# A DATA COLLECTION FRAMEWORK FOR MANAGING ACCESSIBILITY AND INCLUSION IN URBAN HERITAGE

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ABSTRACT:

The successful implementation of inclusive design strategies cannot overlook the development of a preliminary phase aimed at gathering accessibility data of the built environment. This set of information helps achieve two major objectives: planning measures for improving the fruition of a city and communicating to end users the opportunities to exploit places. Specifically, this is fundamental in Cultural Heritage contexts both to survey their specific features and convey their historical values. To this end, such information must be accurate and gathered quickly. This paper aims to provide a set of parameters through which it is possible to comprehensively assess accessibility of Urban Heritage environments. Particularly, such task has been carried out in a more general framework targeted to investigate, how and by which tools, the current design practice achieve the aforementioned objectives. The article proposes a geometric survey through Mobile Laser Scanning system as a data gathering tool. The semantic segmentation of the resulting point cloud is envisioned as a suitable method for the extraction of the accessibility parameters proposed. Basing on first tests applied on a case study, a UNESCO site, the article provides and discusses a final proposal for the best data processing and validation, in addition to the key tools for sharing this information.

## 1. INTRODUCTION

Among the objectives of major sustainable development strategies, inclusion plays a primary role. To this end, the built environment must provide equitable opportunities for well-being and participation in the public realm, addressing people's diverse needs and interests (United Nations Development Programme, 1990). The design response to this topic has been given through the development of regulatory frameworks and methodological approaches (e.g., Universal Design, Design for All), to ensure the full fruition of the spaces and artifacts within them (Keates and Clarkson, 2004, Imrie and Hall, 2001, Steinfeld and Maisel, 2012). This objective, already complex in and of itself, becomes even more complicated in the case of Urban Heritage environment, consisting of historic buildings, pedestrian paths, squares, and monuments. The stratification, the uneven size of urban spaces (streets and sidewalks), and the peculiar urban solutions (not standardized) make this task a great challenge. Especially, the main effort lies in achieving the aim of inclusion while considering conservation needs. Cultural Heritage, in all its scales, embodies a series of knowledge, traditions and historical-cultural values that must be accessible to everyone. However, the fulfilment of the latter requirement must not be the source of the loss of those very same assets we want to preserve for future generations.

Current design practice has not been able to respond to the complexity of issues addressed by the target of inclusion and urban historic context. This discrepancy has originated in the difficulties of managing the numerous requirements that an inclusive environment demands and actualizing the theoretical and legislative recommendations, making it necessary to revise their implementation models. In this renewal process, a connec-

tion has to be established between the new sustainable development strategies and the constraints of the environment, and cartographic tools should play a relevant role as long as to redefine its content and functionality. The first facet to consider is the evolution of the concept of accessibility, no longer simply associated with the overcoming of physical architectural barriers, but which considers the quality of space and the cognitive and sensory dimensions involved (Laurìa, 2003, United Nations, 2006). The second one concerns the purposes and information that these tools must convey. Specifically, it is possible to define two main objectives: the management of data regarding Urban Heritage environment accessibility and the communication of this same information to city users (Marconcini and Pracchi, 2019).

Stemming from these observations, the development of renewed inclusive design strategies cannot neglect the definition of operative tools able to support the architectural project. Not only, these instruments should also foster a complete methodological approach, which not only looks at the physical dimension of the project but also provides all the opportunities to better experience the built environment and historic values of the context. The analysis proposed below is meant to present some reflections on how to complement information and survey techniques to be more effective in tackling inclusion challenges, using precise information about position, dimensions, and characteristics of the urban environment. This support in defining a cognitive framework concerning accessibility performances will therefore foster a quicker and more in-depth analysis towards a design approaches of careful of inclusion needs and Cultural Heritage specificities.

The article, while framing the complex issue of accessibility for people with disabilities and inclusion in Urban Heritage environment and proposing a possible solution, focuses primarily on

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data collection and structuring, defining which are the accessibility parameters that should be addressed in the future project. The core of the paper is the physical accessibility, intended as primary target for the development of inclusive strategies, and here referred simply with the term accessibility. Section 2 describes the state of the art on disability map construction and data collection. The following section 3, describes the project goals with details about the definition of the objectives, i.e. the elements that will have to be reported in the map (section 3.1) and data processing and validation (section 3.2). The last section discusses the results obtained so far, but above all the proposed method. It also identifies the essential features for the communication of the collected data to the final user.

## 2. ACCESSIBILITY: DATA GATHERING AND TOOLS

Accessibility data collection and management in historic Urban Heritage can be exploited in several ways. Typically an expert technician goes directly on site and prepares a list of physical accessibility issues which are then stored in maps, used by administrations to take decisions. Further possibilities for data collection include crowdsourcing, directly involving the end-users of the urban space. Today, Geomatics offers tools that can make the process more accurate and automatic, and less time-consuming. As it appears evident, several approach to urban accessibility passes through GIS (Zimmermann-Janschitz, 2018). As the aim of this paper is to offer a critical reading of the current approaches, it is necessary to evaluate the opportunities that the latest survey techniques are presenting to facilitate and accelerate these processes. Through the analysis of the quality and methods of exploitation of the same information, it will be given a framework from which possible innovations in the deployment of inclusive strategies can be supported. This investigation has been performed from a general point of view, but applied, in practice, to the Italian context and its current planning tools, especially *Piano di Eliminazione delle Barriere Architettoniche* (PEBA - Plan for the Elimination of Architectural Barriers).

### 2.1 PEBA: planning accessibility in Italy

In response to the goal of increasing accessibility to urban spaces and public buildings, today cartography has two main uses: surveying the criticalities within the urban context and, subsequently, planning improving interventions, along with providing this same information to those who can use it to organize their mobility and choose the most suitable services they need.

As previously mentioned, PEBA is the document required by Italian legislation for planning the physical accessibility of a city; it was first introduced with Law 41/1986 as a tool for assessing the accessibility of public buildings and planning measures for improvement. Afterward, it was integrated with Law 104/1992 to consider urban spaces in the process. Although a quick adoption was demanded after its introduction, today this tool is still barely implemented by most Italian municipalities. The reasons behind the current situation are numerous, among them cultural, economic, regulatory, and, in relation to the focus of this paper, methodological issues (Laurìa, 2014). From this standpoint, the criteria through which one can assess the level of accessibility of a city have never been clearly defined. Especially if understood as an urban organism, the latter not only consists of physical features but also of a set of intangible components that determine the possibilities for an individual to experience the built environment. As a result, even

PEBA performances and the design responses it should deliver are hardly determinable, also due to the legislative lack of a proper enforcement regulation. Thus, cartographic tools and their arrangement clearly play a key role in inclusive planning strategies.

Information and communication devices are something we resort to repeatedly in our lives. Particularly, for people with disabilities, these are an essential means by which they can overcome adverse circumstances that limit their day-to-day activities. The use of urban maps is crucial when evaluating the reachability of Points of Interest (POI) and the feasibility of accessing these places and the services offered within them, in accordance with one's needs and capabilities. To this end, the cartography produced as part of PEBA, most of the time, is not easily accessible and understandable by the largest number of city users. As a result, several initiatives have started, mostly pursuing a bottom-up approach, to share this kind of information for a non-technical audience. The chance to reach more and more people, however, has turned into the need to convey a larger amount of data, often of differing nature.

For communication reasons, but also the compilation of policy documents such as PEBA, the focus has been shifted to the search for fast solutions to gathering information and managing them.

### 2.2 Crowdsourcing experiences

The aforementioned strategy has acknowledged crowdsourcing as one of the main processes for acquiring information on urban accessibility. Despite several definitions have been linked to this practice, it can be defined as a participatory activity, mostly performed online, in which a subject (individual or group) proposes, in a mutually beneficial relationship, to share and exploit a set of resources (Estellés-Arolas et al., 2015).

Public institutions, third sector (voluntary) associations, or even small-medium service companies, particularly aware of the needs of people with disabilities, have tried to leverage this approach to promote the exchange of information regarding the accessibility of public places and spaces. This action has already been undertaken from the standpoint of the two purposes that this kind of tool can achieve: providing information to end-users and preparing strategic planning documents.

Regarding the first instance, one of the best-known projects is Wheelmap (wheelmap.org) run by the nonprofit organization Sozialhelden e.V. which strives to make people aware of problems in society and to motivate them to change their way of thinking (https://news.wheelmap.org/en/faq/). The objective is to facilitate the identification of wheelchair-accessible places. It is based on the free participation of citizens who can evaluate the accessibility of public spaces and toilets, insert explanatory photos and add new places. Technically, the map is based on the architecture of OpenStreetMap and provides a signaling system related to the metaphor of traffic lights (green for fully accessible places, yellow for partially accessible, and red for inaccessible). The user can access the map either through the web or through Android or iOS apps. On the project's website, parameters are given to assigning a color to accessible public spaces and toilets. There is no data validation, but the possibility to insert images helps the end user in the evaluation of barriers. As the name suggests, this project is aimed exclusively at wheelchair accessibility.

Another similar example is the project sidewalk (sidewalk-sea.cs.washington.edu/) designed and operated by the Makeability Lab at the University of Washington. According to the website, "users already mapped 826 miles of Seattle, WA-that's 83.9% of the city". The structure is quite similar to the previous one, but in this project, there is not only the phase of insertion of new observations but also data validation (Saha et al., 2019). The insertion phase, through the attribution of a label to the object, is based on the Americans with Disabilities Act (ADA) specifications and exploits the Google Maps API development environment. According to a specific webpage ("Find wheelchair-accessible places") the user can "edit a business's accessibility attributes" and the same page helps the user to understand wheelchair accessibility (entrance, restroom, seating, parking, elevator). The main categories are Curb Ramp, Missing Curb Ramp, Obstacle, and Surface Problem. The validation phase involves the analysis of 10 labels entered by other users. This validation takes place through the evaluation of a photo that depicts the object of interest and classification of difficulty, using the usual traffic light convention. To date, the system can only be used via desktop, as specific apps are not available and touch controls are not implemented. The necessity to specify what are the needs of wheelchair users to be mapped and the validation function respond to the great topic of the correctness of the data entered: not being able to verify them individually, one tries to carefully identify the criteria and entrusts the verification to a third person.

### 2.3 Geomatics and accessibility

In the projects analyzed, the source of geographic data is always cartography. Obviously, both the Wheelmap and Sidewalk projects are based on existing GIS (OpenStreetMAp the first, Google maps the second). The difference, however, is in the management of the geometric-geographic data as a new layer related to accessibility. In the first case, the attributes of the layer are linked to objects that already exist on the cartography, to which labels (colored traffic lights) and eventually images are linked. In the case of the Sidewalk project, on the other hand, the users' directions are reported on the cartography using the spherical panoramas made available through Google Street View (therefore already geo-referenced). As described in (Saha et al., 2019), the labels suggested by the users are generally referred to the panoramas, and then their position is translated from 3D into 2D latitude and longitude coordinates.

A different solution is suggested in this paper, where the elements to be mapped have to be detected in the real world, as they need not only a position but also some geometric attributes. According to the objectives to be mapped (see par. 3.1), it will be necessary to identify specific elements in the digital representation of the city. To do so, a very powerful instrument is the 3D pointcloud implemented in Geomatics applications. Urban environments are typically characterized by a wide extension of the territory and the co-presence of several elements: roads, sidewalks, pedestrian areas, parks, and buildings. Pointclouds are a very suitable tool for the correct identification and characterization of the mentioned accessibility parameters, especially where they are focused on the ground and on the lower portion of the city. Several Geomatics techniques can be implemented to survey an urban environment, the choice should be driven by the purpose of the survey and, in this case, by the need for an adequate point density on the ground. Terrestrial Laser Scanning (TLS), digital satellite imaging technologies, Airborne Laser Scanning (ALS), Unmanned Aerial Systems (UAS) photogrammetry, Mobile Laser Scanning (MLS)

are all suitable approaches. In comparison with the other technologies, MLS systems have the flexible mobility and proven ability to collect highly dense pointcloud data with cost-saving and time-efficiency measurements (Ma et al., 2018). Plus, the continuous collection of MLS pointclouds of high point density allows the acquisition of detailed road features such as curbs and surface road marking (Wang et al., 2019). Another category of instruments suitable for a fast urban data acquisition is represented by Portable Mobile Mapping Systems (PMMS); the authors of (Nocerino et al., 2019) also provide useful tables that describe the suitability of mapping techniques depending on the applications and also a list of most recent portable mobile mapping systems. Portable mobile mapping systems are either suitable for indoor mobile mapping (di Filippo et al., 2018, Lehtola et al., 2017), and outdoor mapping (Tucci et al., 2018, Fassi and Perfetti, 2019). After geometric data collection, the pointclouds -actually a 3D model of reality- do not provide any information other than the spatial position of points. In order to extract information from a pointcloud it is necessary to perform a semantic segmentation MLS pointcloud; semantic segmentation can be achieved following feature-based methods, or deep learning methods (Wang et al., 2020).

In the literature, the pointcloud semantic segmentation approaches related to accessibility issues are focused on the detection and segmentation of urban objects like curbs, ramps, sidewalks, steps in building's façade entrances (Ishikawa et al., 2018, Serna and Marcotegui, 2013, Hou and Ai, 2020, Balado et al., 2017). The purpose of the segmentation is, then, to characterize sidewalks and curbs accessibility, relating to specific national standards of the authors of the various papers. Other authors use the detected object to perform navigable path computations (Balado et al., 2019) or safety assessment (Soilán et al., 2018). In all the presented papers, the detected elements and the criteria used to assess them are referred to some national standards or best practice, what probably is missing is a direct confrontation (an open discussion) with interested users or experts in the field. Very often, the detected elements belong to standardization which is very common in recent urban environments, but not so suitable if dealing with historic buildings and roads.

## 3. PROJECT

Considering what has been outlined in the previous sections, this project aims to find a method to provide accurate and useful information about the accessibility of Urban Heritage; Figure 1 shows a scheme of the proposed project's workflow.

This section of the paper wants to set some methodological matters that would allow to define the cognitive framework necessary for the proper implementation of ICTs and their more effective use towards fully inclusive design strategies. The entire process could be split into several parts. The first step of the whole operation (stage 1 in Figure 1) is the definition of evaluation parameters for accessibility, here intended as all the elements that have to be mapped in an ideal accessibility map. They represent also the features to be investigated in the following step (data acquisition and processing, stage 2 in Figure 1) through the semantic segmentation of the point cloud. Finally, the processed data from the survey will be compared with the defined accessibility parameters, in order to provide an accessibility evaluation (stage 3 in Figure 1). The core of this paper is the definition and discussion of the aforementioned accessibility parameters.
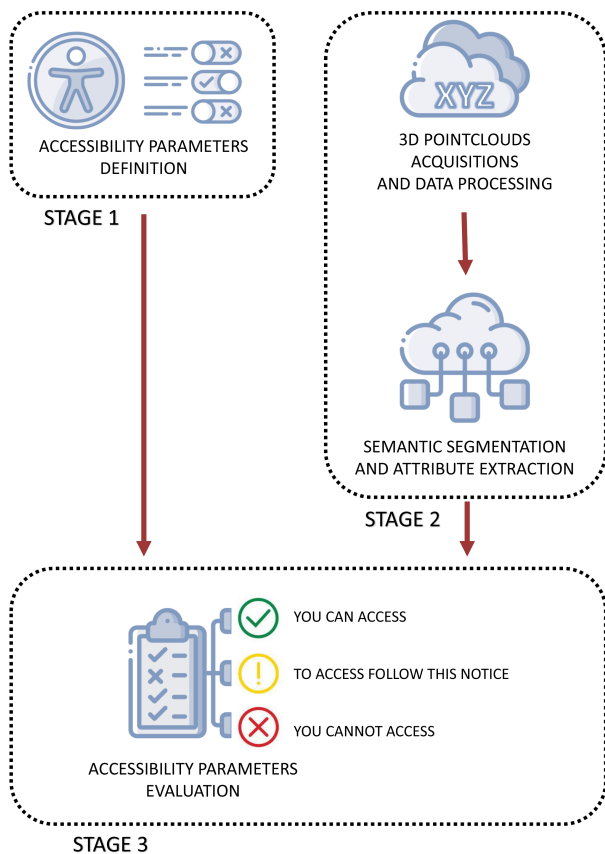
Figure 1. The main workflow of the proposed project, composed by 3 stages: the delineation of accessibility parameters, the 3D data acquisition and segmentation, the evaluation of accessibility through parameters assess. Stage 1 is the main topic of this paper.

A last step, not addressed in this paper, but long debated by the authors as the necessary result, is the implementation of an accessibility map which is really effective for people with disabilities, probably not a simple WebGIS, but something more immediate, implemented with the help of newest technologies, such as mixed reality. The project involves experts from different research fields, as evidence of the interdisciplinarity of the treated topic.

## 3.1 Accessibility evaluation parameters

In the workflow, the stage 1 (see Figure 1) entails setting out the information to be embedded in the map. Specifically, this involves the description of all the parameters that should be entered in a possible field, or series of fields, related to the accessibility of historic city. The accomplishment of such operation is not immediate. It is paramount to overcome a view of disability that is limited to its most visible displays, such as physical and visual impairments, especially from the perspective of a design approach that ensures a better fruition of the built environment in conditions of comfort and safety for as many people as possible. In this regard, it is required a more exhaustive reading of environmental criticalities that are not only expressions of "present" urban and architectural barriers, but also indicators of "absent" qualities (Laurìa, 2012).

In light of this introduction, the Italian legislative framework is the first necessary, but not sufficient, reference to achieve

the inclusive methodology envisaged here. Nationally, D.M. n. 236/1989 and D.P.R. n. 506/1999 set the minimum dimensional parameters and requirements of accessibility that must be respected. Moreover, legislation concerning Cultural Heritage has stated the provision of the best conditions for the public use and enjoyment of heritage, also by people with disabilities, as a condition for the promotion of culture. Although the latter broadly address the concept of architectural barriers, they fail to account for quality indicators, implementation strategies and all those suggestions that the cultural debate on inclusion has introduced over the years. For this reason, referring to the literature on the subject, the parameters that will follow are the results of a cross-reading of legislative prescriptions (Italian regulation: D.M. n. 236/1989 and D.P.R. n. 506/1999; Lombardy Region regulation: L.R. n. 6/1989), people's needs frameworks (literature and applied research), the most up-to-date and careful design practice (case studies analysis and empirical investigation), and evaluation criteria and similar tools internationally developed (e.g., the manuals "Building for Everyone: A Universal Design Approach" by the Center for Excellence in Universal Design of the Irish National Disability Authority) to assess the level of urban accessibility in Cultural Heritage environment.

Public space represents one of the most difficult conditions to address, especially for Cultural Heritage sites, both for the complexity of the issues related to the design of outdoor areas and the difficulty of managing the relations between the open space and the equipment, services and public facilities that it connects. In order to establish some key principles leading to the definition of the evaluation criteria of the urban environment, there are three main concepts that must be taken into account: the continuity of the horizontal surface, the safety and comfort for the person in the use of spaces (Argentin et al., 2008). These three qualities must be considered as mutually dependent and influential; indeed, the paths and the spaces within a city must be designed as a comfortable and safe place for anyone who wants to move along them, allowing the transition from one situation to another in the widest possible autonomy and freedom. Furthermore, since the public space is a multifaceted system where social relations and activities are carried out, any project intervention should not only pay particular attention to vulnerable users but also be included in a framework of more general considerations regarding safety and comfort for the pedestrian.

| urban physical accessibility | |
|---|---|
| parameter definition | reference value of minimum requirements |
| level difference | ≤ 2,5 cm [1] |
| minimum path width | ≥ 90 cm [1] |
| | every 10 m, 150 x 150 cm area [1] |
| optimal path width | ≥ 150 cm [3] |
| longitudinal slope | ≤ 5% [2,3] |
| transversal slope | ≤ 1% [1] |

Table 1. Proposed parameters for the assess of urban physical accessibility. Sources are 1: Italian regulation, 2: Lombardy Region regulation, 3: literature and empirical investigation.

The first parameters to be presented are those that assess in detail the dimensional features of urban spaces and paths. In order to maintain the continuity of the horizontal surfaces, there shouldn't be any interruption of the paths due to the occurrence of obstacles. This requires that minimum dimensional performances are met, especially to make sure that people using mobility aids have adequate spaces to move around safely and without fatigue. Table 1 outlines these first minimum dimensions for assessing urban accessibility while considering higher quality accomplishment for a fully inclusive experience of the city. A clear example of the latter need is the parameter of the minimum path width, which the standards set at 90 cm, considering the person who uses the wheelchair as the limit condition. However, if we consider a dimension of 150 cm, e.g., it would allow a blind person to be accompanied by a caregiver or someone in a wheelchair and a parent with a stroller coming from different directions to meet along the way without blocking each other's passage. Even for a person with hearing impairments, it is important to have the opportunity to come up beside their companion to read the lips movement or support other forms of communication. In short, given the conditions of limited comfort in the interactions between people and the surroundings, in addition to the lack of safe space for everyone to stay in an area dedicated to pedestrians, a width of the path less than the dimension needed to maneuver can be considered a negative evaluation criteria of accessibility.

Once presented the concept of the quality of the project and the idea of providing the best possible condition for all to access the built environment, the second evaluation criteria to be introduced here are aimed to analyze the qualitative features of a path or, more in general, the open space. Table 2 shows the features of flooring, related to its materials and processing techniques, in order to assess whether it may be a source of fatigue or danger for the person. Additionally, it is important to highlight within the requirements the reference to the choice of durable materials to avoid their deterioration; however, in the long run, maintenance becomes a necessary action to preserve the appropriate state of practicability of a surface. For this reason, in cartography should be noted the poor maintenance conditions of pavements, in order to distinguish those situations where the features of the materials and their processing, only if properly maintained, would ensure accessibility.

| flooring features | |
|---|---|
| parameter definition | reference value of minimum requirements |
| flooring materials and/or processing quality | non-slip properties [1,3] |
| | complanarity of elements [1,3] |
| | junction width ≤ 5 mm [1,3] |
| | junction height ≤ 2 mm [1,3] |
| | durability over time [1,3] |
| maintenance level | junction width ≤ 5 mm [1,3] |
| | junction height ≤ 2 mm [1,3] |
| | lack or damage to materials [1,3] |

Table 2. Proposed parameters for the assess of flooring features. Sources are 1: Italian regulation, 3: literature and empirical investigation.

Although the properties of the horizontal surface described above play a fundamental role in fostering access to the urban environment by people with visual and/or cognitive impairments, these are not sufficient to guarantee the necessary safety and comfort conditions that can meet their needs.

The Italian legislation, besides minor exceptions, does not give recommendations regarding accessibility for people with sensorial and cognitive impairments. However, it requires the project to provide specific performances, principally aimed at supporting orientation and at removing those elements that may represent a source of danger. Particularly, the main issue is related to the types of hints that a visually and/or cognitive impaired person uses to navigate the space. These can be natural guides or integrated information solutions that use multiple sensorial exchange channels to help users knowing the area in which they move (Argentin et al., 2008, Baracco, 2016). On the basis of these considerations, a parameter should be introduced to address those situations where the insufficient presence of natural guides and the absence of integrative solutions prevents people, especially those with sensorial and cognitive impairments, from moving in the built environment autonomously and safely (Table 3).

| wayfinding resources | |
|---|---|
| parameter definition | reference value of minimum requirements |
| presence of signage and wayfinding solutions | presence of natural guides [1,3] |
| | presence of integrated solutions and multi-channel communication system [1,3] |

Table 3. Proposed parameters for the assess of wayfinding resources. Sources are 1: Italian regulation, 3: literature and empirical investigation.

While the evaluation criteria introduced so far make it possible to analyze the current accessibility status of the urban environment and its paths, it is nevertheless considered essential to address a specific situation, i.e. the pedestrian crossing points. The peculiar condition of holding both vehicular and pedestrian flows requires special arrangements to guarantee everyone's safety. Specifically, in Table 4, for these important junctions was considered meaningful to set parameters to assess the physical features of the crosswalks and observe the potential and functional presence of guidance tools.

The parameters introduced so far are able to describe the accessibility conditions of open spaces and, especially, of its horizontal surface. However, in order to provide the overall picture of the urban environment, it is necessary to address the components with which one interacts within it: street furniture and public transport. Starting from the first reference, the main issue is to provide everyone with the opportunity to undertake the selected route, regardless of their residual capabilities, especially physical. The above results in the presence of appropriate seating and rest places along the paths, outdistanced to allow everyone to reach them. While the legislation does not give any specific instructions, in current practice the distance between two resting areas should be within the range of 50 to 200 meters. Particularly, in accordance with revised reference values, the parameter used for the survey detects the absence of rest solutions, placed at a maximum distance of 150 meters

| crosswalks | |
|---|---|
| parameter definition | reference value of minimum requirements |
| physical features of the crosswalk | level difference $\leq$ 2,5 cm [1,3] |
| | longitudinal slope $\leq$ 5% [1,3] |
| | transversal slope $\leq$ 1% [1,3] |
| | flooring materials and/or processing quality [1,3] |
| | maintainance level [1,3] |
| presence of signage and wayfinding solutions | presence of integrated solutions and multi-channel communication system [1,3] |

Table 4. Proposed parameters for the assess of crosswalks. Sources are 1: Italian regulation, 3: literature and empirical investigation.

| urban furniture | |
|---|---|
| parameter definition | reference value of minimum requirements |
| distance of resting areas | $\leq$ 150 m [3,4] |
| physical conformation | various [1,3,4] |
| communication channels | various [1,3,4] |
| position in space | various [1,3,4] |

| public transport stops | |
|---|---|
| parameter definition | reference value of minimum requirements |
| physical conformation | various [1,3,4] |
| communication channels | various [1,3,4] |
| position in space | various [1,3,4] |

Table 5. Proposed parameters for the assess of urban furniture (top) and public transport stops (bottom). The latter define the general evaluation criteria, however multiple requirements must be addressed for the individual object (for this reason the term *various* was used). Sources are 1: Italian regulation, 3: literature and empirical investigation, 4: Irish National Disability Authority.

from each other (Irish National Disability Authority, 2012). Additionally, Table 5 describes three main parameters to evaluate, once combined, how street furniture affects the level of inclusion provided by a place, in relation to the interaction that people have with the objects in the space.

The same approach can be applied to the topic of the public transport, which must be conceived as an integrated system where not only the vehicles are accessible, as required by Italian legislation, but also all the approach paths, bus stops and street furniture inside them, verifying that the different elements interface correctly. Despite the need to ensure the functioning of the entire network, the bus stop, being the interface between the urban environments and the vehicles, is the weakest element

of the system. For this reason, also in this case, were defined three main parameters to assess the impact these places have on people's freedom to move (see Table 5).

Finally, in relation to the issues of the connections, a last factor should be introduced to verify if the presence of properly designed parking spaces reserved for people with disability is guaranteed.

### 3.2 Data retrieval and validation

Once the parameters have been determined, two issues arise: how to collect real data and how to verify them. The experiences presented in section 2.2 highlighted the huge possibilities of crowdsourcing, but have also highlighted the need for verification. In the cases analyzed, verification occurs through the specific definition of a sort of thesaurus and then by validation through photographs. However, there is a lack of a system which guarantees a greater objectivity, and, above all, that allows for quantification, where necessary. Whether crowdsourcing to report existing impediments, or using other systems for initial problem detection, this research suggests to use the pointcloud as the main tool in this second activity, following the scheme of Figure 1 which describes the suggested workflow. Through algorithms of segmentation and classification, in fact, it is possible not only to indicate the precise location of any object, but also to give an analytical description with measurements.

The research foresees to realize the survey of the area to be mapped through the mobile 3D acquisition systems introduced in section 2.3. Today mobile mapping systems, both terrestrial and aerial, allows a good level of precision and accuracy at urban level. And, not to forget, they can work in a national reference system, so that all data can be georeferenced since the beginning in the specific reference system. The result is a pointcloud of the urban space that can be analyzed using algorithms that operate in the field of 3D geometric features, recognition of materials from the intensity values of the pointcloud, artificial intelligence applied to photos.

In a virtuous project, the phases of data retrieval and validation must be closely linked and as automatic as possible, thus excluding the subjective contribution of the operator. For this reason, the workflow foresees the contribution of the volunteer cartographer to understand where to look (and then add a label), but the use of automatic algorithms to verify its presence and quantify it.

At the end of the process, once the objectives have been defined and the elements have been recognized in the pointcloud (identified with position and measurements) a logic function will help the mapmaker (or the public authority) to automatically verify if the actual state of the element (sidewalk, flooring, etc) respects the reference parameters. When the result is positive, it means that there are no impediments to urban accessibility, otherwise, an advice (according to the tool selected for the communication to the final user) will help the disabled person avoid that situation (either through an alternate route or through a specific notification that also contains the reason for non-accessibility).

### 4. CASE STUDY: THE CENTER OF SABBIONETA

The first attempt of this research regards the historic center of Sabbioneta, listed, together with Mantua, as UNESCO site

since 2008. The history of the city, the permanence of the original Renaissance characters, the presence of POI such as the numerous monuments that characterize it, make this small city an interesting case for the initial study. In it we find, in fact, many of the exceptions that characterize the historic heritage and make it complex, precisely because of the stratification and lack of standardization. In addition, its limited size and well-defined borders (from the Renaissance circle of walls) makes it possible to keep under control not only the objectives, but also the paths of visitors and citizens.

The focus of this paper is to define the accessibility parameters (see section 3.1), which then became the element to be segmented and classified in the pointcloud in the next phases of the project. The pointcloud used for the classification step has been acquired through the Leica Pegasus 2 mobile system which integrates, on a single vehicle a laser scanner, a IMU system, a GNSS unit and a photographic acquisition system. The precision on the single point and the georeferencing quality of the numerous tracks acquired during the survey, allow its use on a urban scale. First segmentation results are described in (Treccani et al., 2021), where the data processing have regarded the identification of sidewalks, further steps of the research will focus on the evaluation of specific parameters between those described in this paper and identified in the topic of urban accessibility. From the pointcloud, attributes like position and dimension of sidewalk will be automatically detected and transferred by a shape file into a GIS environment. In addition, the elevation and paving material of the sidewalks will also be quantified.

The authors are working, now, to find a way to extract a raw state of conservation of the sidewalk paving in order to find the possible presence of holes. The collected data can then be used to assess accessibility; as an example, using a logic function, if the width of the sidewalk is less than 90 cm, the system will notify that the POI is not accessible, or it suggests to follow some notices. If the assessment comes to a positive results, the accessibility is guaranteed.

## 5. DISCUSSION AND CONCLUSIONS

In the previous sections the importance of accessibility has been highlighted, considering both the requirements of the disabled and the necessity by the public administrations to produce tailored maps and plans. The workflow suggested by the authors consists of a first, fundamental, operation: the definition of accessibility parameters, as those elements that are necessary to allow the accessibility to people with different needs. This definition takes into account the national regulation but also includes a number of observations that arise from in-depth study and, above all, the need for large inclusion. The definition of those parameters is the core of this paper.

The next step, here only introduced, aims to objectify those parameters through measurements and observations that arise directly from the pointclouds. This procedure allows to avoid errors in evaluations and, above all, to provide each element with objective numerical parameters. The research activity continues in different directions, thus reflecting the multidisciplinary aspect that characterizes it. On the one hand, it is to define the best algorithms for the segmentation and classification of the elements of the pointcloud. In particular, it is advisable to analyze the possibilities offered by artificial intelligence, even with the difficulties of working in many different environments, consisting of modern urban contexts, standardized and



Figure 2. A street in Sabbioneta, site for the development of this research empirical investigation. The picture shows some features of the historical city that doesn't meet the minimum standard of accessibility, e.g. undersized pedestrian sidewalks and quality of the road material that prevent a safe crossing of the same.
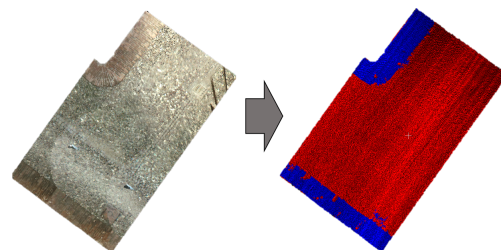


Figure 3. The next step of the project will deal with point cloud segmentation. Here is a first example of portion of road, on left, and its classification in street (red) and sidewalks (blue), on right.

with well-defined rules and instead historic centers with very different rules and often not attributable to unique parameters.

Starting from data, collected and validated, it will also be necessary to find a method to organize the information according to the different end-users and their needs. In this area, even more vast, it will be necessary to define the different ways of accessing data that cannot be only WebGIS with georeferenced indications or a 3D city model, but that must necessarily contemplate the possibilities offered by virtual and augmented reality systems such as wearable devices and headsets.

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