# Designing Accessible Digital Services for the Future Public Transportation: Towards Lighter Testbed (LiTe)

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This paper represents the design process of the LiTe - Lighter Testbed of a tram stop and tram car to facilitate user evaluations in a realistic context. According to previous studies, people using public transportation seek services that improve travel experiences with the help of novel technology. In the future, accessible digital services will be integrated into all modes of transportation to provide a seamless experience. There is a need to offer physical and local access to innovative co-creation processes providing an environment and support for enabling the testing of novel solutions in an open but safe environment. This way, we can ensure the usability, accessibility, effectiveness, and safety of public transportation services in the Tampere area and further expand it to other cities.

CCS Concepts: • **Human-centered computing → Accessibility**; **Accessibility design and evaluation methods**;

Additional Key Words and Phrases: Accessibility, Public Transport, Testbed, Service Design

**ACM Reference Format:**
Tero Avellan, Alisa Burova, Juhani Linna, Juho Kuusikko, and Markku Turunen. 2022. Designing Accessible Digital Services for the Future Public Transportation: Towards Lighter Testbed (LiTe). In *25th International Academic Mindtrek conference (Academic Mindtrek 2022), November 16–18, 2022, Tampere, Finland*. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3569219.3569419

## 1 INTRODUCTION

As the railway transportation system develops in Tampere Region (Finland), using Information and Communication Technologies (ICT) has an essential role in this process. To partly replace the existing bus-centered system, deploying a tram transportation system is essential to sustainable city development [25], targeting sustainable mobility and reducing motor road traffic. Nevertheless, achieving it, the attractiveness of public transportation should be increased by advancing how users experience the service as a whole.

According to previous studies [5–8, 11, 12, 17, 18, 20], people using public transportation seek services that improve travel experiences with the help of novel technology. There is a need to offer physical and local access to innovative co-creation processes providing an environment and support for enabling the testing of novel solutions in an open but safe environment. This way, we can ensure the usability, accessibility, effectiveness, and safety of public transportation services in the Tampere area and further expand it to other cities.

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In the future, accessible digital services will be integrated into all modes of transportation to provide a seamless experience [9]. However, there is a lack of research data and understanding on how to design for accessibility to respect different user groups, especially some people with special needs, highlighting the need for further testing and investigation experiences of these groups. Especially the emerging technologies of the mixed-reality continuum, also known as Extended Reality (XR), can positively shape the deployment of transportation infrastructure [1] by providing a flexible means of designing and evaluating intelligent services related to public transportation. Providing data directly from the users and necessary research knowledge, ICT can boost and advance accessibility in public transportation on many levels [26].

Despite XR technologies' potential, technologies cannot fully address the needs of accessibility-related evaluations due to yet limited technical capabilities, such as a lack of physical barriers and boundaries. At the same time, the design and evaluation activities in real contexts are rather complex. For example, operating a tram stop would be constantly full of people traffic. Therefore, there is a need for a realistic-to-context environment to facilitate various testing scenarios.

In this paper, we present the concept and design process of the physical prototype of a tram stop and tram car, namely LiTe – the Lighter Testbed. To facilitate passenger experience and accessibility test scenarios, LiTe can be used independently or in combination with XR technologies, such as Augmented Reality (AR) and Virtual Reality (VR). Further, using testbeds to experiment and develop transportation technology cost-efficiently is common [15].

## 2 RELATED WORK

There are demands for Intelligent Transportation Systems (ITS), which aim to develop innovative services around transportation systems and intelligent use of transportation networks. Therefore, the need to pilot and evaluate these services must be addressed with users in mind. Building the design and development activities around the users have been widely practiced in the field of Human-Computer Interaction (HCI) and has evolved into the definition of the ISO standards, namely ISO 13407:1999 [10, 13], revised by ISO 9241-210:2010 [14].

Early-phase user studies and evaluations in real context have shown a significant increase in the quality of outcoming products and services, lowering the gap in understanding user needs, challenges, and attitudes and linking the solution to address them. Furthermore, the ability to measure addressing user needs provides robust metrics [10], ensuring accessibility for all. However, in the field of public transportation, a similar approach referred to as a passenger-centric innovation [5] has not been fully established. Focusing on technical and ergonomic aspects cannot fully address public transportation attractiveness. Instead, focusing on how passengers experience the service leads to new areas for innovation and interdisciplinary collaboration [5]. One way it can be achieved is by developing methodologies and tools to gather knowledge about passenger experiences, including gains and struggles associated with public transportation.

Studies demonstrate the usefulness of even simplistic methodologies for testing and evaluating passenger preferences, needs and expectations to make public transportation more attractive and accessible prior to development [2, 11, 12, 21]. For instance, Schelenz et al. [21] presented how to utilize agent-based simulation to evaluate the performance of bus layouts from passengers' perspectives, which would help to model passenger behavior already at the design phase of the bus. The study by Astfalk et al. [2] presented the potential of non-functional prototypes to elicit user acceptance of novel technologies, the example of air taxis. Further, the study by Hilden et al. [11] presented a concept of the Travel Experience Toolkit, which considers three areas of passenger experience, such as user, context, and system, delivering tools to focus on passengers' needs when developing digital services for public transportation.

Testbeds have been widely applied in the context of public transportation as a cost-efficient solution to facilitate experimentation and transportation technology development in a safe and controlled environment. Typically, established as a scale-down or simplified simulation consisting of software, hardware, network, and communication components [15]. The study by Biddlestone et.al. [3], propose using an indoor testbed as a low-cost way to simulate urban scenarios to support the decision-making process and the problems of situation awareness.

## 3 DESIGN PROCESS

This work was performed in line with the Smart Campus program [22], aiming to connect research institutes, such as universities and industries, and boost sustainable design and development in the Tampere region. The design process started in the spring of 2021 and was adopted from the service design methodology and consisted of five phases, shown in figure 1. At the core, there is customer-centered design with various tools and methods. Essential in this work is public transportation and especially passenger services, which have combined traditionally different service design methods [11]. Service design generally focuses on the user experience, analyzing and improving functionality [16, 19, 24].

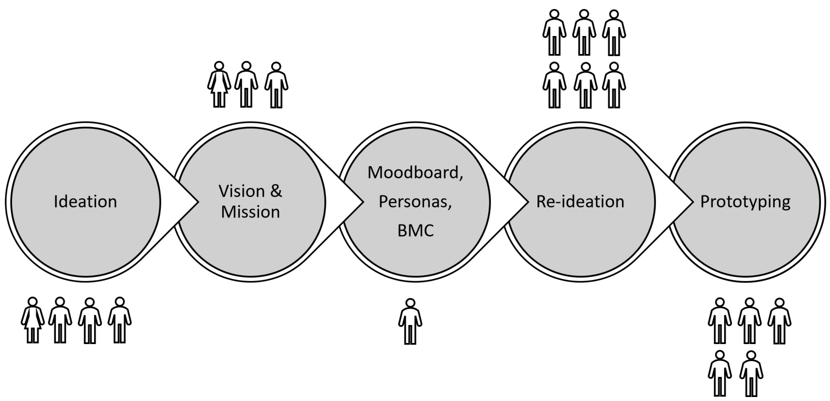


Fig. 1. The design process consists of five phases involving co-collaboration with multiple people during the process.

As part of our research, we followed Research through Design (RtD), translating methods and mental processes from design practice to a research environment [27, 28]. The design process is used as research to contribute to the design activity. Ideation, vision and mission, and re-ideation phases were conducted during workshops related to the VR development of Tampere public transportation [4] and during various meetings and unprompted exchanges involving co-collaboration with multiple people and stakeholders during the whole process.

Due to the epidemic, we initially focused on VR as a tool for designing accessible public transportation services. We hosted the Smart Campus workshop [23] held in June 2021 remotely via Zoom, where 16 participants (14 academic and two industry representatives) contributed to the topic. As an outcome, we defined [4] the following areas where XR technologies should be deployed; *1) holistic transportation service planning in general, 2) designing, testing, and optimization of traffic planning, scheduling, and design of tourist-related digital services (e.g., personalized AR navigation), 3) evaluation of user experience and user engagement, and 4) accessibility.*

In these areas, we expect the LiTe should be deployed as well. The workshop followed two other workshops during spring 2022 [4], influencing and providing another vision and mission combining physical testbed with VR. Six personas, shown in figure 2., were created to describe different stakeholders for the testbed, types of users, and two types of groups. The personas in the first group cover research and development, including industry needs. The personas in the second group cover the end users and the third sector. The third sector includes, for example, organizations representing people with disabilities. Despite being an integral part of the design process, including stakeholders and target users is sometimes ignored. These personas help service developers to understand the varying needs describing the objectives and frustration, needs, limitation, and abilities.

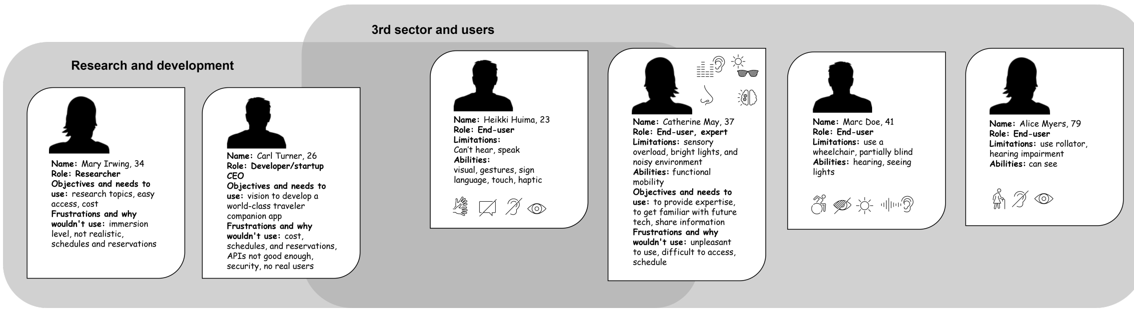


Fig. 2. Personas for the testbed service.

To specify the essential character traits for the testbed, we used the Business Canvas Model (BMC), shown in figure 3., comprised of nine criteria expressing a range from costs and revenues to customer segments and relations, keeping cost efficiency vital. However, we do not have a business; we designed a testbed as a public service. This paper excludes key partners, customer segments, cost structure, and revenue streams. Our primary use for the BMC was to help define key activities and offerings, especially value propositions. To the BMC, we defined concrete platform needs and objects such as *mobile test platforms, physical test platforms, digital test platforms, tram car and stop mockups, and public displays.*

The value proposition is the essential component and answers here the question of why service is valuable, what makes value for the user segment, and the personas we defined earlier. Here we suggest providing *rapid testing, device mounting possibilities, multimodality, mobility, flexible booking, easy access, permission policies, and open data access (APIs).* These are related to the whole testbed concepts for public transportation and merging XR to the physical test environment.

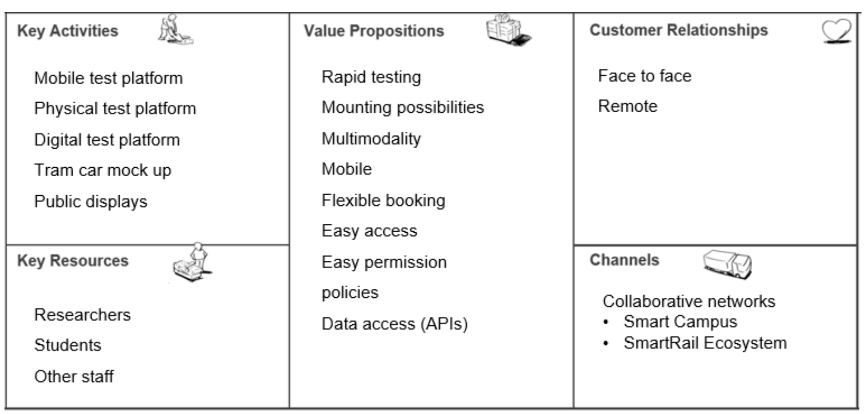


Fig. 3. Part of the Business Model Canvas that includes key activities, key resources, value propositions, customer relationships, and channels (excluded key partners, customer segments, cost structure, and revenue streams).

In practice, the design process involves light prototyping in all phases using sketching. Finally, we ended up with re-ideation and prototyping in three phases. At first, we designed a miniature cardboard model on a scale of 1:17 based on sketches. The miniature model is a helpful observation tool for testing and understanding physical space requirements. To design a look and feel, we modeled a 3D model using Rhinoceros and created concept pictures in Blender. These were bases for more explicit material and structure plans to build a real-size mockup, the Lite testbed. It is a light and modular mockup made from wood on a scale of 1:1. However, because of mobility requirements, the LiTe does not entirely correspond to an actual tram; it is modular. Still, it provides the possibility for easy access and setup for testing novel technologies. Its primary function is to serve as an easy-access test platform for developing accessible digital services.

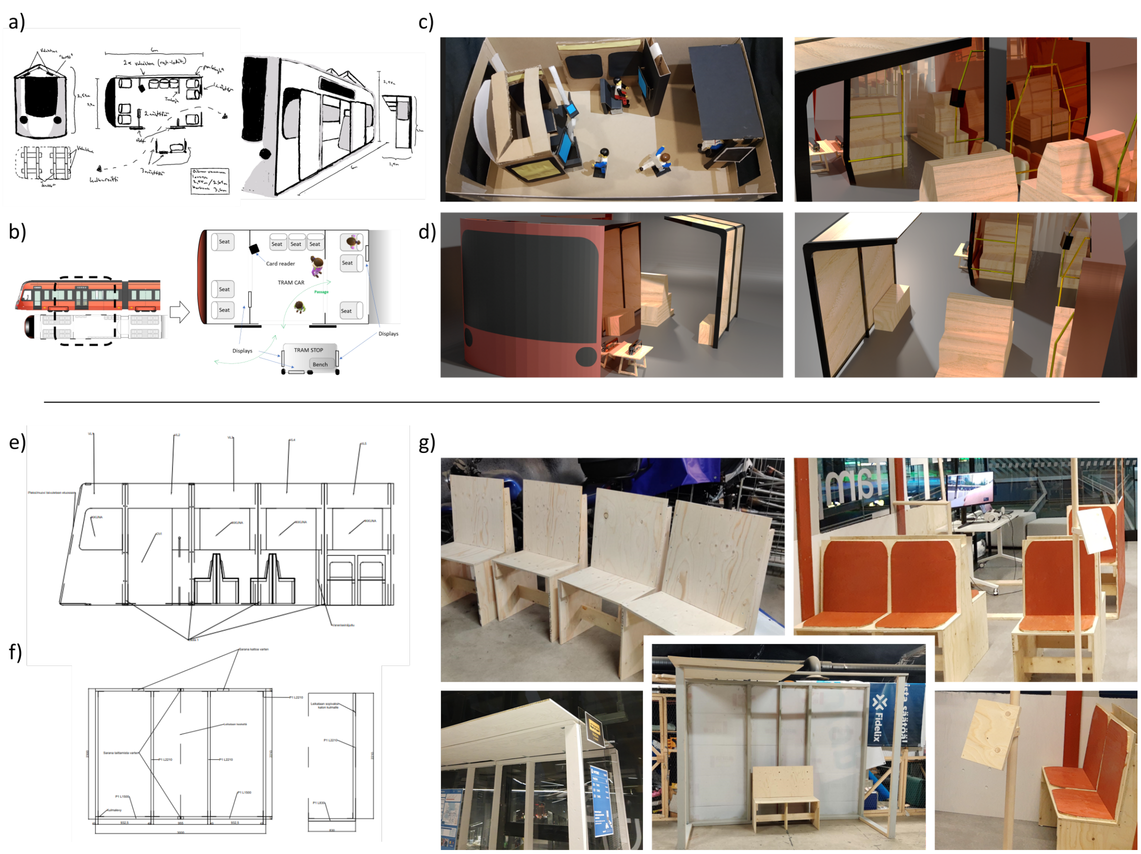


Fig. 4. (a) drawn sketches, (b) detailed plan, (c) the cardboard model in scale 1:17, (d) the 3D model of the concept, (e) CAD drawings of the tram car, (f) CAD drawings of the stop, and (g) some partly finished parts of the mockup.

## 4 CONCLUSION AND FUTURE WORK

The accessibility and attractiveness of public transportation increase by advancing how users experience the service as a whole. In conclusion, we have designed a testbed for service design in public transportation. This paper represents the design process of the LiTe - Lighter Testbed of a tram stop and tram car to facilitate user evaluations in a realistic context. The knowledge can be later generalized as recommendations, and the LiTe can be further utilized in various settings. Due to the epidemic between 2020 and 2022, different projects have been looking for new ways to collect information, one using environments based on VR and the other a light cardboard model. In addition, a preliminary plan of various service design tools, such as design games, has also been considered.

As a lesson to be learned, the physical testbed can be complex, starting from the required space to build and meet value propositions in the BMC. We have learned from previous studies that VR can be used in the planning and rapid testing of public transportation services, especially regarding accessibility [4]. However, VR does not replace experts with real-life experiences and experiences in real-life environments. In contrast to the general understanding, we preset LiTe – a testbed to explore and evaluate the interaction among passengers and technology, focusing on human factors, such as experiences, expectations, and acceptance, which are essential to advance passenger experience. For future work, we aim to merge the LiTe with emerging technologies, such as AR, VR, and IoT, and design immersive environments with physical dimensions implementing test scenarios in the context of public transportation.

## ACKNOWLEDGMENTS

This research is part of the Smart Campus program funded by the Academy of Finland (Grant #337614). The authors would like to thank especially Dr. Jukka Selin and Mr. Juha Ojala from South-Eastern Finland University of Applied Sciences, XAMK for sharing their knowledge and future discussions.

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