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Accessibility of buildings for the functionally impaired: An inventorying method using online tools

The situation in Slovenia in terms of the accessibility of public buildings for functionally impaired persons is concerning. Most often people with disabilities already face barriers when accessing the building (no disabled parking available, stairs leading to the entrance into the building, thresholds that are too high, doors too heavy to open, handles set too high, etc.) and then in the building itself (staircases, unadapted lifts, insufficiently large toilets, etc.). To show potential barriers to the functionally impaired as well as the building owners and maintenance staff, a method is presented for inventorying building accessibility for the functionally impaired using online tools. The method relies on relevant universal accessibility legislation and standards, and it is important because it facilitates an accurate and comparable evaluation of potential barriers and adaptations already in place. Thus, it functions both as a multifunctional framework for evaluating the accessibility of all buildings, which provides an overview of and displays potential barriers to building owners and maintenance staff, and as a guide to building accessibility for the functionally impaired. Also presented is the method's implementation in the online system for inventorying building accessibility, which makes it possible to monitor building accessibility for the needs of the functionally impaired and provides an overview of the barriers detected for the building owners and maintenance staff.

Keywords: accessibility inventorying method, functionally impaired, accessibility monitoring system, indoor accessibility, online app

1 Introduction

Article 26 of the Charter of Fundamental Rights of the European Union (2012, 401) "recognises and respects the right of persons with disabilities to benefit from measures designed to ensure their independence, social and occupational integration and participation in the life of the community." The third operational objective of the European Action Plan 2006-2007 addressing the situation of disabled people in the EU (Commission of the European Communities, 2005) envisages improving accessibility for all, which is connected with the principle of design for all. This principle promotes the design of the environment and various aids that can be used and accessed by all without major barriers and without the need for specialized design and adaptation of the built environment (Hanson, 2005). In the European Union, the right to accessibility of the built environment, information, and communications is addressed from two aspects. The first refers to the right of the disabled to social inclusion and equal opportunities, and the second has to do with the standardization of spatial planning legislation.

In 2014, the European Union Agency for Fundamental Rights posted a report on its website on mandatory accessibility standards for public buildings across the EU member states. The report proceeds from the European Disability Strategy and states that no information was able to be obtained for Slovenia on the standards adopted in this area. Slovenia adopted the ISO 21542:2011 standard (Building Construction – Accessibility and Usability of the Built Environment) in 2011, even though at that time the standard was only available in English. It was translated into Slovenian in 2012 (revised in 2017).

In Slovenia, the fundamental rights to equalization of opportunities derive from Article 14 of the Slovenian Constitution (Sln. *Ustava Republike Slovenije*, Ur. l. RS, no. 33/91-I), which states that "everyone shall be guaranteed equal human rights and fundamental freedoms irrespective of national origin, race, sex, language, religion, political or other conviction, material standing, birth, education, social status, disability or any other personal circumstance." Equal opportunities and non-discrimination of disabled persons is also governed by the Convention on the Rights of Persons with Disabilities, the Equalisation of Opportunities for Persons with Disabilities Act, and the Social Inclusion of Disabled Persons Act.

Barrier-free access is to be provided to all functionally impaired persons. According to Article 3 of the Rules on Universal Construction and the Use of Construction Works (Sln. *Pravilnik o univerzalni graditvi in uporabi objektov*, Ur. l. RS, no. 41/20183), functionally impaired persons include "the disabled and other persons with a permanent or temporary impairment (e.g., limited mobility, vision or hearing impairment, injuries, and chronic disease), disorders (e.g., intellectual disability), or physical characteristics that may also be the result of various life circumstances (e.g., the elderly, children, and pregnant women)". The SIST ISO 21542:2011 standard (and its versions ISO 21542:2012 and ISO 21542:2022) also covers people with hidden (e.g., stamina and allergy) impairments and people with differences in age and stature (including frail persons). A note is added that this also applies to people with temporary impairments. In addition, the standard defines accessibility (to buildings and parts thereof) as "provision of buildings or parts of buildings for people, regardless of disability, age or gender, to be able to gain access to them, into them, to use them and exit from them. Accessibility includes ease of independent approach, entry, evacuation and/or use of a building and its services and facilities, by all of the building's potential users with an assurance of individual health, safety and welfare during the course of those activities." According to the Building Act (Sln. *Gradbeni zakon*, Ur. l. RS, no. 61/2017), universal construction and use of buildings include the construction and use of buildings accessible to all people, regardless of their potential permanent or temporary impairment.

This article explores the accessibility of buildings for functionally impaired persons, who can also be defined as persons with impairments or disabilities, the disabled, or vulnerable groups. Due to their specific needs, three generally acknowledged types of disability are discussed in particular: blindness and visual impairment, limited mobility, and deafness and hearing impairment.

When referring to the movement of the functionally impaired, a distinction must be made between their movement in the home environment, the external environment of their place of residence and beyond, and in the built environment (i.e., in buildings). To improve mobility and navigation for individual groups of people with disabilities, it is first necessary to analyse the spatial conditions (Keerthirathna et al., 2010; Welage & Liu, 2011; Andrade & Ely, 2012; Calder & Mulligan, 2014; Basha, 2015; Gilart-Iglesias et al., 2015; Wolniak, 2016; Stauskis, 2018; Aini et al., 2019; Slaug et al., 2019; Rebernik et al., 2020; Carlsson et al., 2022) and then develop new technological systems and solutions (collect data, create an online platform, produce instructions, etc.).

The built environment must be adapted and planned for the benefit of functionally impaired people (Vovk, 2000; Hanson, 2005), and the accessibility to buildings or the safe multimodal mobility of people in the urban environment must also be considered (Mobasheri et al., 2017; Szaszák & Kecskés, 2020).

Mobility aids play an important role in the lives of people with disabilities or various impairments; they are indispensable for these individuals to live and work independently and safely. New solutions are based on the development of new methods and the use of new technologies (ICT and others). These aids seek to fill the gap caused by a specific disability (e.g., a sensory or physical impairment).

Smart cities include all their residents and also develop smart mobility for people with various impairments, such as urban pedestrian navigation (Mora et al., 2016, 2017; Wheeler et al., 2020), urban transportation (adapted city buses), safe corridors without barriers (e.g., for people with limited mobility), navigation systems for the blind and visually impaired (Virtanen & Koskinen, 2004; Oliveira Neto, 2019; Telles et al., 2021), or solutions that make it possible to propose spatial improvements (Wang et al., 2021). These solutions are interdisciplinary: they combine navigation databases, geographic information systems (GIS), ICT, IoT user experience, and the use of smartphones and navigation platforms (Cohen & de Duarte, 2016; Rashid et al., 2017; Rebernik et al., 2017; Borowczyk, 2018).

The next challenge for software developers and researchers is planning integrated and inclusive accessibility for the functionally impaired – that is, both outdoor accessibility to buildings and accessibility inside buildings, which is supported with new technologies. Quite a few articles and books have focused on the methodology for assessing barrier-free accessibility of public buildings for all types of disability (Vovk, 2000; Sendi & Kerbler, 2009, 2013; Žolgar et al., 2010; Rener et al., 2011, 2012; Vodeb & Bračun Sova, 2011; Kerbler, 2012; Sendi et al., 2012; Sendi, 2014; Biere Arenas et al., 2016). The accessibility evaluation methods presented usually refer to outdoor accessibility, and some of them also use IT tools. Only a few refer to the evaluation of indoor accessibility. The methods do not seek to define whether a barrier can be overcome by the functionally impaired and whether a solution actually agrees with universal accessibility standards. Standardized accessibility evaluation and thus comparability between the buildings examined are provided for exclusively by sector-specific legislation (the Building Act and the Rules on Universal Construction and the Use of Construction Works) and standards (SIST ISO 21542:2011 and its versions ISO 21542:2012 and ISO 21542:2022). Therefore, a study was conducted to develop a method based on the relevant standards, legislation, and the Rules on Universal Construction. Using online tools and technologies, this method subsequently made it possible to develop a system to evaluate and display the accessibility of buildings for the functionally impaired.

2 Description of the method for inventorying accessibility

The method was developed in four steps:

- Step 1: reviewing online sources related to outdoor and indoor accessibility of the built environment. As part of the review, seeking possible solutions for on-site collection of electronic data on indoor and outdoor building accessibility for the functionally impaired, and possible solutions for organizing the data collected and providing open access to these data for various users (i.e., for functionally impaired persons looking for information on accessibility; the buildings' owners and maintenance staff, who can use this information to remove barriers; and those inventorying building accessibility);
- Step 2: producing a method for inventorying building accessibility for the functionally impaired using digital tools (Bizjak, 2014; Bizjak et al., 2017);
- Step 3: using this method to produce the basic part of a system for online inventorying and monitoring building accessibility for the functionally impaired;
- Step 4: testing the method on the ground using the online system for inventorying building accessibility.

2.1 Step 1: Reviewing literature on indoor and outdoor accessibility of the built environment

The literature review included a keyword search. Keywords such as *accessibility*, *people with disabilitie*s, *functionally impaired persons*, *disabled parking space*, *interactive accessibility map*, *mobile accessibility app*, and *wheelchair accessible* were used. The search results provided insight into the methods described in research and other articles. They are presented below.

A study from Brazil (Cohen & de Duarte, 2016) focused on the use of a smartphone app called Virtual Accessibility Guide (*Guida de acessibilidade*), which helps functionally impaired people, the elderly, and others visit tourist sites in Brazilian cities. The guide provides information on accessibility to tourist sites, such as disabled parking spaces and accessible routes from the parking area to the site, with a description of barriers in line with the Brazilian technical standards. The method used for inventorying accessibility relies on the technical standards of accessibility, based on which data are displayed to the user.

Another smartphone-related example is an app that provides support to the blind and visually impaired at intersections with traffic signals (Liao, 2013). The app employs sensors built into the smartphone (e.g., GPS) and a device installed in the traffic controller cabinet that wirelessly communicates real-time signal phasing and timing information. Based on both technologies, blind or visually impaired persons that stop at a smart intersection can use their smartphones to obtain signal phasing and timing information. Because the system uses smartphone sensors, which can also detect the direction of the user's movement, the app detects the user's walking direction at the signalized intersection and accordingly communicates the status of the pedestrian signal to the user, so he or she can safely cross the street. In this case, the method employs external sensors and built-in smartphone sensors to capture data, which are then analysed in the smartphone app and communicated to the blind user in the form of an audio message.

Navigating and crossing streets in a wheelchair can be a major problem if the kerbs at the intersections are not dropped, there are no raised pedestrian crossings, the pavements are too narrow or contain barriers, and so on. Various interactive maps, such as the one provided on the Slovenian website *Dostopnost prostora* (Spatial Accessibility; Internet 1, 2022), can be of great help in this regard. Based on an interactive online GIS system, this site makes it possible to search for and display accessible routes for persons with reduced mobility and the blind and visually impaired (e.g., routes to public toilets, disabled parking spaces, public transport stops, pedestrian crossings, and other public infrastructure). The map also shows physical barriers, such as stairs, inappropriate ramp inclination, and inappropriately dropped kerbs. A similar search tool is also used by the System of Accessible Itineraries designed for Porto, Portugal (Lopes & Alves, 2021). Users can also help create interactive maps of accessibility of public and other buildings (i.e., through crowdsourcing). A good example is the Wheelmap app (https://Wheelmap.org/), an interactive map for smartphones that allows users to provide information on how easily accessible a selected building or destination is (Mobasheri et al., 2017). The map is based on the OpenStreetMap open-source platform, which only allows users to add information to the maps. The Wheelmap app is composed of two parts: one in which users can edit and enter new data on accessibility, and one that serves as a platform for the app's developers so they can test its new functionalities. The app also uses a RESTful API programming interface that makes it possible to access the interactive map data from other apps. A programming interface is also used by the web portal *Dostopnost prostora* (Internet 1, 2022), on which data can be accessed and edited; these data can also be used in other online apps (Rener et al., 2019).

Map developers collect data required to produce interactive maps in two ways: by checking route accessibility on site or by reviewing satellite images and using Google Street View. Data contributed by app users as part of crowdsourcing are often used to inventory barriers in open space. Users enter their information about places and the barriers in them in the app's database, thus sharing data on spatial conditions with other app users.

Locations and data on accessibility can also be added on the pridem.si website (Internet 4, 2022), which allows users to enter information on building accessibility in a simple manner, using symbols (pictograms). The symbols depict diverse elements (e.g., a symbol for toilets with a door at least 80 cm wide, grab bars next to the toilet bowl, and sufficient room to turn the wheelchair, or a symbol for an accessible common toilet), and the website also provides an explanation of all the symbols, so that users that want to enter information about the accessibility of a specific location can more easily decide which symbol better describes the type of accessibility.

In this case as well, crowdsourcing was used to capture data on building accessibility. The process used a set of symbols that were standardized by the app developers and describe the type of barrier. Users can inventory the accessibility of a building using symbols that they select in the app. This allows all the buildings to be inventoried in a uniform way. The standardized symbols do not adhere to the standards that apply to the built environment. Ljubljana by Wheelchair (2022) is a similar smartphone app developed by the same authors, which provides an overview of building accessibility for people with reduced mobility. However, it does not allow crowdsourcing or adding accessibility descriptions for other users to see.

Built environment accessibility standards provide a framework that can be used for examining whether a specific built environment is accessible or not. Websites providing information on building accessibility for the functionally impaired rely on the practical experience of the functionally impaired that enter the accessibility information (Internet 2, 2022; Ljubljana by Wheelchair, 2022; Internet 3, 2022; Internet 4, 2022). This often means that some buildings are not accessible to all. A good example supporting this is that a specific building is considered accessible if it has a ramp even if this ramp is steeper than what is required in the applicable standard and physically weaker persons cannot use it to access the building without assistance. Therefore, relevant standards should be taken into account when evaluating accessibility. A test methodology for analysing and evaluating the accessibility of public buildings for the functionally impaired using a questionnaire designed based on a review of building legislation was implemented as part of a research project conducted in partnership between Vilnius Gediminas Technical University's Department of Urban Design and Helsinki University of Technology's SOTERA research institute for healthcare facilities (Stauskis, 2005).

This methodology uses a questionnaire that was developed based on the legislation governing universal accessibility in Lithuania and its neighbouring countries. However, the questions referred only to outdoor building accessibility – that is, the routes to buildings, including pedestrian paths, pedestrian crossings, and parking areas (e.g., "Is the required number of accessible parking spaces provided?", "Are pedestrian paths not less than 1200 mm wide?"; Stauskis, 2005: 149). The possible answers to each question were *Yes* (accessible), *No* (inaccessible), and *N/A* (not available). The questions were tested by functionally impaired individuals (a physically strong and a physically weak wheelchair user, a person with crutches, a blind person, etc.). It should be noted that the testing included persons with various physical ability. What may be accessible for a physically strong adult wheelchair user may not be accessible for a physically weaker elderly person or a child in a wheelchair. In addition, the blind and visually impaired, and the deaf and hard of hearing should also be considered. The latter move more easily through spaces, but they are often faced with barriers related to audio communication and the ability to understand complex texts.

Public buildings can vary greatly in terms of architecture and the facilities they offer. Therefore, methods for inventorying them must take universal construction standards into account, be flexible in considering the buildings' facilities, and allow the use of electronic devices (tablets, smartphones, laptops, etc.) and their sensors (GPS, camera, mobile network connection, etc.).

The review of the literature and websites showed that only a few methods for capturing building accessibility data use online tools. Data are most often captured by using online interactive maps and through crowdsourcing. Some methods are supported by universal construction standards or standards governing the accessibility of the built environment. The examples described above, which refer to outdoor accessibility, examine pedestrian areas and level crossings (pavement width, the presence of dropped kerbs at pedestrian crossings, sufficiently large disabled parking spaces, etc.). There are even fewer examples referring to indoor accessibility, which covers entry into the building (stairs, ramps, thresholds) and indoor access to toilets, lifts, accommodation, and so on. In this context, some examples mention the use of standards as a method for describing accessibility as part of inventorying, but without describing the use of electronic devices and online tools in inventorying.

2.2 Step 2: A method for inventorying building accessibility for the functionally impaired using 2.0 digital tools

The relevant Slovenian universal accessibility legislation (i.e., the Building Act and the Rules on Universal Construction and the Use of Construction Works) and standards (i.e., ISO 21542:2011, SIST 1186:2016, SIST 4190-5:2012, and SIST 60118-4:2015) were the starting point for capturing and monitoring data on outdoor and indoor building accessibility for the functionally impaired. Based on these sources, questions were formulated that make it possible to describe a barrier and determine whether it can be overcome. The relevant source (i.e., law, standard, etc.) is added to every question. For example, the questions asked the following:

- Whether there is sufficient room to manoeuvre in front of and behind the desk (at least 1,500 × 1,500 mm, but preferably 1,800 × 1,800 mm); there must be sufficient manoeuvring room in front of and behind an information desk for a wheelchair user to be able to turn around;
- Whether the desk is furnished with assistive listening technology (a hearing induction loop); this tells a hard-of-hearing person whether he or she can speak normally with the person on the other side of the desk.

The questions selected provided a sufficiently large database based on which different sets of questions describing individual elements (e.g., outdoor access to the exterior door, the exterior door itself, the lobby, the information desk, the staircase, rooms, etc.) to be evaluated in terms of accessibility were formulated in the next step. For example, over thirty questions were available for evaluating the accessibility of the exterior door, covering all types of functional accessibility. The questions may also refer to the size and width of the door, door type (e.g., an automatic, sliding, or swinging door), the height and shape of the handle, whether the door is made of glass, what kind of threshold is in front of the door, and so on.

The building data in the database are linked to an electronic inventory sheet, which is why data on individual buildings (i.e., address, a photo of the front, geographic coordinates, the cadastral municipality code, the building code from the cadastre of buildings, etc.) must be entered in the database before starting the inventory. During the inventory, the sets of questions prepared in advance, covering the individual building element assessed, are entered in the inventory sheet. These questions are not linked to the table of questions, which allows redundant questions to be deleted from the sheet (in the case of the exterior door mentioned above, there may be several questions referring to various types of doors, which can be deleted once the relevant type of exterior door is established). The fact that

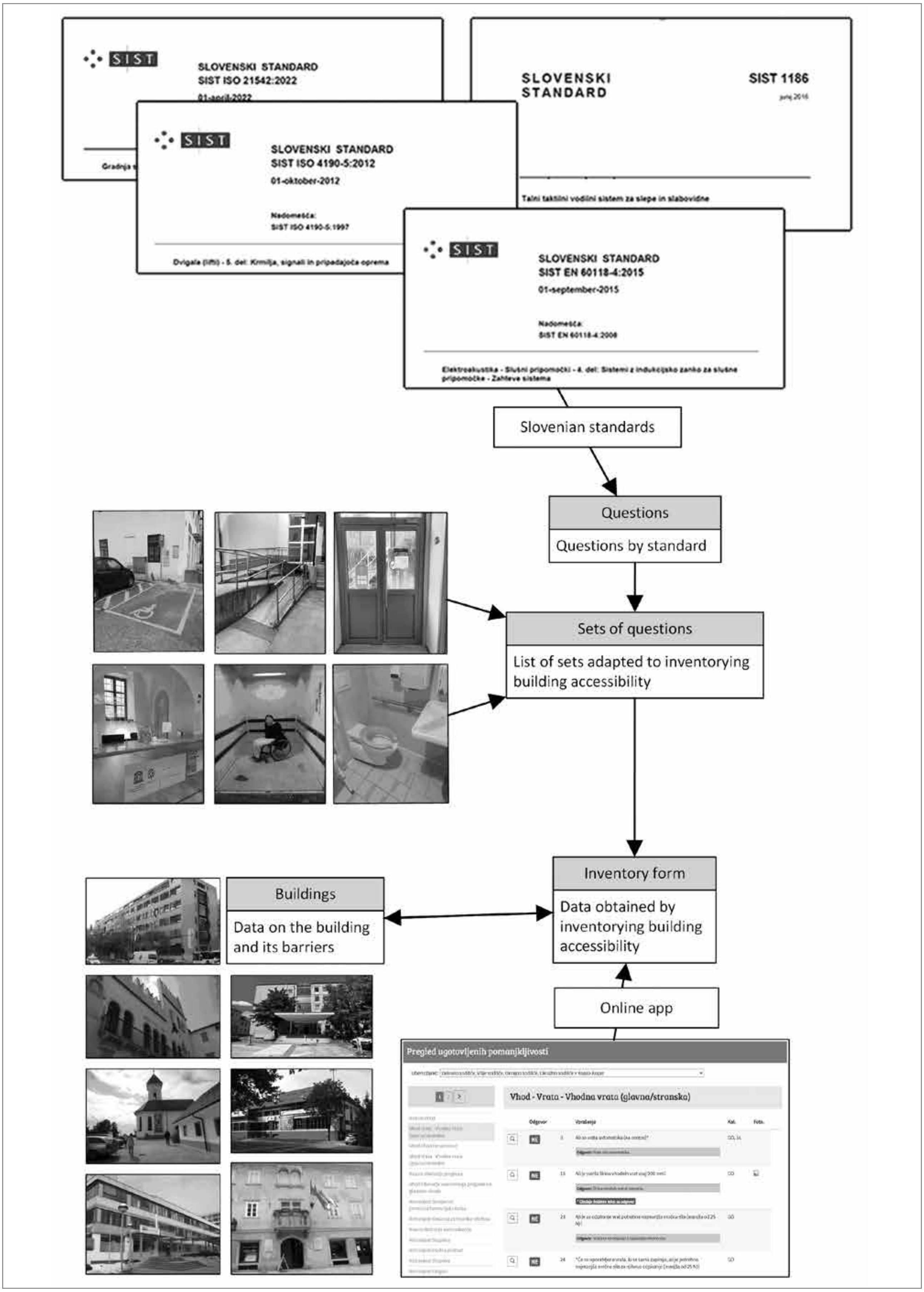

Figure 1: A diagram presenting the method for inventorying building accessibility (illustration: author).

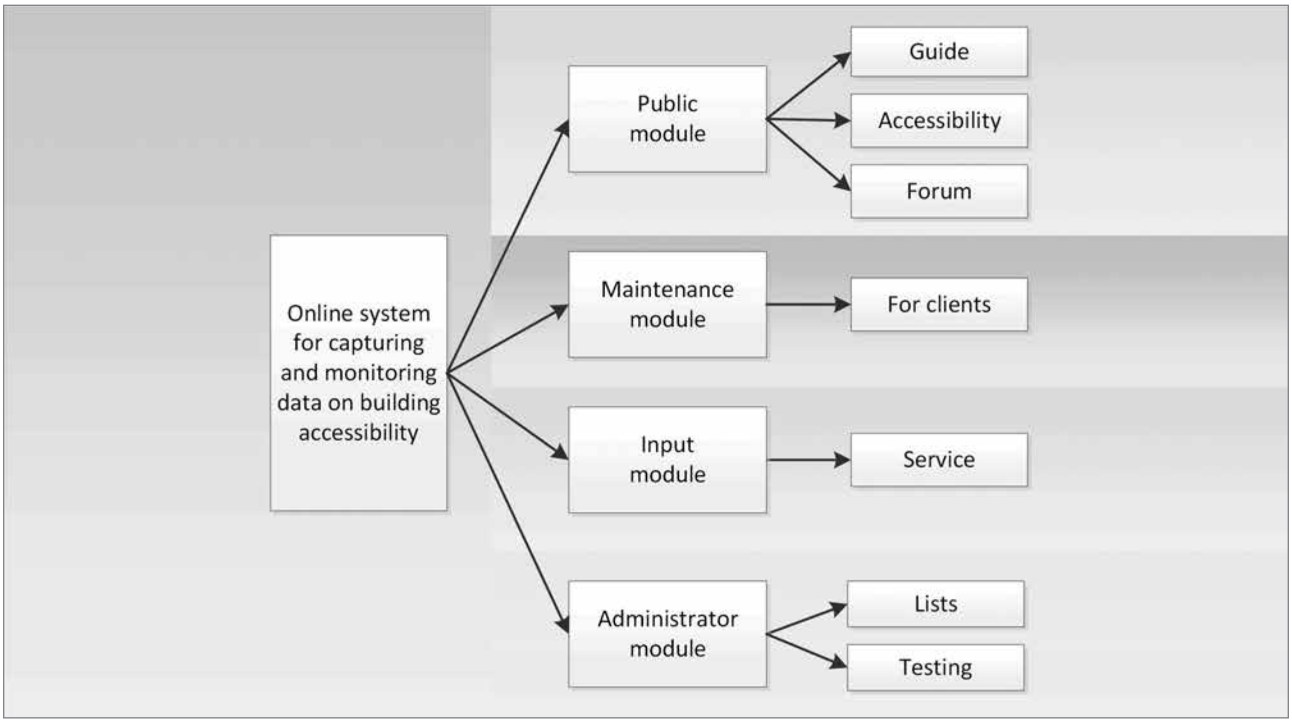

Figure 2: The system's model (illustration: author).

the inventory sheet is not linked to the table of questions also makes it possible for the questions to remain unaltered in the inventory sheet, even though the questions in the table may change due to amended legislation or standards. This retains the chronological traceability of the sources that the questions about the accessibility of elements examined were drawn from. Based on the method described (Figure 1), an online system was produced for capturing and monitoring data on the accessibility of buildings for the functionally impaired.

2.3 Step 3: Producing an online data capturing and monitoring system

Based on implementing the above method in practice, an online system was produced for capturing and monitoring data on the outdoor and indoor accessibility of the buildings studied (Internet 2, 2016). Because this system can also be used by other participants in the evaluation process – such as the clients commissioning the inventory, the maintenance staff, and users interested in whether a building is accessible and how – it includes more functions than merely data capturing.

The system is composed of four interconnected modules (Figure 2). The public module is intended for users that want to check the accessibility of the buildings evaluated. The maintenance module is aimed at the maintenance staff and owners of the buildings examined, for which data have been entered into the database. The input module is intended for on-site building evaluators, who can enter data on the building examined directly in the database via the internet connection on their smartphones or tablets; it has been developed based on the method for inventorying building accessibility for the functionally impaired using online tools. The administrator module is to be used by system administrators to test the system's operation and add new functionalities.

Only the input module, which was developed based on the method for inventorying building accessibility for the functionally impaired, is presented below. The starting point for developing the input module and subsequently the entire system is the client–server architecture (Figure 3). The core of a functioning system is DNN CMS (Sellers & Walker, 2009; Washington & Lackey, 2010), which operates in the Microsoft Internet Information Server (MS IIS) environment. CMS is an open-source modular system that makes it possible to add programmable modules and thus new functionalities. The modules are based on Microsoft.NET technology, and they all use the MS SQL relational database (Donahoo & Speegle, 2005; Mistry & Misner, 2014). A relational database makes it possible to store any type of data, which are then combined into interrelated tables. Due to database optimization, some repeating data are stored in lists. CMS also includes a module for creating one's own social network.

In developing the system, the XMOD Pro programmable module was used to create the forms for entering data in the database and the templates for displaying building accessibility data from the database (Ryan, 2020). In addition, the API

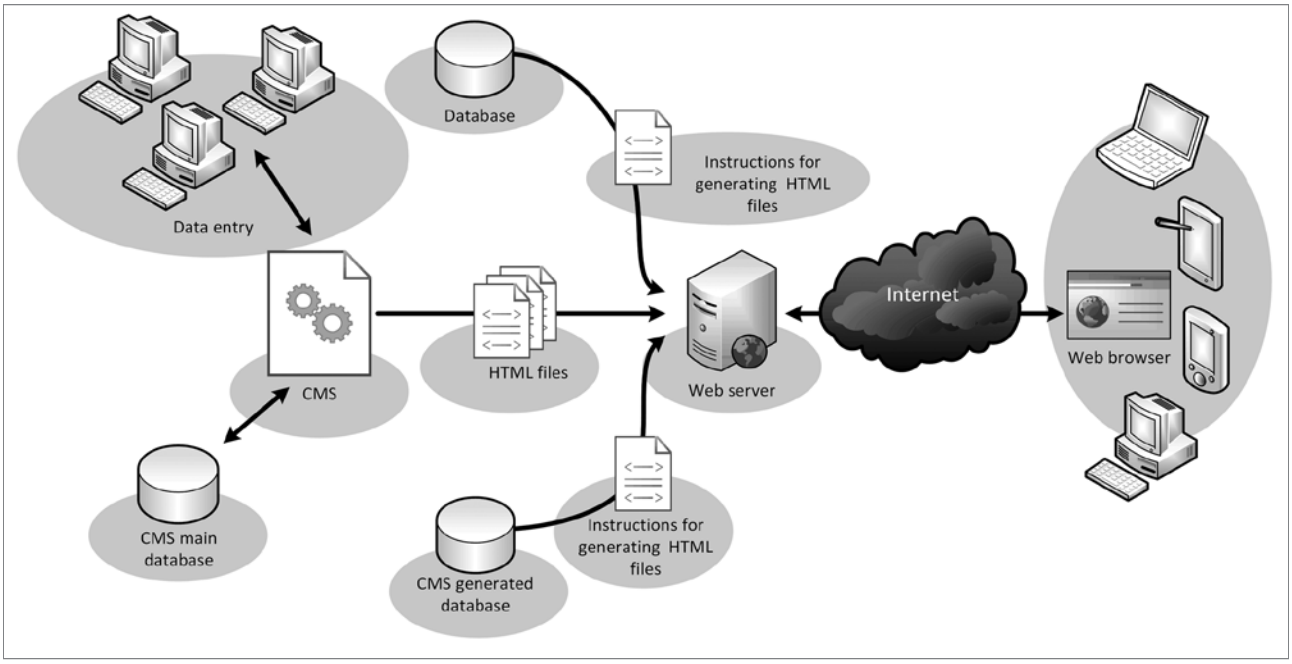

Figure 3: The CMS architecture (illustration: author).

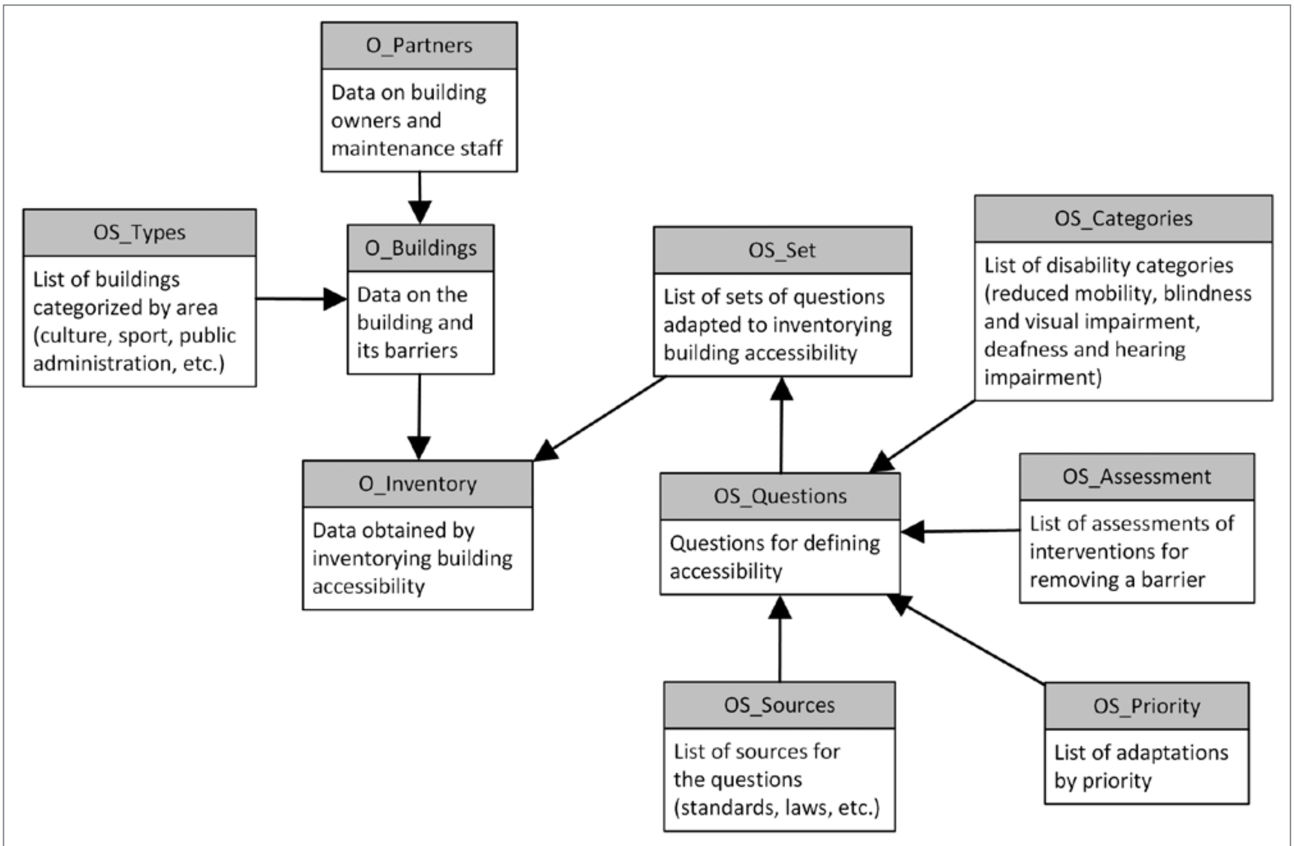

Figure 4: Organization of tables in the database (illustration: author).

REST module was used for the programmatic exchange of data between web portals or services (Vojnović, 2019; Hussein, 2021; Liu et al., 2022; Martin-Lopez et al., 2022), and Razor syntax was employed for programming additional system functionalities (Brind & Spaanjaars, 2011; Chadwick, 2011; Microsoft, 2011). Also used were modules for creating an online forum and an HTML module for creating descriptive webpages on the portal.

The data captured during the inventory and other data relevant for the system's operation are stored in the MS SQL relational database. The system uses two databases. The first one contains

Vstavi nov objekt:

Ime objekta:
Naslov:
Kraj:
Šifra katastrske občine: 1000-LEVEC (ŽALEC)
Identifikacijska številka stavbe:
Identifikacijska številka dela stavbe (lahko jih je več, predeljenih z vejico):
Tip objekta/področje: Javni prostor
Naročnik: Urbanistični inštitut RS
Slika (ime datoteke):
Opis slike:
Datum:
X koordinata:
Y koordinata:
Ocena:
Prikaz v iskalniku (0-NE, 1-DA):
Prikaz zunanje dostopnosti (0-NE, 1-DA):

Figure 5: Part of a data entry form (source: screenshot of the Slovenian online app).

Seznam vprašanj

Show 25 entries

Search:

ID	KATEGORIJA	Vprašanje	Vir	Pogoj	Ocena	Pomembnost
1	GO	Ali je zagotovljeno dovolj parkirnih mest za za gibalno ovirane osebe? (1 dostopno pm na 10pm / 2 na 50 / 4 na 100 / 6 na 200 / 6 na več kot 200 / +plus 1 na vsakih 100 dodatnih parkirnih mest)	14	Obvezno	Obvezna prilagoditev	Večji poseg v stavbi, brez potrebnih dokumentov, dražja izvedba
2	GO	Če je zagotovljeno le eno parkirno mesto za gibalno ovirane, ali je parkirno mesto tik ob vhodu?	8	Obvezno	Koristna prilagoditev	Večji poseg v stavbi, brez potrebnih dokumentov, dražja izvedba
3	GO	*Če ni parkirišča, ali je urejen prostor za kratkotrajno ustavitev vozila?	8	Obvezno	Obvezna prilagoditev	Večji poseg v stavbi, brez potrebnih dokumentov, dražja izvedba
4	GO	Ali je širina parkirnega mesta za gibalno ovirane najmanj 3900 mm?	14	Obvezno	Potrebna prilagoditev	Manjši poseg, cenejša izvedba
5	GO	Ali je dolžina parkirnega mesta za gibalno ovirane najmanj 5400 mm?	14	Koristno	Potrebna prilagoditev	Manjši poseg, cenejša izvedba
6	GO	Ali je prostor za izstop iz avtomobila, ki si ga delita dva sosednja parkirna mesta širok vsaj 1500 mm?	14	Obvezno	Koristna prilagoditev	Manjši poseg, cenejša izvedba
7	GO	Ali je parkirno mesto za gibalno ovirane blizu vhoda (oddaljeno do 50 m od vhoda)?	8	Obvezno	Koristna prilagoditev	Manjši poseg, cenejša izvedba
27	SL	Ali ima dostopna pot ustrezne talne oznake za orientacijo slepih in slabovidnih?	8	Obvezno	Potrebna prilagoditev	Manjši poseg, cenejša izvedba
28	SL	Ali je vidljivost dostopne poti izboljšana skozi uporabo kontrastnih površin in barv materialov?	9	Obvezno	Potrebna prilagoditev	Manjši poseg, cenejša izvedba
31	SL	*Če so na poti ali v stavbi (nevarni) predmeti, ki so nižji od 1000 mm, ali so dobro vidni in vizualno kontrastni z okolico?	17	Obvezno	Potrebna prilagoditev	Manjši poseg, cenejša izvedba

Figure 6: Part of the questions shown in the display template (source: screenshot of the Slovenian online app).

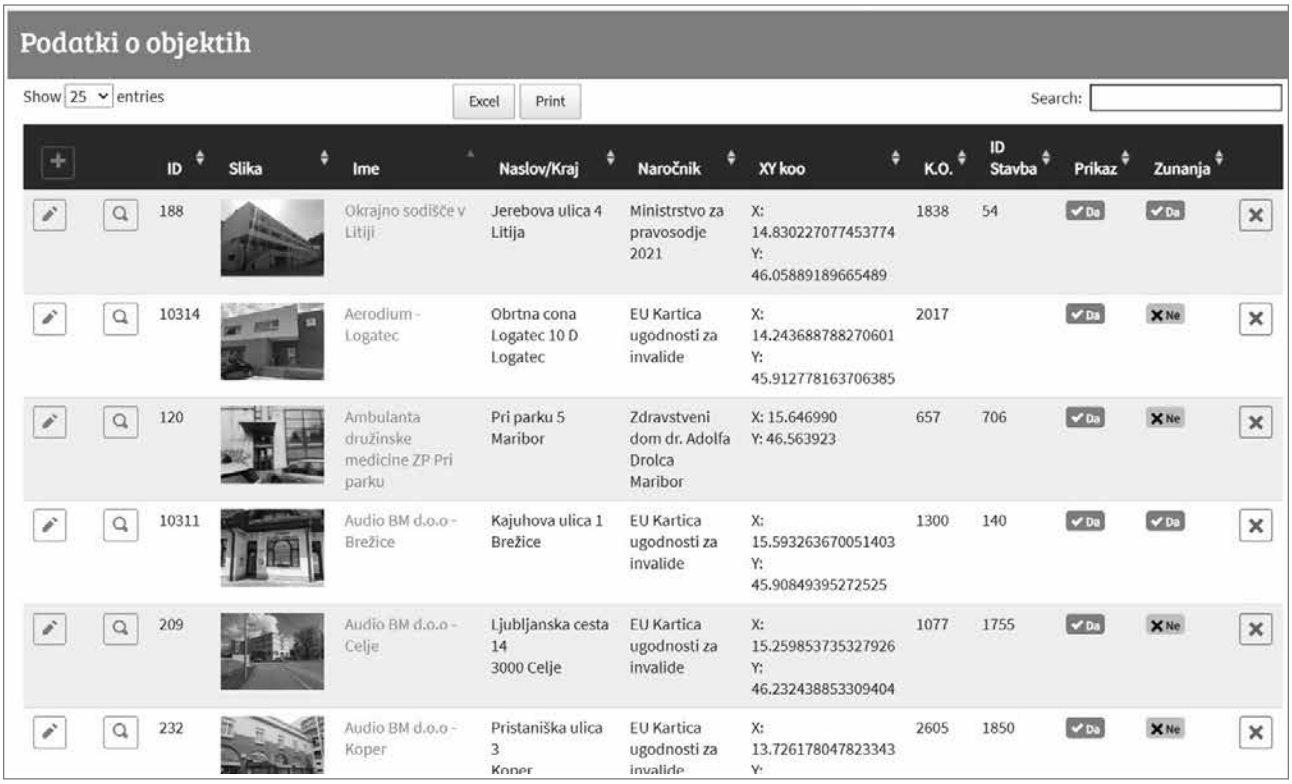

Figure 7: Data on buildings displayed in the display template (source: screenshot of the Slovenian online app).

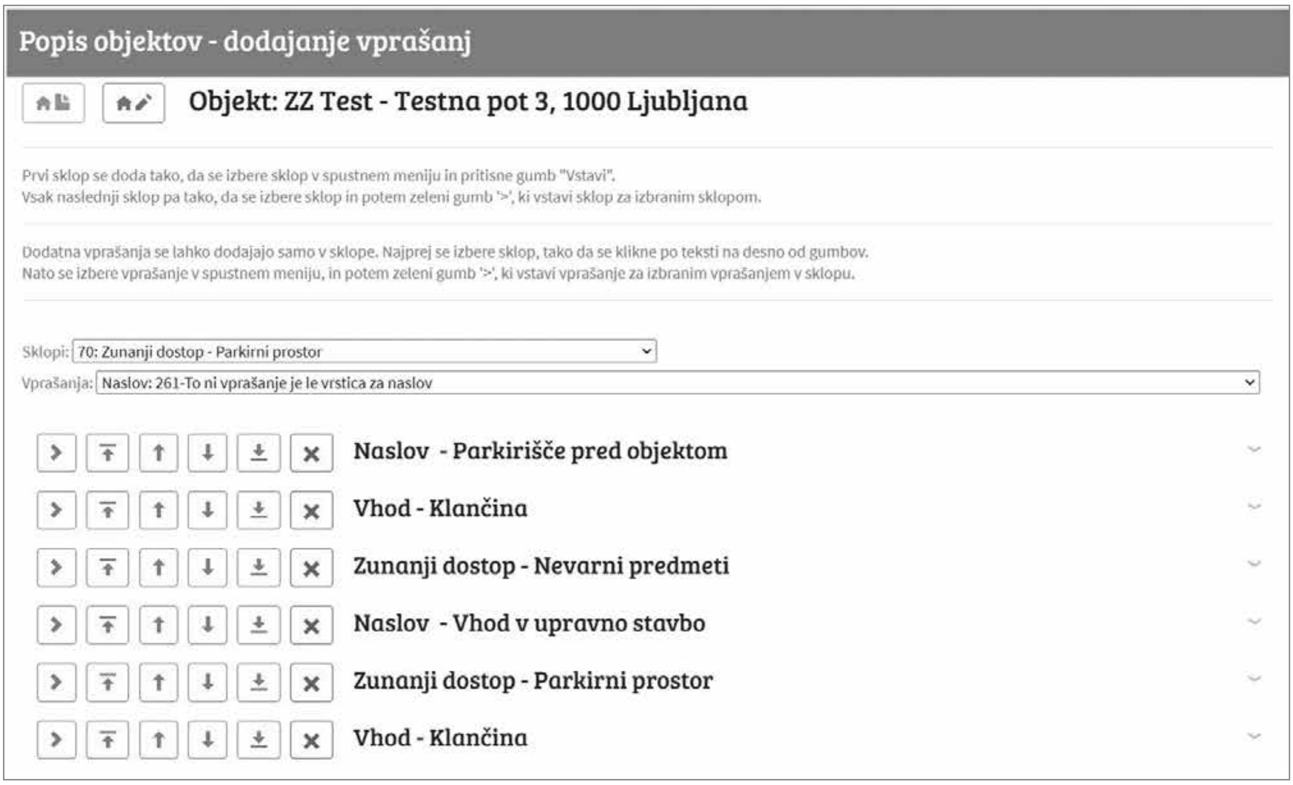

Figure 8: Form for entering and sorting inventory elements (source: screenshot of the Slovenian online app).

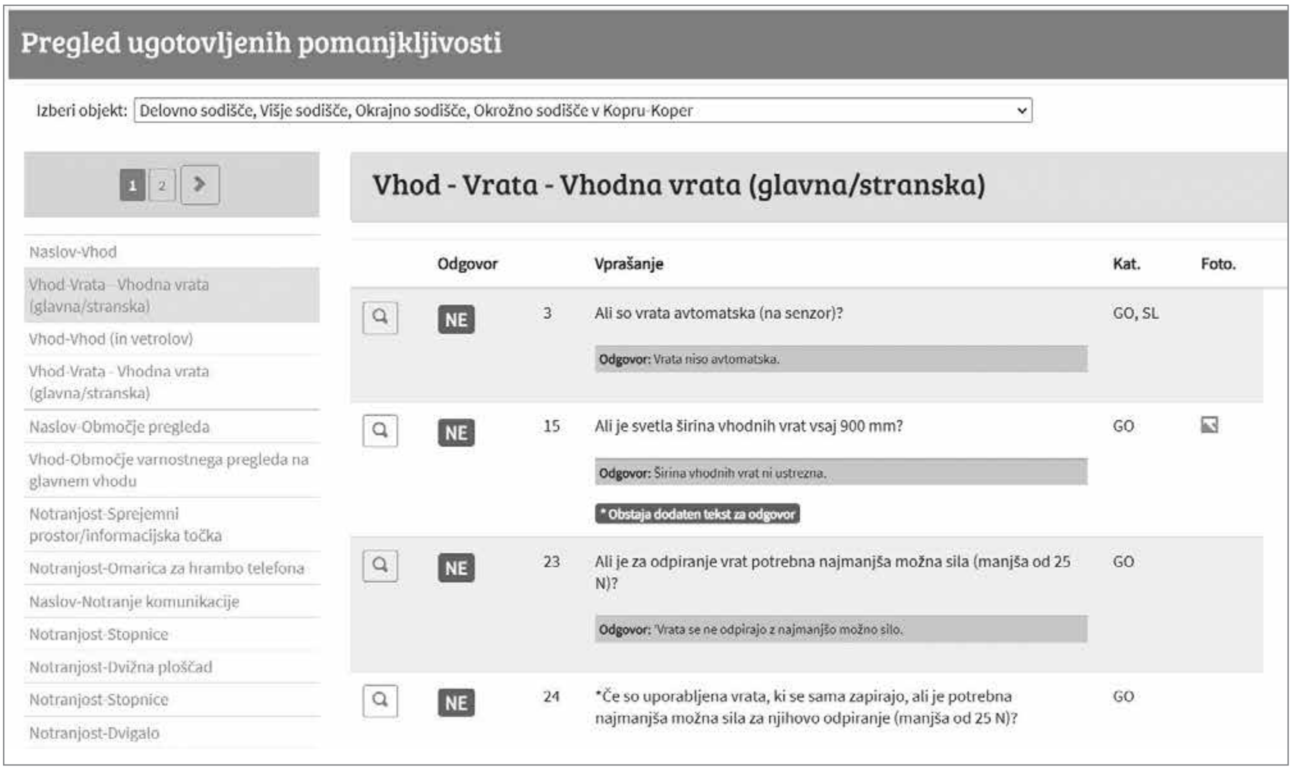

Figure 9: Form for providing quick answers to questions related to a specific evaluation element (source: screenshot of the Slovenian online app).

data that the system uses for its smooth operation, and the second, separate database contains data on the buildings and their barriers. This separate database can be used by external users via the API server, and, at the same time, it protects the main database, which external users cannot access. In the separate database, some data are stored in the form of lists (prefixed with OS_ in Figure 4) that were prepared when the database was created and are rarely changed or updated. Other data (prefixed with O_ in Figure 4) are updated during the building evaluation.

Based on the database, data entry forms and display templates were produced using the XMOD Pro programmable module. Every data entry form makes it possible to enter new data and edit or delete the data already entered (Figure 5). The display templates allow the user to review the data stored in the database tables, sort them, and display them in greater detail if needed (Figure 6). These templates make it possible to enter data on the lists, buildings (Figure 7), and clients ordering the inventories.

Inventorying barriers in front of and inside a building requires a more complex data entry form, which must allow the evaluator to add elements that he or she encounters while inventorying the building. At the same time, the form must be adapted to allow replying to the questions on a tablet or smartphone. Therefore, this form was created using Razor syntax for programming additional functionalities in the C# programming language. Figure 8 shows the form for entering and sorting the inventory elements, and Figure 9 shows the same form with answers provided to the questions related to a specific evaluation element. Answers can be provided in a quick or detailed mode. In the quick mode, the evaluator simply taps *Yes*, *No*, or *N/A* on his or her tablet or smartphone. In the detailed mode (Figure 10), the evaluator can add a photo of the barrier or additional notes that can help in removing the barrier.

After all the required data have been entered in the forms, the building's accessibility is automatically displayed in the public and maintenance module. In the public module, the display is available to everyone that wants to find out whether a building is easily accessible and whether there are any barriers at its entrance or indoors. They can also use the guide to search for buildings in the database. In the maintenance module, the clients ordering the inventory can review the potential barriers, based on which they can monitor and remove them.

2.4 Step 4: Testing the method using the online data capturing and monitoring system

Testing the method using the system produced was carried out as part of various research projects (Sendi et al., 2015, 2019, 2021; Bizjak et al., 2021) and other projects, in which one of the goals was to determine the accessibility of public buildings

Figure 10: Form for providing detailed answers to questions related to a specific evaluation element (source: screenshot of the Slovenian online app).

for all types of disability. Testing took place in four stages:

1. Checking whether the questions on accessibility that have already been entered in the database need to be updated or modified in line with any changes to the relevant legislation and standards;
2. Sets of questions by building type (e.g., sports, cultural, judicial buildings, etc.) and its specific features were prepared in advance;
3. For on-site testing, a tablet connected with the system via mobile data was used; a manual system of entering data on printed forms was also used for comparison. In addition to the institute's evaluators, people with disabilities (persons with reduced mobility, the blind and visually impaired, and the deaf and hard of hearing) took part in the testing. Due to the inventory's complexity, the evaluators offered a quick introductory course for the participants before starting the inventory;
4. After the on-site inventories were completed, the results collected via tablets and manually on site were compared against one another.

Until the publication of this article, a total of 286 buildings were evaluated and entered in the database using the online system described. Over the past year, the portal has been visited by 636 users (89% of whom have been new users), with 16,469 visits to various portal webpages recorded. The average visit duration in 1,191 sessions was approximately thirteen minutes. Seventy-four per cent of users accessed the web portal via Windows, 18% via Android, 5% via IOS, and 3% via other operating systems.

3 Discussion

Barrier-free accessibility is the right of each and every individual. It is provided in the constitution and in EU and other documents. It must be ensured in both the outdoor and indoor built environment. It is a mandatory prerequisite for all new construction, as stipulated by laws and standards. With older buildings, barriers must be removed and necessary adaptations made to ensure accessibility for all. Building owners and maintenance staff implement the laws that require them to adapt their buildings to meet the universal accessibility requirements to varying degrees of success. They often fail to adhere to the standards in which the necessary adaptations are very clearly defined. To date, there has been no methodology available to check whether adaptations adhere to the applicable standards, nor any system based on such methodology that would make it possible to check the adaptations electronically. Based on the method presented in this article, an electronic online system was developed that makes it possible to check whether the adaptations meet the standards. The sector-specific standards may even be overly detailed for certain barriers. Therefore, a building must be inventoried by a qualified evaluator that understands how functionally impaired people move through places and which barriers they may encounter. Using the online system, the evaluator can check in a very short time for any building whether it is accessible for the functionally impaired and whether any barrier adaptations meet the standards prescribed. If the standard does not envisage a better solution, a qualified evaluator can propose one in the online system.

However, the testing revealed certain deficiencies of the method and the system developed on its basis. The method presented is intended for a detailed inventory of barriers that is based on standards. A detailed inventory allows a detailed inspection of barriers and their potential adaptations. It is of the greatest benefit to the owners and maintenance staff of the buildings inspected because, through a detailed inspection like this, they obtain a great deal of useful information that they can use to remove barriers or make necessary adaptations. It is less useful to the functionally impaired, who only wish to check whether a building is easily accessible, because there are far too many data, which make it difficult to find basic information about access and potential barriers. However, the method is also applicable to simpler inventories. The target research project "Dostopnost objektov v javni rabi za potrebe invalidov" (*Accessibility* of Facilities in Public Use for the Needs of the Disabled; Sendi et al., 2021) provided guidelines for adapting the accessibility evaluation methodology to entering a simpler inventory in the system, which is based on the proposed minimum accessibility standards. Introducing a simpler inventory into the system would allow building owners that wish to enter information about the accessibility of their buildings into the system based on the proposed minimum standards to carry out self-assessments. In this case, the methodology will have to be adapted and the system will have to be improved to also allow for the entry of a simpler inventory. Improvements should include the option to register or log in to a building owners' portal, search through the building register to determine the code of an individual building, define the building's geographic coordinates, and select the building's intended use. This last feature will allow the person entering the data to see questions specific to the building's typology and intended use. The option to enter a simple inventory designed in this way can be used by anyone that would like to inventory the accessibility of his or her building and display that information on a web portal.

4 Conclusion

On-site data capturing using smartphones or tablets is working – but it is working more slowly than expected. Because replying to questions is very complex, this takes more time. On-site data entry should make inventorying faster. In addition, the display on smartphones is not optimized because the app was initially intended for tablets, which have larger displays than smartphones. The system's users, especially the buildings' owners and maintenance staff, welcomed the chance to see the barriers and enter information about their potential removal. Nonetheless, there is still room for further improving the online building accessibility monitoring system. Accelerating the on-site inventory of buildings via tablets is one task that can improve the system. In addition, the smartphone user experience should also be improved. Moreover, tools should be added to the portal to facilitate the use of the online system for the blind and visually impaired, and the method should be updated to also allow the entry of a simpler building accessibility inventory. Once the method is updated, the users, building owners, and maintenance staff will be able to perform self-evaluations. This will contribute to greater usefulness and familiarity with the online system. However, first and foremost, functionally impaired persons will be able to obtain information on building accessibility in one place, and the building's owners and maintenance staff will receive information that will help them remove barriers or modify adaptations that do not comply with the applicable standards.

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