Designing and Evaluating Barrier-Free Travel Assistance Services

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Abstract. Using public means of transport implies making travel arrangements. Passengers have to study route schedules and are required to obtain tickets. For these tasks (mobile) assistance services already enable travelers to comfortably compile their journeys online. Nevertheless, we consider these services inadequate providing complicated interfaces with proprietary handling concepts. People are supposed to operate technical systems and negotiate through a jungle of tariffs, although these tasks could be automated without requiring users' attention. The Be-In/Be-Out (BIBO) principle implements this consideration and enables hands-free interaction for all travelers (especially handicapped people) automatically obtaining their rights to use means of transport while boarding. The infrastructure in the vehicles detects the presence of passengers and initiates invoicing in the background. We have developed a prototypical BIBO system including elaborated privacy concepts for multimodal barrier-free transport and have been evaluating user acceptance against the background of the transparent passenger. As a result, users confirm simplification of service consumption, convenience of use, efficiency and time savings in contrast to their lack of trust.

Keywords: Be-In/Be-Out (BIBO) · Transparent passenger · User acceptance

1 Introduction

Users of public means of transport may access a manifold spectrum of ancillary (mobile) services (e.g., departure apps, delay monitors, vehicle position indicators, online ticket services, etc.) helping them to conquer necessary tasks during their journey. However, we question the appropriateness of these services: Do they really provide the support we actually need? Or are they tailored for distinguished user groups? Do we face too many complicated user interfaces? The past has revealed that many of our supporting services have a deep technical background. Because there is interconnectedness of traffic data, because there are smartphones, and because there are special sensors, technicians have developed systems for other technicians (casually expressed). Humans and their individual requirements have taken a back seat (if we consider complicated handlings at ticket

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printers, cumbersome input options at web-sites, a manifold of mobile apps that all implement different interaction paradigms, and the jungle of tariffs, in general [1, 2]).

Derived from these inadequacies, we have a vision of developing appropriate (intermodal) travel assistance services enabling self-determined and sustainable mobility. Human beings and their personal needs, their travel habits and problems – and not technical achievements – should be the main stimuli for designing supporting systems [14]. Travelers should not care about actively and consciously operating technical interfaces. They should be able to stay focused to their current activities without spending time for consuming fiddling, automatable services. Instead, the surrounding environment, equipped with unobtrusive embedded technology, should automatically and context-sensitively trigger processes "in the background", i.e. unnoticed by their users without bothering them to manually interact with complicated technical interfaces.

In the course of a national research project within the realm of the research initiative "Mobility of the Future", funded by the Austrian government from 2014 to 2016 with cooperating universities, public transportation companies and NGOs representing different person groups with special needs, we have developed new paradigms and technical systems for user guidance and conceived an emancipated mobility approach, serving people with disabilities as well as children, elderly people or humans with cognitive impairments. Our ambition was to simplify usage of public transport by new ideas and technological solutions. Users and their needs were put forward for designing innovative services that omit technology-focused interfaces and assist travelers seamlessly.

2 Be-In/Be-Out (BIBO)

For our investigations, we have picked the process of obtaining tickets as an exemplary service with immature accessibility concepts. The current process is time-consuming and complicated: Ticket printers and online platforms confuse travelers with pricing models, force them to study tariffs and require detailed route specifications for creating a ticket. They compel travelers to interrupt their journey in order to make demands on the service. Our approach for an appropriate (barrier-free) ticketing system is derived from the Be-In/Be-Out (BIBO) principle [9] enabling people to implicitly obtain tickets simply by entering and leaving public means of transport. The infrastructure in busses and trains detects the passengers' presence and issues tickets while boarding (referring to the exact routes passengers have taken). Thus, people are able to interact with a technical system while continuing their natural behavior – no need to glimpse at displays or to press buttons.

The legal prerequisites for BIBO systems are clear: A contract between transit company and passenger may come off without active acknowledgement by the passenger, so the boarding process on its own may initiate ticketing. However, the technical implementation is challenging: How can we design a system that declines operating technical interfaces? We could think of a pure infrastructure-based system, i.e. technical gadgets in the vehicles detect and identify boarding passengers with no prerequisites for travelers (whatever technology enables such a scenario – we believe that there is no mature one at present). Yet, we would not agree with direct personal identification as included in this process. It will be indispensable to have passengers carry electronic equipment identifying them, but offering encryption. This technical "companion" is supposed to be unobtrusive and should be some kind of commodity item a traveler is carrying anyway, e.g., his mobile phone. While the mobile phone is predestined due to its distribution and computing power, it must not be the exclusive gadget if we want to fulfill our demands in respect to self-determined mobility. Even if passengers are able to operate mobile phones, we should not force users to install apps and associate electronic tickets with their phone. We think of an alternative – a simple object like a key fob (equipped with transmission technology and a battery) that passengers keep in their pockets performing the equal procedure for ticket issuing as the mobile phone – and granting barrier-free service consumption quintessentially.

Considering these requirements, we chose Bluetooth Low Energy (BLE) for implementing a prototypical BIBO system [11]. BLE is available in all recent smartphone generations and is currently causing a hype in terms of autonomous identification with battery life times of more than two years (catchword: "iBeacons"). Whereas BIBO systems in their current test setups from Siemens [17], Trapeze [18] or Scheidt and Bachmann [15] are based on active Radio Frequency Identification (RFID), we are convinced that BLE is more powerful and offers better opportunities for distribution [13]. We have conducted a series of tests investigating technical feasibility and user acceptance. We have conceived a privacy concept counteracting the issue of the transparent passenger, who is wearing gadgets determining entry and exit points. In this paper, we try to quantify simplicity, manifest users' thoughts about service easement and respond to their concerns regarding privacy and misuse.

3 Economic Relevance

BIBO systems seem to have economic potential, as large producers have implemented and tested technological variants using active RFID. But how many users do BIBO systems actually address? We have put an eye on the potential target groups and tried to find out a figure characterizing the market size. The numbers of passengers using public means of transport in Vienna in 2013 give some insights (see Fig. 1.).

We do not address travelers using public means of transport on an annual basis. Annual season tickets (and also school season tickets, monthly or weekly tickets) already enable passengers to simply hop on and off arbitrarily without infrastructural technology (although, usage of such tickets is often limited to certain transit companies, and exact route payoffs are unavailable). We want to support passengers that use public means of transport every now and then (e.g., business travelers staying in a foreign town for just a day or two, or also tourists), i.e. people that obtain single tickets or short-time passes at on-site ticket printers.

The figures from our transport partner Vienna Public Transportation Systems (Wiener Linien) from 2013 classify 23.4 % of all passengers into this category (i.e. 13.9 % single tickets and 9.5 % short-time passes), so nearly ¼ of all passengers in Vienna. Considering the total passenger count of 900 Million people in 2013, we calculate a potential market size of nearly 600,000 passengers a day, just in Vienna. This means 600,000 printed tickets each day.

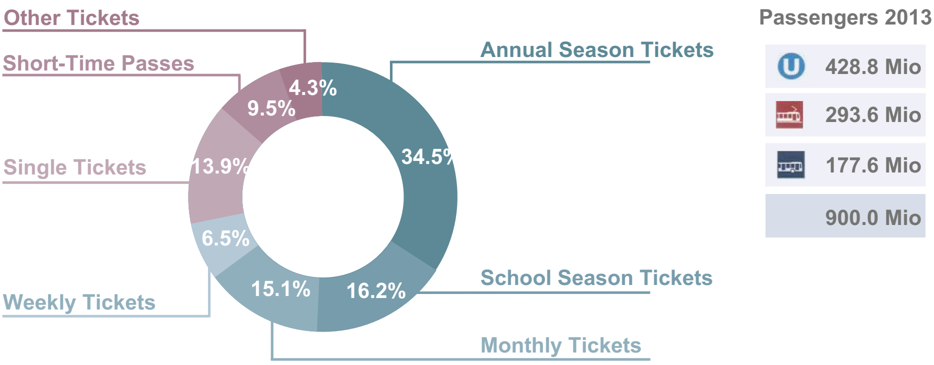

Fig. 1. Passenger Figures for Vienna (*Source: Wiener Linien, "Zahlen, Daten, Fakten", 2013, in German*)

4 State-of-the-Art

The technical basis for BIBO systems has been RFID with active tags carried by the passengers. A series of research projects use this technology for implementing prototypical and nearly market-ready BIBO systems: One of the first implementations was EasyRide [5] implemented by the Swiss Federal Railways Association, Transports Publics Genevois, Swatch, Siemens and Ascom, with comprehensive user tests (i.e. 900 participants) in Geneva and Basel. While the basic concept turned out to be applicable, the project was not pursued, as technology was immature in 2001. The project Calypso by RATP, Innovatron, ASK, Otlis, and Carris [9] ended with similar results (80 % detection rate). However, the interaction principles were promising and have been adopted in consecutive research projects, like Allfa [4] or FastTRACK [9]: Allfa is a BIBO system built by Siemens VDO, Fraunhofer, GWT and VVO and has been tested for half a year in Dresden, Germany, in busses, trams and trains with 2,000 users or about 120,000 trips, resulting in an overall acceptance rate of 68 % (20 % uncertain and 12 % rejecting). Current implementations based on (mature) active RFID enable passengers to utilize public transport systems on test routes in Switzerland or Germany with a small, battery-empowered RFID tag. The most familiar systems are Esprit from Scheidt and Bachmann with a small LED display on the tag [16], ComfoAccess from Trapeze in Switzerland [18] or the eTicket system from Siemens in Germany [17].

The BIBO concept comprises a contactless, mid-range radio-based identification and communication principle where passengers carry electronic tags. The mid-range aspect allows creating on-board architectures with a single communication unit in the center of a vehicle. Mid-range communication on the other hand is prone to uncertainty regarding reliable assignment of passenger and vehicle. This specific disadvantage can be compensated by virtual fences at the entrance doors (i.e. vicinity detectors) ensuring to unambiguously recognize boarding activities of passengers (Walk-In/Walk-Out, WIWO) [9]. Further variants are Check-In/Check-Out (CICO) systems, where users actively have to "show" their electronic tags at special entry- and exit gates, or Check-In/Be-Out (CIBO) systems as a combination of CICO and BIBO.

With the BLE standard defined in 2010, an alternative technology evolved in the field of low-power mid-range data transfer [10], which we consider an enabling technology for BIBO systems, as well (with additional benefits compared to RFID). We observe the same technology shift in the field of indoor positioning systems, where BLE [16] gradually replaces active RFID [6]. The basic interaction principle for BLE-based BIBO systems could be a copy compared to the active RFID approach with a battery-driven tag carried by the passengers. Beyond, BLE-based BIBO systems could additionally utilize smartphones as mobile entities. Given that all recent smartphone generations have BLE onboard while comparable active RFID systems in smartphones are rare, we conclude that a BLE-based ticketing system is highly attractive both from a practical and commercial standpoint. It facilitates additional options, e.g., monitoring, proprietary encryption, system openness, the chance to evaluate signal strengths for proximity determination, larger distribution channels, etc. Also the British Department for Transport considers BLE a future technology for BIBO [9] and confirms the pretended advantages in terms of hybrid applicability (both via tag or smartphone).

The BIBO approach is regarded proven (both conceptually and technologically by active RFID and also recently by BLE [11, 13]). Yet, it is unclear whether users would accept this new interaction paradigm considering the risk of becoming transparent to transportation providers. The tests in Dresden reveal that more than 30 % of the passengers reject BIBO or are uncertain about it [4]. While we do not know the reasons for denial, we assume that passengers (1) feared being traced and (2) refused to carry additional RFID tags (note that the service was unavailable on mobile phones then).

5 The Transparent Passenger

The issue of the transparent passenger addresses the technical possibility of transit companies to exactly trace customers on their routes. Hence, it is indispensable to provide an elaborated privacy concept along with BIBO systems preventing passengers from disclosing their personal data. Without that, we would create the next step towards a supervised society. Apart from the option of an anonymous prepaid version (which we do not favor, though, as it always comes along with the problem of too low balance), we present an accounting model that separates movement and personal data and therefore counteracts the transparent passenger. Figure 2 provides a closer look.

Previously we had two players: the passenger and the transit company. Now the bank enters as mediator. Passengers inform their bank that they want to use the BIBO system. The bank encodes their personal data and provides an encrypted key that authorizes passengers to use the new electronic ticket. For the transit companies, passengers are now anonymous numbers. Their movements via public transportation cannot be traced to them personally. At the end of each month the accrued costs are transferred to the bank, where the anonymous numbers are mapped back to real customers. As the bank receives no movement information, we have a clear separation of personal and dynamic data. The bank simply bills passengers for their fares. Thus, the passengers are the only persons who know where and when they traveled and how much they paid.

This principle follows the idea of Apple Pay[1] or Google Wallet[2], where the payment process is separated from the purchased wares. Payments in the US may already be carried out by this mechanism (or at least a similar version of it). Europe is supposed to adopt anonymous payments, which creates the future basis for our accounting model.

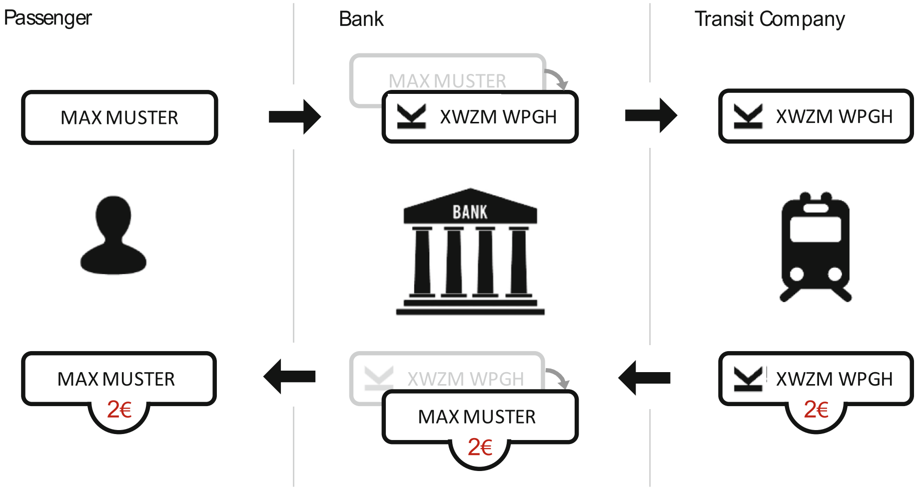

Fig. 2. Avoiding the transparent passenger

6 Research Methodology

While the basic concepts for our BIBO system were clear (i.e. hands-free interaction requiring no attention by its users, a pricing model referring to the exact routes passengers have taken, a privacy mechanism separating movement and personal data, and a technology choice including smartphones and arbitrary commodity items), we were facing two main research questions that had to be answered in the course of our research project eliminating uncertainness before the development of a product:

1. Does the proposed BIBO principle ease multimodal service consumption for users? Do passengers consider it an adequate interaction method in respect to barrier-free, emancipated and self-determined mobility?
2. Are passengers concerned about privacy? Are they worried about personal route recordings as BIBO ticketing is based on automatic technical detections, or what measures can be implemented in order to take passengers' fears?

In order to answer these questions, we have implemented a prototypical BIBO system based on BLE and installed it in busses of our transportation partners (for a detailed technical description of the system we refer to [7, 8, 11–13]). Therewith, we conducted a

[1] http://www.apple.com/apple-pay/.
[2] https://www.google.com/wallet/.

series of structured and application-oriented user acceptance tests in December 2015. We intended to "measure" the appropriateness of usability with persons from different target groups representing people with mobility handicaps (amongst them blind and cognitively impaired people from our NGO project partners). They could either participate using our BIBO app on their private phones or were handed out key fobs (see a 3D-print-out of an encasing frame for BLE beacons in Fig. 3 with a simple visual monitoring metaphor triggered by a click on the fob illuminating red when not checked in and green when checked in, respectively vibrating for visually impaired people).

Fig. 3. Electronic key fobs

The test has been conducted with two technically equipped busses from our project partner Upper Austrian Regional Public Transportation Association on predefined routes in Linz (see an impression of the circular routes in Fig. 4 with a total distance of 12 km and 26 bus stops).

After a short oral briefing about the functions of our BIBO system the test persons were requested to hop on and off the two reversely driving busses and experience the BIBO interaction paradigm while riding (including random ticket verifications by special inspectors and live monitoring options for the passengers regarding their covered distances. In addition, they were requested to complete a questionnaire regarding simplicity of use and their confidence in such a system or their privacy concerns.

For this test we chose a small sample of test persons in order to gain first insights into usability and privacy concerns (note that the tests will be extended to a larger sample size in a second step in order to quantify the results in an acceptancy study).

We have used the System Usability Score (SUS) method [19, 20] for small sample sizes in order to deduct valid statements in terms of usable or unusable systems. The SUS method aggregates the answers of 10 standardized questions with one of five responses that range from *strongly agree* to *strongly disagree* and calculates a total score, the interpretation of which is depicted in Fig. 5: A value of 100 describes a perfect system without any usability problems. Values above 70 stand for good and excellent usability. Values between 50 and 70 may be interpreted as marginal, and anything below indicates severe problems.

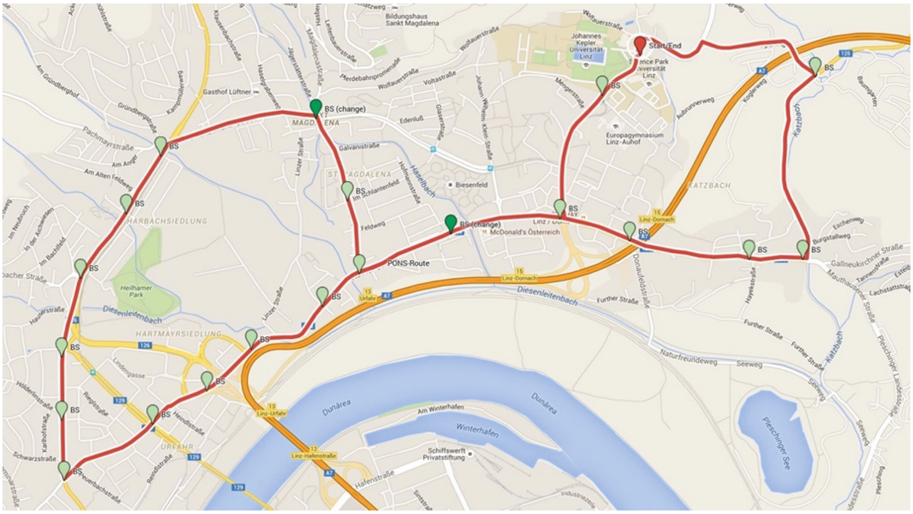

Fig. 4. Test routes

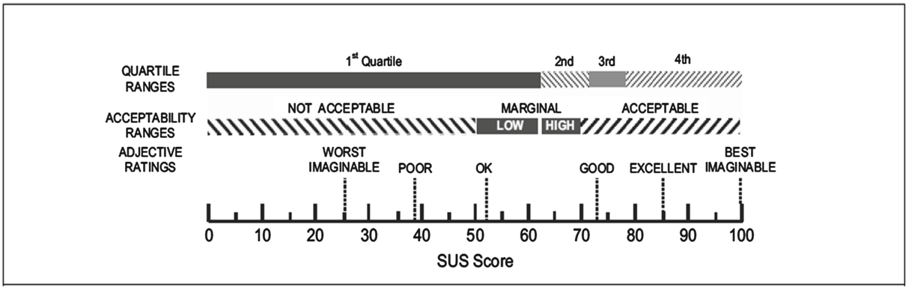

Fig. 5. System Usability Score (SUS)

7 Results

The test had been conducted with 16 test persons whereby 1 person was visually impaired and 1 person had cognitive limitations. The majority of the test persons were students aged 21 to 30 (8 persons), 4 persons were between 31 and 40 and 2 persons each were either below 20 or above 40 years. None of the test persons was older than 50 years. We had a balanced sample of persons regarding their attitude in terms of public means of transport: half of the persons enjoy using bus and train and the other half had a neutral attitude with just 1 person disliking public transport. 9 persons have not heard about the Be-In/Be-Out principle at all, 5 at least knew about smart card solutions (either CICO systems or multimodal city tickets, e.g., the Oyster Card in London) and only 2 were familiar with contactless and hands-free ticketing services. All of the test persons were technophile, i.e. they had no concerns using mobile technology. 10 persons even regarded themselves as early adopters, especially those with physical and mental impairments. Note that all of our NGO partners having disabilities (i.e. blind and visually handicapped people) exceedingly favor the use of smartphones as these devices enlarge their options for information and communication.

For these test persons we have calculated a SUS score, which is also valid for small samples. The overall SUS score for the test persons is 86.0, which attests excellent usability within the SUS scale (see Table 1).

Table 1. SUS Score

N°	SUS Question / Test Person	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	⌀	Corr
1	would use system frequently	4	4	4	4	3	4	1	4	4	3	4	4	3	4	1	4	3,4	3,4
2	found system complex	0	1	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0,3	3,7
3	thought system easy to use	4	4	4	4	4	-	3	4	4	4	4	4	4	3	4	4	3,9	3,9
4	need support of technical person	0	0	0	0	0	1	0	3	0	0	-	2	0	0	0	0	0,4	3,6
5	found functions well integrated	4	3	3	3	3	3	3	0	3	3	4	3	3	5	2	3	3,0	3,0
6	too much inconsistency	0	1	1	2	2	0	0	4	0	2	2	0	0	2	2	3	1,3	2,7
7	people would learn quickly	4	4	4	3	3	4	4	0	4	3	3	4	4	3	3	4	3,4	3,4
8	found system cumbersome	0	0	0	1	0	0	0	4	0	0	1	0	0	0	0	0	0,4	3,6
9	felt confident	1	3	3	3	2	4	4	4	4	3	4	4	3	3	2	3	3,1	3,1
10	needed to learn a lot before	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0,1	3,9
																		Sum	34,4
	Score (4 = strongly agree ... 0 = strongly disagree)																	**SUS**	**86,0**

The main positive impact factors for the test persons were: approved simplicity, usability and economic or personal benefit. The main negative impact factors refer to the lack of trust in such a system and to concerns regarding security of personal data (despite the transparency concept for separating movement and personal data). Figure 6 gives an impression on the answers of the test persons (1 is best … 5 is worst).

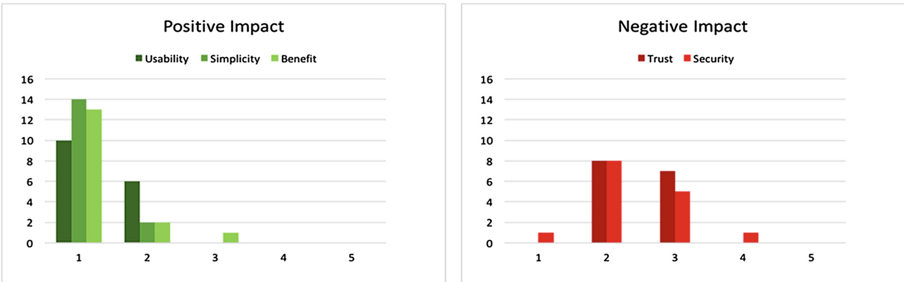

Fig. 6. Impact factors

These figures confirm simplification of service consumption (as assumed for research question 1). The test persons attested (in personal statements): simplicity, clearness, convenience of use, efficiency, time saving, the inclusion of various target groups with physical or cognitive impairments and the fact that people do not have to think about or cannot forget to obtain tickets, anymore. In contrast, the test persons were concerned about empty batteries, lost key fobs, special cases with cars or cyclists near the busses (i.e. within the signal range of BLE), still the transparent passenger (see research question 2) and monitoring live costs vs. Monthly accrued costs (including bonuses if applicable, e.g., for frequently taken routes). Some test persons also missed acoustic signals when boarding confirming the successful operation of the service.

As our testing sample was small we do not dare to compare active RFID-based vs. BLE-based BIBO systems in respect of usability and privacy. However, our investigations indicate that the majority of travelers prefer to use their mobile phones prior to beacons (10 out of 16 would use their smartphones, 3 the fobs and another 3 would not care), which implicates that our assumption in terms of required smartphone availability for BIBO systems is presumably correct, thus favoring the BLE-based version.

8 Conclusion and Future Work

Be-In/Be-Out systems are considered to represent one of the next steps towards barrier-free travel assistance services [14, 17, 18]. Their concepts are supposed to simplify utilization of public transport. As the major focus of our research, we have extended the scope of existing RFID-based BIBO systems by using an alternative, but potentially more powerful embedded state-of-the-art technology, BLE, and have developed privacy concepts counteracting the transparent passenger. Whereas the final tests for measuring the potentials of our system are still to come, we have a preliminary result with a small test group confirming simplicity and convenience of use. The users' confidence in BIBO systems is still not fully at hand inferring that special campaigns ought to eliminate people's concerns prior to commercial launch. Our attention was also called to special cases, e.g., dyschromatopsia (i.e. the disability to distinguish between red and green) hindering people to decode our monitoring metaphor on the key fobs.

Besides these deficiencies, we are also discussing options for multimodal and area-wide roll-outs, because many scientifically successful and economically valuable research projects fail because of lacking strategic or political concepts for commercial conversion. Our research project is built on a clear vision and on a solid basis concerning economic transfer from the very first:

The regulation (EC) No 1370/2007[3] [3] administers the assignment of public transport for European members. The main objectives of this regulation are *"[…] to guarantee safe, efficient and high- quality passenger transport services through regulated competition, guaranteeing also transparency and performance of public passenger transport services, having regard to social, environmental and regional development factors, or to offer specific tariff conditions to certain categories of traveler, such as pensioners, and to eliminate the disparities between transport undertakings from different Member States […]."*

[3] Regulation (EC) No 1370/2007 of the European Parliament on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70.

The translation of this regulation means that until 2021 every transit company in Europe has to acquire licenses from a central instance for operating selected routes. These licenses pre-scribe transportation frequencies, barrier-free appointments, and technical equipment for a networked integration. As the grantor of these licenses in Austria is a member of this research team, we are able to sustainably implement technical requirements for BIBO systems as part of future licenses, enabling us to roll out research results area-wide within a multimodal transportation environment.

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