Innovative Technological Solutions for Cities as a Response to the Challenges of Multimodal Mobility for All Citizens

Inovativne tehnološke rešitve mest kot odgovor na izzive multimodalne mobilnosti za vse prebivalce

Jani Demšar
Cartography
Geodetic Institute of Slovenia
Jamova cesta 2
Ljubljana, Slovenia
jani.demsar@gis.si

Marina Lovrić
Spatial Management
Geodetic Institute of Slovenia
Jamova cesta 2
Ljubljana, Slovenia
marina.lovric@gis.si

Roman Rener
Cartography
Geodetic Institute of Slovenia
Jamova cesta 2
Ljubljana, Slovenia
roman.rener@gis.si

Abstract

Mobility is a fundamental right of all people, crucial for social participation, as recognized also by the UN Convention on the Rights of Persons with Disabilities. Despite this, persons with disabilities often face challenges when using public spaces and transport. This paper emphasizes the importance of physical accessibility, digital tools, and stakeholder collaboration to foster inclusivity. Using mixed-methods approach, including data cataloguing, field verification, surveys, and workshops, the study highlights the need for comprehensive data integration and accessible infrastructure to support independent mobility for persons with disabilities. It is important to approach and develop mobility solutions for people with disabilities. These include methodology implementation, standards, pilot testing, adaptation, and integration of the entire system in the country, and the knowledge transfer to all stakeholders.

Keywords

multimodal mobility, spatial data, persons with disabilities, public transport, accessibility

1 Introduction

Mobility is a fundamental aspect of human life, enabling individuals to navigate their environments and actively participate in society. This right to independent movement extends to everyone, regardless of personal circumstances. The United Nations Convention on the Rights of Persons with Disabilities guarantees this fundamental right to independent mobility for persons with disabilities (PwD) [1]. However, PwD often face significant barriers when navigating public spaces and utilizing public transportation.

Digital data play a crucial role in supporting efficient multimodal mobility, especially when it comes to understanding the entirety of the system, from standards to implementation. Real-time route planning apps that consider accessibility needs, designated accessible parking information, and integrated ticketing systems across various transportation modes facilitate independent mobility. The primary aim of this paper is to explore innovative technological solutions that can bridge the gap between current challenges and the vision of inclusive urban mobility.

Furthermore, this paper presents research based on key projects including, "Enabling Multimodal Mobility for Persons with Various Disabilities" [3], "Spatial Data Support for Public Passenger Transport Management – Persons with Disabilities in Public Passenger Transport" [4] and "Analysis of Conceptual Designs of Information and Technical System Support for Persons with Disabilities to Increase Social Inclusion" [4]. These projects provide insights into the current state of accessibility of public spaces and public transport infrastructure, addressing the specific experiences of PwD.

2 Methods

Understanding the travel needs of PwD is crucial for planning cities with effective public transport, accessible public spaces, and diverse options for multimodal mobility. We employed a mixed-methods approach in our research to address this topic. We developed various methodologies and object catalogues for data capture in the office. We developed methodologies for the four groups focused on in the project, such as persons with mobility impairments, persons with visual impairments, the deaf and those with hearing impairment, and the elderly. We have covered the elements related to the mobility and accessibility of the space for these people in the object catalogue. In the catalogue, elements are described as attributes with corresponding values. All elements are depicted in real-life scenarios with maps and photos, providing precise locations and real-world contexts. With the help of catalogues, we captured data in the office on a desktop computer with an Open-Source

Information Society 2024, 7–11 October 2024, Ljubljana, Slovenia

https://doi.org/10.70314/is.2024.DIGIN.2

Geographic Information System (GIS) program tool. We used the latest orthophoto in Slovenian national coordinate system D96/TM with an accuracy of 0.25 m as the basis for captured data as background.

For this purpose, we created libraries composed of thematic characters, which we took from the object catalogues of the project. Verification of captured field data was carried out using a digital approach; with open-source mobile data capture application for Android, iOS, and macOS. Field data verification was supported by persons with mobility impairments as a participatory method. We created data capture layers that include areas for data capture, physical barriers (both permanent and temporary), routes, public facilities, parking spaces for PwD, bus stops and railway stations, as well as points of interest. Each layer contains different types of data. For example, for paths, we captured information on sidewalks, roads without sidewalks, bicycle paths, pedestrian crossings, tactile pavement elements, building edges, green spaces, fences, and stairways. Data on physical barriers includes obstacles such as steps, high curbs, hazardous objects on paths, unsuitable surfaces, traffic signs blocking sidewalks, low pegs, and movable barriers like parked cars, flower beds, advertising boards, and outdoor seating from restaurants. Temporary obstacles, such as construction sites, were also documented, including details on the duration of closures for excavation works. Additionally, we captured location data of accessible toilets for PwD, and accessibility of public transport (e.g. accessibility of bus stops and vehicles) to support route planning.

To better understand the travel habits, experiences with different modes of transport and the willingness to use the "on-call transport model among people with disabilities, we conducted a survey. The survey was conducted using the online platform - 1ka, chosen for its user-friendly interface, open-source nature, and accessibility features that cater to users with visual impairments. To ensure comprehensive data capture and increase survey participation, we employed two supplementary methods. The first method involved collecting data at social events organized by organizations for people with disabilities, allowing us to engage closely with respondents and gather opinions and information in a more informal setting. The second method involved collecting data through employment centres that cater to PwD. In both cases, respondents were given the option to complete the questionnaire either online or in person.

Finally, we conducted various workshops with persons with different types of disabilities, including those with mobility impairments, the blind and visually impaired, and the deaf and hard of hearing. These workshops were organized as focus groups, where we facilitated guided conversations through specific questions to gather as much useful information as possible. These sessions provided us with in-depth insights into how PwD navigate through different environments, how they use assistive devices, and how they prepare for travel and use public transportation. We also gained new knowledge about various technological aids and applications.

2.1 Volunteer Graphic Information for Data maintenance

For data maintenance, we used the participatory data maintenance method. We relied on similar voluntary data capture tests that have already been carried out, such as research conducted by Triglav Čekada and Radovan [6]. Participatory data maintenance is the editing and maintenance of data after the completion of data capture. Emphasis is placed on the participation of various PwD, who are often ignored in wider research or data capture. Many research projects confirm that people respond positively to changes when they are offered the opportunity to actively participate [7] in decision-making or spatial planning. The approach to data capture was based on Volunteer Geographic Information (VGI), as a new source of geospatial data. Term Volunteer Geographic Information is relatively new according to Goodchild, and it is understood as geographic data created and contributed voluntarily by individuals, often through online platforms and mobile technologies [8]. Numerous studies show that GIS, through the use of smart mobile phones, has established itself as an effective tool for ensuring participation [9][10][11][12]. This technology allows residents to actively contribute to shaping their living environment through mobile GIS applications, by capturing and sharing spatial data in real-time [13][14].

Figure 1: Demonstration of a data capture workshop.

3 Results

As highlighted in the previous chapter, we captured data for four groups of PwD included in the project. This data was then entered into the database, organized topologically, and verified for suitability in navigation applications. To visualize the captured data, we developed the Web Accessibility Viewer - a web-based GIS tool equipped with basic functionalities for displaying and defining the properties of the various layers.

Our database currently contains data for 79 municipalities, covering all groups of PwD considered in the project. The captured data includes 3,170 parking spaces designated for PwD and 5,100 physical barriers, such as dropped kerbs, inadequate ramps, unsuitable pavement surfaces, and obstructions on paths. Additionally, we have documented 1,650 accessible bus stops and 59 railway stations. In terms of public facilities, there are 4,750 identified, of which 288 have accessible toilets for PwD. For individuals with sensory impairments, 508 audible traffic signals and 921 tactile pavement elements have been captured. Furthermore, we have captured data on 712 points of interest across the municipalities.

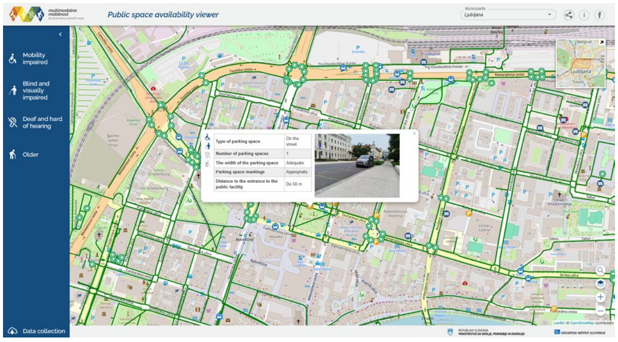

Figure 2: Web Accessibility Viewer displaying parking place from data bases.

Analysis of the survey responses highlighted current challenges in public transport, the experiences and travel habits of the respondents, as well as their actual intention to use the "on-call transport" service. A total of 921 respondents participated in the survey. The majority of respondents are from urban areas of Slovenia, more specifically Ljubljana, Maribor, Celje, Kranj, and Novo mesto.

We understand the "on-call transport" service as a service that provides transportation from the starting point to the endpoint of a journey, with both points being within the operational area of the call center. If a passenger travels outside this area, the service offers transport to the nearest accessible public transport station. This allows passengers to continue their journey using other forms of public transport, enhancing their mobility and access to a broader area. It is essential to mention that the "on-call transport" model acts as a bridge between individual transport and complements existing public transport systems.

The "on-call transport" service not only supports the independence and improves mobility of vulnerable groups but also strengthens their social inclusion and independence. Although originally designed for the transportation of PwD, the "on-call transport" service has the potential to benefit the wider community. It presents a solution that could be adapted for other vulnerable groups, such as the elderly, children, or those without private transportation in remote areas.

The majority of respondents expressed interest in using "on-call transport" if the advance notice period was 12 hours or less. A small number of respondents indicated that they would consider replacing their personal car with "on-call transport" if given the option.

Our data analysis showed that most of respondents are employed, which is probably the consequence of distributing the survey in employment centers to capture a wide range of individuals with diverse experiences and travel habits. Retirees represent the second largest group, while students and self-employed individuals constitute the smallest portion of respondents.

The analysis of field data capture, survey findings and different workshops reveals that public transport accessibility for PwD is often inadequate. Respondents cited unreliability, inaccessibility, and poor organization as some of the most significant issues, leading many to prefer using personal cars over public transport. Most stations and intercity public transport vehicles are inaccessible, as highlighted also by the Advocate of the Principle of Equality in Special Reports [15][16]. However, urban areas tend to be more accessible and the overall situation is gradually and consistently improving.

4 Discussion

As we previously established, digital data on the accessibility of public spaces and infrastructure can be captured both methodically and in a participatory way, when shared by PwD via smart mobile phones using a GIS app, thus becoming part of big data. We define big data as large-scale datasets originating from heterogeneous sources and collected in the urban environment using sensors integrated in an Internet of Things (IoT) system [17]. An IoT system combines devices such as smartphones and different sensors into a single network connected to a common server. As central elements of the IoT, sensors enable cities to collect real-time data from public transport usage and traffic flow analysis to energy consumption and weather conditions [18]. Advanced analytics tools can process and correlate this data to extract useful information to improve city planning and management decisions [19].

The importance of big data in the context of accessibility is multi-layered. These data enable the analysis and understanding of mobility patterns, use and accessibility of public spaces and infrastructure. With the help of this data, administrations or urban planning and design professionals can identify areas where improvements of accessibility are needed. Moreover, big data allows for a dynamic response to the needs of the population, as it can detect and predict changes in mobility and space use patterns. Providing accurate, real-time information on accessibility of public transport using big data improves travel planning options for PwD. This not only reduces the risk of encountering unexpected barriers, but also highlights the importance of big data in the design and planning of more accessible and inclusive public spaces. The Ljubljana Passenger Transport's Urbana mobile app is a good example of the use of big data and sensor technologies in practice, as it allows users in need of an accessible bus to order transport for a specific time and location, while the location of the bus can be monitored in real time directly through the app.

The integration of different databases which include data on accessibility and data on public passenger transport is essential for improving and enabling independent mobility of PwD. Combining data on accessible bus locations, accessible station locations, accessible sidewalks and physical barriers, and timetables allows people with different disabilities to access key information for route planning. All data are in standard format for GIS and can be converted for various application use.

To successfully implement knowledge into practice and ensure accessible public spaces, efficient public transport, and other mobility options within the context of multimodal mobility, cooperation among stakeholders at local, regional, and national levels, as well as experts in spatial planning, is essential. For digital data on accessibility of public spaces and infrastructure to be useful and effectively integrated into various systems, collaboration with urban planners, public transport operators, organizers of on-demand transport services, and representatives of PwD is necessary. This collaborative approach will help address the shortcomings and contribute to the improvement of data in the future.

5 Conclusion

In an era of rapid technological transformation, urban population growth, and ageing population, urban design faces increasing challenges to create spaces that are accessible and inclusive. The rise in the number of individuals with disabilities necessitates barrier-free access to public spaces. Over the past decade, we have witnessed a transition from traditional city concepts to the design of dynamic and adaptable urban environments. This shift is not merely physical but represents a profound change in our approach to urban design.

By centering the design process around people and leveraging innovative technological solutions, cities are becoming not only technologically advanced but also inclusive and responsive to the needs of their inhabitants. This new paradigm prioritizes accessibility and inclusiveness, ensuring that urban spaces accommodate everyone, regardless of their physical abilities. Through this approach, we are crafting cities that embody the principles of universal design, fostering environments where all individuals can thrive and participate fully in society.

The article describes the approach to the development of the entire system from methodology, standards, the use of new technologies and building a base for the purpose of mobility of persons with disabilities. It is especially worth emphasizing the involvement, sharing knowledge and collaboration between system developers and users.

In this context, technological solutions play a pivotal role in advancing multimodal mobility and enhancing urban accessibility. The integration of various transportation options such as walking, cycling, and public transit requires seamless coordination facilitated by cutting-edge technologies. Real-time data, smart infrastructure, and advanced analytics are transforming how cities manage and optimize their transportation networks.

Acknowledgments

We would like to extend our sincere thanks to the Ministry of Environment, Climate, and Energy for funding the project "Enabling Multimodal Mobility for Persons with Various Disabilities" for eight consecutive years, allowing us to improve and raise awareness about the importance of accessible environments.

We are also grateful to The National Council of Disability Organizations of Slovenia for their extensive support in implementing the project "Spatial Data Support for Public Passenger Transport Management – Persons with Disabilities in Public Passenger Transport."

The authors of the article would also like to thank the Slovenian Research and Innovation Agency (ARIS) and the Ministry of Labour, Family, Social Affairs and Equal Opportunities (MDDSZ), who financing the research project entitled "Analiza konceptualnih zasnov informacijske in tehnične sistemske podpore invalidom za povečanje socialne vključenosti" No. V2-2252, targeted research program "CRP-2022", made it possible to carry out part of the research and results of this article.

Note that there is a section break at the end of references to balance the columns (and this text is a part of the new section). If you have no space left at the end of your paper, you can delete it.

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