purchase scenario that would not have been possible with the current system—tickets for a small group of individuals travelling together. Emphasis was also placed on ensuring that the users would receive a choice of different offers to simulate the somewhat complex fare structure and the corresponding selection by the user.

The four selected use case scenarios were as follows:

(1) Standard ticket for a single person.
(2) Discount ticket for a family of two adults and one child.
(3) Ticket for a single person for a return journey in the local transport network.
(4) Tickets for a group of three adults—including one travel card holder—for a return journey in the local transport network.

Design 1 [D1]: By the end of Design Phase 1, several mockups had been developed based on ideas developed at workshops attended by members of the target groups and media/usability experts.

Brainstorming and Creativity Workshop: In a workshop attended by eight media and usability experts from the Danube University Krems, a range of creative ideas for a new TVM was developed and collected. These included new ways of selecting a destination, such as by entering the target station in a search bar on the start screen (similar to the Google Toolbar) or selecting it on a map. The TVM would then display a selectable list of possible train connections. Another suggestion was an "intelligent" TVM which recognizes a customer, instantly provides a list of his/her most recent journeys, knows his/her current position, and offers the best deals to the customer's most frequent destinations from the current location.

Wireframes Layout: Based on the ideas collected and the catalog of requirements, five alternatives for a new start screen were developed in cooperation with a group of media designers. Fig. 6 shows a wireframe of the start screen used in the current ticket systems (left, frequently criticized as overloaded) alongside one of the new "less cluttered" alternatives (right, which also incorporates some of the features discussed at the creativity workshop).

Pilot [P]: In a next step, we organized an eight-person focus group with members of the specific target groups (four senior citizens and four younger people, two members of each group with little technological literacy, see Fig. 3). We also organized a second focus group with eight usability experts. The primary aim of the focus groups was to gather feedback on the wireframes layout of the start screens and obtain ideas and feedback regarding the structure of the purchase process. Special focus was placed in the discussions on how the system could enhance UX. What do people think about when they approach a TVM? How could the start screen convey the message that the system is easy to use? The key responses here were that the start screen should be clearly structured and that it should not be overloaded or confusing. The first focus group also voiced certain misgivings about the map-based selection of the destination ("You have to select the destination on the map? I'm not very good at geography."). The search bar was received in a particularly positive manner and described in general—even by those people who virtually never used a computer—as a recognizable and easy-to-use function. We therefore implemented the search bar in the subsequent prototypes.

Design 2 [D2]: In Design Phase 2, prototypes were created by the design partner and the software

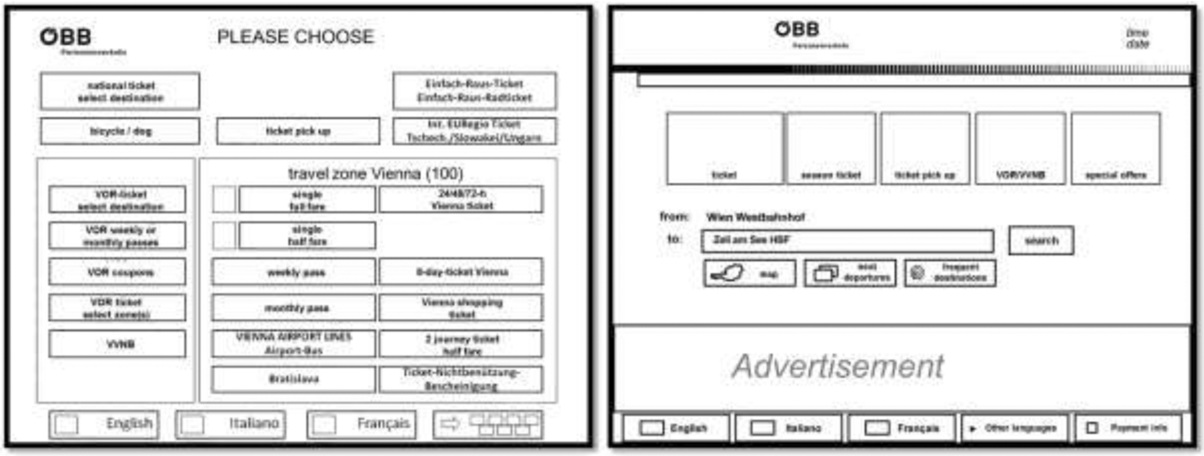

Fig. 6. Wireframes of the start screens of the current TVM (left) and one of the new designs (right).

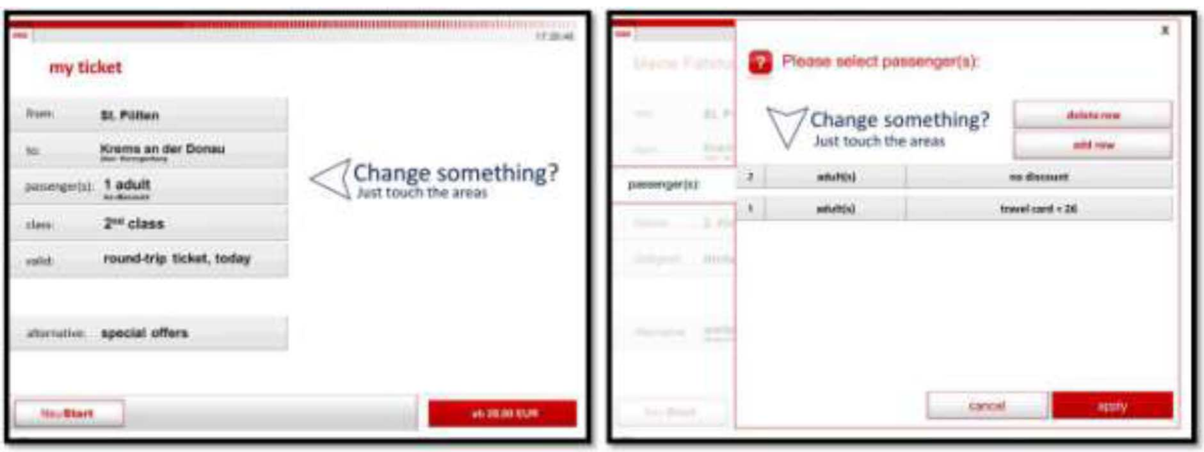

Fig. 7. Prototype A—overview (left) and passenger selection submenu (right) screens.

partner in the project team. Following the focus groups, where the wireframes had been discussed at length, design workshops were subsequently arranged within the project team (media designers, human–computer interaction (HCI) experts, ÖBB). These workshops were very productive, with an exchange of ideas that led to the creation of three different prototypes. The following could be selected on each of these four prototypes: destination, different types of passengers (adults, children, families, dogs. . .), date of travel, and ticket class.

Prototype A—"Virtual Ticket": The first interface was a contemporary adaption of the TVM system already in place at ÖBB stations. It featured a ticket-like overview and typical human–computer interaction elements like submenus and drop-down menus. (See Fig. 7.)

Prototype B—"Netherlands Clone": This system was a modification of the easy-to-use system currently used in the Netherlands. All possible options can be seen immediately and the current selection is highlighted. To account for the higher complexity of the Austrian fare system in comparison to its counterpart in the Netherlands, we developed a novel person configuration approach in which passengers could be selected graphically. (See Fig. 8.)

Prototype C—"Train Metaphor": Although largely similar to prototype B, this option extended the graphical metaphor by using a train narrative and animations. The selected passengers "move" into a train, and any options selected are visualized by train wagons moving into the correct position. (See Fig. 9.) More detailed information on this prototype can be found (and seen) in [13].

Software Mockup Testing: In a 2×2 laboratory experiment, 48 participants with differing levels of computer SE (24 low, 24 high) and of different

Fig. 8. Prototype B—Passenger selection (left) and options (right) screens.

ages (24 over and 24 under the age of 55) interacted with the three prototypes (within-design, balanced order). The interfaces were presented to the participants on a touchscreen. For each prototype, the participants were given four fictitious travel stories and tasks based on the use cases described before. The time needed to complete the tasks was recorded in the logfiles along with the user interactions and errors. In addition, the participants were encouraged to verbalize their thoughts and feelings via think-aloud techniques to track their subjective experiences during the purchase process. At the end of the experiment, the participants were required to complete a short usability questionnaire on their system preferences as well as a short semantic differential based on the AttrakDiff questionnaire to measure the hedonic qualities of the three prototypes [14]. After the experiment, we conducted interviews with the participants to acquire insights into their explicit knowledge of the buying processes. During these interviews, the participants also had the opportunity to give reasons for their stated preferences and to freely formulate their experiences with the prototypes.

Repeated measures analysis of variance indicated significant effects both for between-subjects factors and for within-subjects factors. Firstly, the amount of time and number of user interactions per trial were higher for participants with low computer literacy $(F(2{,}44) = 11.85, p < 0.001, \eta_p^2 = 0.35)$ and older participants $(F(2{,}44) = 7.96, p < 0.01, \eta_p^2 = 0.27)$ with no significant interaction. Second, the participants needed less time and fewer screen interactions to complete the tasks with prototype C (train metaphor) than with the other prototypes $(F(4{,}42) = 3.79, p < 0.05, \eta_p^2 = 0.27)$.

Errors or difficulties in use were encountered almost exclusively in the selection of passengers—the participants chose the wrong kind or wrong number of passengers or selected a wrong travel card (such as forgetting or not finding the discount option, choosing the wrong discount option, or mixing up individual and family travel cards) in a surprisingly frequent number of cases when using prototypes A and B. Virtually no such errors were recorded when the participants used prototype C. (See Table I.)

Usability ratings (as well as user preference) for prototype C were independent of individual computer SE levels (see Fig. 10), unlike prototypes A and B, which were assessed less positively by participants with lower computer SE scores $(F(1) = 9.42,\ p < 0.01, \eta_p^2 = 0.17)$. Prototype C received better usability ratings than prototypes A and B $(F(2) = 18.11, p < 0.001, \eta_p^2 = 0.28)$.

The critical problems with these prototypes were reflected in the comments made by participants (and recorded during the experiment). Prototypes A and B both triggered negative experiences with passenger selection: *"I can't press the 'Complete' button until I've chosen all the passengers."*, *"Oh no, here we go again! If I select two adults, I can't add the child."* Other statements related to navigation problems ("*There's so much information on the screen, but not what I need to know.*") or difficulties grasping the general software concept ("*Typical developer logic…* ").

Older participants were particularly prone to stopping during the difficult cases and asking (or looking at) the test coordinator for support.

Fig. 9. Prototype C—Passenger selection (left) and options (right) screens.

TABLE I
ERRORS RECORDED IN USE CASE 2 (FAMILY)

Error Type	Prototype A	Prototype B	Prototype C
Incorrect number of passengers	20	11	5
No family discount selected	28	15	8
Incorrect type of passengers	11	8	1
No travel card selected	13	15	8

Prototypes A and B also elicited verbal reactions among participants in this age group that indicated an aversion to using this kind of TVM in the future: *"I'd rather go by car!", "I'd rather stand in line at the counter behind ten other people.", "Very confusing. If this were real life, I would walk away from the machine now."*

A few of the younger, computer literate participants indicated a preference for prototype B, even though they had encountered difficulties with it in the initial trials: "*It's actually very easy.*" The same target group described prototype A as "*possibly too computer-like*" or *"complicated"*. Nevertheless, they did appreciate the simple approach to purchasing a ticket for a single journey offered by this system: *"It's simple for one person."* Comments on the moving train and graphical selection of passengers were almost exclusively positive: "*It's fun*", "*Neat, I like the train going around*", "*Cool!*", "*The figures are very concise*". Only one participant did not like the basic idea behind this system: "*That's nonsense—I want to buy a ticket, not play with a toy.*"

Software Refinements: The results of the software test indicated that prototype C ("Train Metaphor") was perceived to be easy to use by people with a generally low level of computer SE, and that this target group could be encouraged to consider using the TVM option when confronted with such a system. By applying an everyday graphical metaphor (selecting passengers by moving them into a train), the user was guided through the purchase process without a need for specific computer domain knowledge. These findings led to the consortium's decision to develop this interface further and drop the other two prototypes. Nonetheless, some aspects still needed further refinement or were incomplete, such as the automatic display of a choice of low-cost options for the selected parameters or a personalization system that allowed users to select their most frequent routes. The look and feel of the prototype were also revised to better reflect the ÖBB's corporate identity and branding. (See Fig. 11.)

Integrated Software and Hardware Prototype: A hardware development workshop for representatives of the specific target groups, hardware developers, industrial designers, and representatives of the ÖBB was subsequently held at the Danube University Krems. The aim of this workshop was not only to find innovative ways of guaranteeing accessibility and facilitating use of the new TVM, but also to discuss the feasibility of the newly identified possibilities. An industrial designer hired by the ÖBB subsequently designed the TVM prototype in line with the requirements catalog and ideas generated at this workshop. The machine was then built by the hardware manufacturers in the consortium and featured two special hardware elements designed to increase accessibility and efficiency (see Fig. 12): a QR code reader used not only by the personalization system but also to allow the user to quickly buy the same (or return

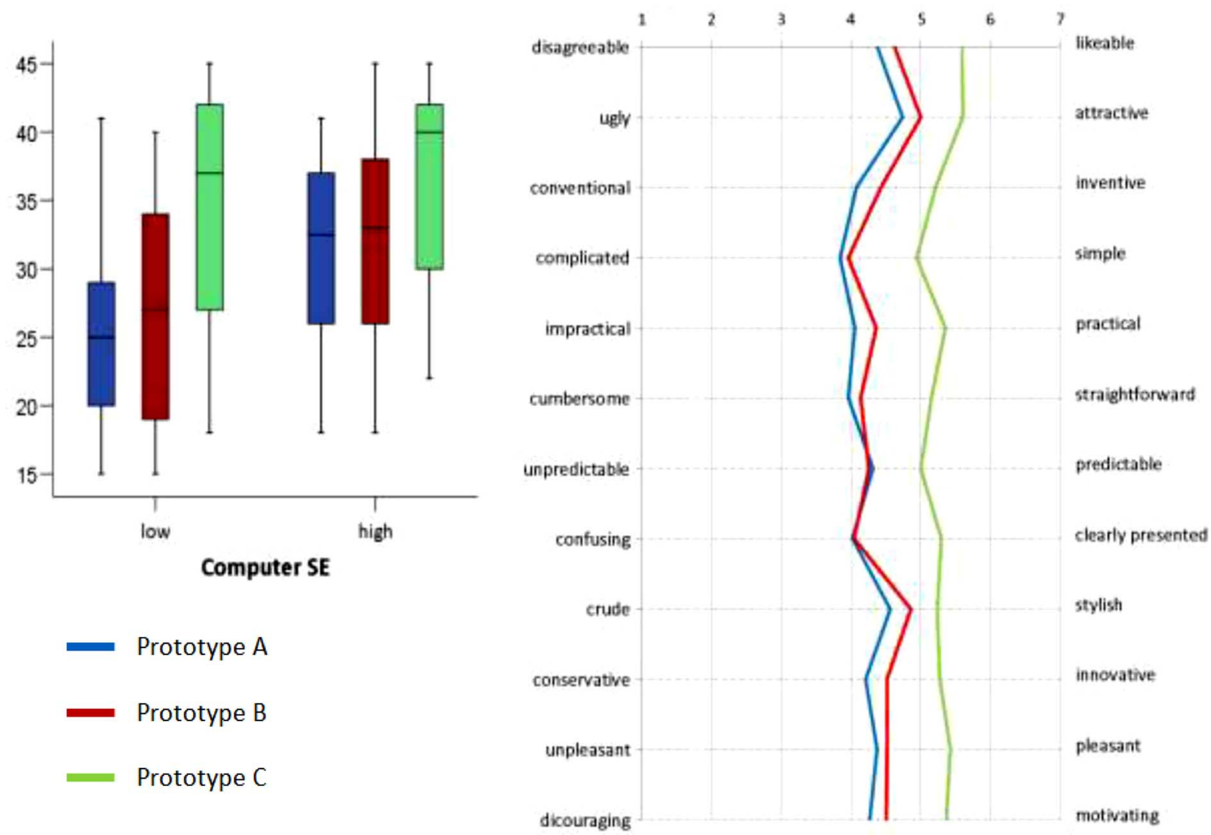

Fig. 10. Usability ratings (left) and semantic differential (right) for the three prototypes.

ticket to a) ticket by simply scanning the original; a very large vertically mounted touchscreen that automatically adjusts the active part of the display to the height of the user (inspired by [15]). The integrated prototype and refined software were used for the final round of user tests

Results of User Testing: Similar to the mockup testing described before, a 2×2 laboratory experiment (within-design, balanced order) was conducted with 48 participants with differing levels of computer SE (24 low, 24 high) and of different ages (24 over and 24 under the age of 55). The participants were given the same four fictitious travel stories used in the mockup tests, but this time, they interacted with the TVM prototype. They also had to solve one additional task: they were handed a ticket with a QR code and told to buy the return ticket for this route. The same measurements used in the software mockup testing were also taken in this experiment (time needed to solve the tasks and user interactions/errors). In addition to the short usability questionnaire, participants were also asked to complete an enhanced version of the semantic differential before the postexperiment interview. Since computer SE is dependent on the subjective feeling of having made progress during training [4], the participants were asked to rate their confidence of being able to successfully buy a valid ticket before and after the trials. The SE questionnaire used was created specifically for this experiment and was based on the approach described by Bandura [16]. Finally, in a very similar approach to the product reaction card method [17] used to assess brands and products [18], the participants were given a list of 50 different adjectives and were asked to select the five words that they felt best described the TVM.

The observations of the test participants' behavior revealed some critical issues with the vertically mounted touchscreen. The most common such issues were a parallax error (in 25 cases, almost half the participants in the test), followed by an inadvertent touching of the screen with the heel of the hand (in 16 cases). In addition, some testers unintentionally adjusted the height of the screen, since many of them did not realize that height adjustment was a deliberate function ("*I got a real fright when the screen moved.*"). As a consequence, participants had to adjust their posture to the (usually too low) position of the screen, causing

Fig. 11. Refined software—passenger selection (left) and options (right) screens.

additional parallax and typing errors (18 cases). Virtually none of the testers recognized the reason for this problem, assuming instead that either they were at fault or that there were still some basic problems with this version of the software.

The problems encountered with the personalization/quick purchase function resulted primarily from the fact that the testers were not familiar with or unable to find the QR code reader. (See Fig. 13.) A few of them associated the code with the mobile phone function: *"I have to take a photo of that with an iPhone. But I haven't got one!"* Half the testers looked for the QR code on the screen first, while many of them either ignored the slot containing the reader or confused it with the ticket dispenser and tried to use other hardware components to read the code: the slot for banknotes was the most common choice (17 people), but some participants also tried to hold the ticket to the camera (7), the screen (5), or the debit/credit card payment slot (4). Nine people were unable to position the ticket correctly, usually holding it too high. Several users reported that they would have been able to find the QR code reader quicker if the symbol displayed at the top of the reader had been a QR symbol instead of a bar-code symbol. Only 17 testers were able to use the QR code without any assistance.

Despite these difficulties, all of the participants said in the postexperiment interviews that they were extremely impressed with the new hardware components. They praised the QR personalization function for its potential time-saving capacity and welcomed the reduced typing requirements. At the same time, some participants expressed data security concerns, particularly since the machine would allow the ÖBB to monitor and store mobility behavior data. It was also pointed out that features of this kind would have to be clearly communicated in the future because—with the exception of "early adopters"—most users would not find them out for themselves.

The only problems explicitly mentioned with regard to the touchscreen were potential hygiene issues and the general lack of feedback provided on the screen. In the interviews, the participants were very positive about the height adjustment option—but only after the function had been explained to them in detail: *"That must have been developed by real experts—but you wouldn't have known unless you were told."* A further perceived advantage of the system was the fact that people with poor eyesight could get very close to the screen without having to bend over.

One of the major points learned about the hardware features from the user tests was that they could easily interfere negatively with normal usage of the TVM. The weaknesses in the touchscreen and the software used to control the height adjustment (which could, at best, be described as "experimental," lacked reliable face recognition and was very susceptible to changing light conditions) caused severe problems and confusion by not working properly in every trial. If this system was actually to be implemented in a real TVM, it would need to be guaranteed that the hardware was 100% dependable. The problems encountered by the participants in using the new hardware clearly indicate that the usability (and especially the visibility) of such systems has to be enhanced. Providing additional feedback and information, such as through acoustical signals and/or onscreen

Fig. 12. TVM currently in use (left) and created by the project consortium (right).

Fig. 13. Correct usage of the QR code scanner.

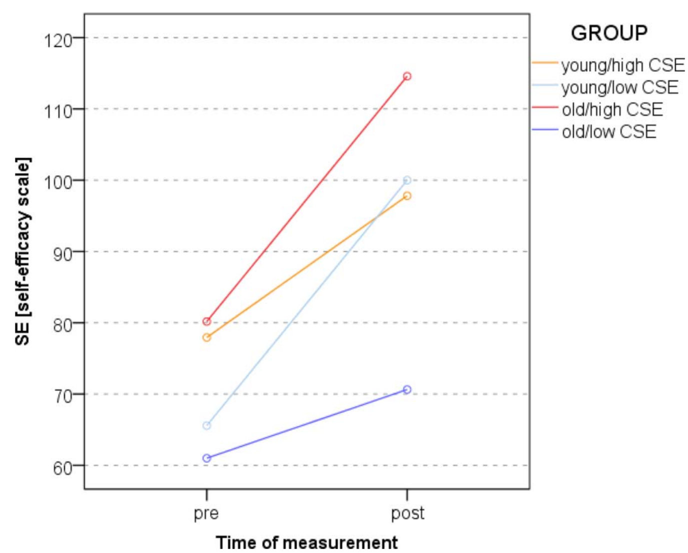

Fig. 14. Changes in ticket purchase SE for the test group.

explanations, might also facilitate interaction with the more innovative hardware components.

In addition to the observed results, the statistical analysis revealed that the starting values for the ticket purchase SE scale (measured before solving the tasks) were significantly higher for participants with a high level of computer SE (CSE) than for those with low computer SE ($F(1) = 9.17, p < 0.01, \eta_p^2 = 0.28$). Yet, these values also increased significantly after the participants had used the TVM ($F(1, 49) = 29.41, p < 0.001, \eta_p^2 = 0.38$). The only exception here was the group of elderly people with low CSE (significant interaction: time of measurement*age*CSE, $F(1{,}49) = 4.70$, $p < 0.05, \eta_p^2 = 0.09$). (See Fig. 14.) Overall, the machine did not (as yet) succeed in conveying a sense of success among the members of this particularly relevant target group and raising their confidence in their own abilities.

The semantic differential also produced different results within the different groups. In general, the TVM was assessed most positively by older people

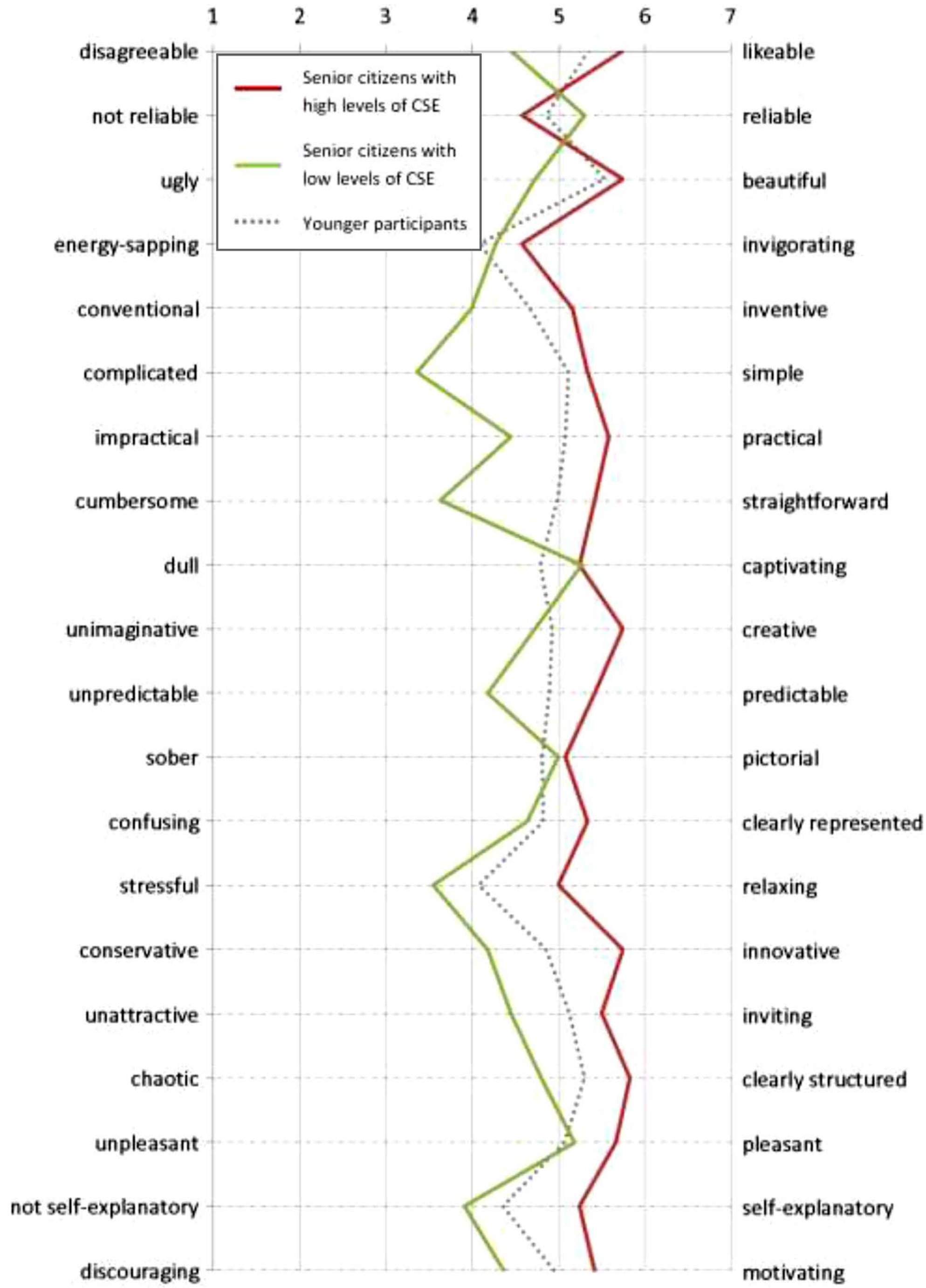

Fig. 15. Semantic differential.

with a higher level of CSE and most negatively by older people with a lower level of CSE. The latter group's more negative impression of the machine is also reflected in its choice of descriptive terms: cumbersome, complicated, stressful, not self-explanatory. (See Fig. 15.) These experiences are reflected by the statements collected in the think-aloud protocols: "*I would get nervous now if people were waiting behind me.*" or "*How did I manage that? How did I get the two adults into the train?*" Touchscreen issues seemed to be partly to blame for the unsatisfactory experiences. One user even gave up at the end of the trial after failing to hit the "Buy Ticket" button as a result of the parallax error: "*It just doesn't work! Is there something else I still have to do? I don't know what to do next!*". Furthermore, the difficulties encountered in selecting the different offers—a point criticized by the majority of the participants—seemed to add to the impression that the system was complicated:

"*Cut out the ÖBB jargon! Get rid of their internal codes!*"

Of the list of 50 characteristics provided to the participants with the request to select the five that they felt best described the TVM (product reaction card method), the following were most frequently selected: structured process (17), well thought through (15), usable (14), satisfying (13), innovative (9), advanced (9), useful (8), comprehensible (7), accessible (7), helpful (6). It is also important to note that the participants did not opt for the more emotional descriptors, but instead chose to emphasize the more practical and efficient aspects of the TVM. As one person put it: *"I can get my ticket—and that's what I want."*

CONCLUSIONS, LIMITATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

What can be learned from the INNOMAT case study for the development of other self-service systems? In this final section, we will begin by deriving conclusions from our case study and discussing its limitations before going on to delineate suggestions for further research.

Conclusions The INNOMAT project lasted more than three years. The concepts and the design of the machine were developed by an interdisciplinary team of ergonomics, barrier-freedom, design, hardware, and software engineers and specialists. In potential realization terms, the participation of future operator of the machine (in this case, the ÖBB) within the project team and their feedback were of particular importance. From a development perspective, the interdisciplinarity of the team presented a great opportunity, and confronting designers, hardware developers, and software specialists with the diverse needs and experiences of different user groups helped us to realize novel technical and conceptual solutions and overcome limiting factors.

An important challenge for the design of public information and self-service systems like a TVM is the heterogeneity of possible users [19] and the manifold user demands. This is why the INNOMAT project chose to follow the UCD approach. In our opinion, the UCD methods, which helped us to get to know the context of use, merit specific mention here: The participant observations, interviews, and video analyses allowed us to identify various needs, barriers, fears, and requests that needed to be taken into account. The design process was supported by explicating the user needs and by focusing on frequently neglected user groups. We found that in a system designed for different user groups, some of the many requirements were clearly contradictory (for example, although users with little technological literacy argued for a step-by-step system that guides users through the whole process, expert users also had to be taken into consideration). It is necessary—and worth the effort—to search for reasonable compromises. In our case, we excluded some groups from our target groups (for example, blind users were excluded early in the project) and developed novel approaches to meet contradicting requirements (for example, a QR scanner as a fast-access mode for experienced users).

We know from recent studies that self-service technologies have a particularly high impact on people with low affinity to technology; they pose a barrier to their participation in daily life and further enlarge the digital divide in society. Our case study was able to show that low computer SE, especially in older people, influences interaction with a novel TVM. However, we were also able to show that by aligning the design of such a machine with the narrative scripts of users, fewer interaction problems and errors occurred than when the design was based on machine logic. Our semantic differential and qualitative interview data likewise indicate that the UX was higher for a narrative interaction design.

We can therefore conclude that a narrative design approach is of particular value for self-service systems [13]. However, adopting this new approach instead of developing another variant of existing interaction schemes did require a great deal of negotiation within the project team. It also required a great deal of collaboration on the parts of the human–computer interaction and design partners. Despite being involved in the process from the very start, the actual design ideas contributed by the (potential) users were of limited use in resolving the heterogeneous requirements for an inclusive self-service terminal. Nevertheless, they did provide us with a lot of information on their thoughts and needs, which broadened our knowledge about UX and ultimately influenced the design itself.

In our UCD approach, the development was broken down into, planned, and launched in four phases, each with its own individual substeps: context of use, requirements analysis, design, and evaluation. While all of the process steps were ultimately completed as planned, some adaptations did prove necessary along the way, especially with regard to the user tests. The project team wanted to cover a broad cross section of the actual target group, which meant that in the course of the project, more than 250 people were involved in the focus groups, interviews, and experiments. In line with the theoretical plan, the first set of tests formed the basis for the decision on the subsequent design, while the second experiment produced recommendations for the implementation of the TVM. The tests were well planned, coherent, and conclusive, but, in practice, also very time and resource intensive. The experiments produced very detailed data, which subsequently meant that a great deal of time and effort was required to analyze it, determine the key points for the next iteration, communicate this information to the designers and the hardware/software developers, and negotiate the necessary design decisions. For some projects, it might be worth considering a more flexible approach with smaller iterations—which are less time consuming and involve fewer resources—as they can make it easier to steer the project and handle detailed design questions. It also proved to be difficult to plan the UCD process prior to the start of the project, as is suggested in [5]. For example, the target groups for the prototype had to be adapted during the CoU phase: more designs were realized than had been planned in advance and programming took longer than had been scheduled (to mention just a few of the alterations that proved necessary). While a rough work schedule is a definite necessity, adjustments and detailed planning should follow at a later stage and might require additional resources.

Although this case study was a research project, the development of the INNOMAT prototype was still restricted by some design limitations, a situation which might also arise in the development of other self-service systems.

(1) Technical realization proved to be a limiting factor for the design. For example, the placement of hardware elements inside the machine limited the arrangement of external elements.
(2) To lay the foundations for the future production of the new generation of TVM in Austria, the interface had to mirror the existing fare structure. From earlier research, we knew that the complexity of the railway fare structure (more than 1000 different types of tickets) is one of the major problems in the use of the current TVM [8]. This issue has been repeatedly raised in surveys, focus groups, and other types of evaluations and, therefore, also had a strong influence on this project as well, although it was essentially a matter of corporate strategy for the ÖBB and not directly linked to the development of the TVM. Nonetheless, the main goal of this project was to reduce complexity in the purchase process without limiting the customer's ticket options. Essentially, this meant that the project team had to think of ways of using the TVM to at least reduce any need on the part of the customer to take the fare structure into consideration. The idea was to design a "smart" system that could limit the possible fare options to those offers which were actually available and which represented the best value options for the selected parameters and the current train station. Users would then be able to make their decisions based on prices and product descriptions. Although a remarkable effort was made during the design process to reduce the number of options, the project team could basically only acknowledge customer dissatisfaction with the fare situation, since it had neither the mandate nor the authority to influence the existing fare structure. However, the project team did at least document the potential hurdles and dissatisfaction and communicate the problems to management at the ÖBB during project meetings.
(3) Also related to the complex fare structure, the names used for the individual tickets and a (lack of) knowledge of the terms and restrictions of use, areas of validity, and similar issues remained potential hurdles—as was seen in the final laboratory experiment.
(4) One other important factor that has to be considered is the fact that TVMs are usually embedded in other sales channels. Interoperability can therefore only be guaranteed if there is broad support from the actual company and adequate coordination and communication with other projects or neighboring systems (such as the website and the TVM sales channels). This raises the question of how to deal with incongruent systems (such as the interfaces used on the internet and the TVM) and with projects that are insufficiently linked.

From a UX perspective, we would like to emphasize, in particular, that it is not simply sufficient for a self-service system to be "usable." A positive emotional experience is required to encourage widespread use by a broad public. Prior studies show that negative feelings toward the system and low technological SE hinder access to self-service TVM [2]–[4], [8]. We therefore controlled in this case study for user technological SE and strived to develop a system which raised positive emotional reactions. To assess these, we observed how users interacted with the TVM and documented their emotional behavior. We also asked the participants to fill out a semantic differential which showed the emotional valence of the different interfaces. These “soft factors” of use may correlate with usability to some extent, but they add the certain something to a self-service system that will make it a success.

Limitations This paper presents the INNOMAT project from the view of the HCI experts. If the same story were to be told from the perspectives of the other project partners, the emphasis, details, and results would undoubtedly be different. By having collaborated on the design instead of merely evaluating it from an external perspective, we might also be biased by an insider’s view of the design decisions in which we were involved. To reduce any such influence, we placed special emphasis on the objectivity of the test methods.

As already mentioned, the original plans had included more test and development iterations than were finally conducted. The actual duration of the development phases was highly underestimated prior to the project. In order to complete the project within the allotted timeframe and financial resources, two iterations had to be cut. Regrettably, the TVM could not ultimately be evaluated in a real-life setting as originally planned: The development efforts this would have entailed would have far exceeded the available scope and resources. Likewise, the integration of real cash verification elements and a debit/credit card payment function would have created legal and financial hurdles. Consequently, only previously defined use cases were realized and no links could be developed for actual, valid tickets. Accordingly, a field test will be conducted when a fully functioning TVM has been built.

Suggestions for Future Research The UCD approach proved to be valuable for the development of self-service systems like TVM, and we would like to encourage further research on self-service systems using this approach.

Some interesting questions remained open after our case study. One such question is how frequent use of the new TVM would influence technological SE and UX? We assume that by using the TVM more often and becoming more familiar with the interaction, users will produce fewer errors and can build up a positive feeling toward the machine, a factor which again might increase technological SE.

A second open question would be whether (and to what extent) the problems with the hardware (parallax error, height adjustment, QR scanner) influenced technological SE and UX. The impact of such problems would seem to be important in decisions as to whether self-service technologies can be installed despite the existence of “minor bugs” or whether such features should be excluded if no guarantee can be given that they will function 100% correctly. Our qualitative data suggest the latter.

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