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Innovative Accesibility Data Inventory Tools for Urban Environments in Historic Sites

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Abstract. The development of the cognitive framework regarding the current performances of the historic built environment in physical accessibility plays a key role in the definition of inclusive design strategies. To this end, this paper presents the comparison between two survey methodologies: one based on an on-site investigation, and one based on a semi-automatic process, using artificial intelligence. The presentation of the two methods aims at describing the processes, underlining their potential outcomes, and the procedures for presenting and interpreting the data. The result is a set of observations to propose a strategy that integrates both the approaches, to exploit ICT in managing inclusive design processes.

Keywords. Physical accessibility, Survey, Laser scanning, Methodological approach, ICT

1. Introduction

Developing inclusive planning and design strategies requires to cope with the multiple needs of the city's users, regardless of one's physical, sensory, and cognitive capabilities. Actors involved in decision-making and design processes must provide a range of performances for the built environment, addressing the complex system of different design scales, the tangible and intangible components of the project and much more.

A discrepancy between legislative, cultural, and methodological advancements and the design practice has arisen from the difficulties in properly understanding the topic of inclusion and managing the variety of actions that could lead to this outcome [1, 2]. Stemming from this premise, an integration of current tools to support inclusive processes is deemed essential. Particularly, the early stages of survey and knowledge acquisition require an accurate reading of the environmental accessibility, as well as operational optimization that ensures the effectiveness of the following design phases.

In the field of architectural design and urban planning there is a general agreement that ICT may play an increasing role in the promotion of inclusion, both as an operational tool and as a system for information sharing [3]. The first application is the focus of this contribution, in continuity with previous works from the authors [4] and showing the

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progress of a research project whose purpose was the definition and assessment of urban features useful for the analysis of the built environment physical accessibility [5].

The initial parameters were previously selected through the systemization of legislative prescriptions, literature review, applied research analysis and the study of some experiences of design practice. This paper aims to show and compare two different accessibility data inventories: one based on Direct Experience (from now DE) and a second that applies Artificial Intelligence tools (from now AI). The work presented in [4], continued, and after the detection of sidewalk surfaces on the digital 3D survey, their geometric attributes were computed and a sidewalk network was generated and stored in a shapefile [6], in order to be easily visualized, implemented and exploited by the interested users, at all levels, from the public entities to the planners and the citizens.

The case study for the empirical investigation (conducted during 2021) has been the city of Sabbioneta (Mantua), an UNESCO World Heritage Site. The choice of working in an historic city allowed to address the complexity of the peculiarities that characterize cultural heritage, testing several performances of the two methods, e.g. reliability, accuracy, control capacity and data collection speed.

2. Empirical Investigation: comparing two methods

The two different surveys started from the definition of some methodological choices, based on two principal aims: (1) provide a reading of the level of inclusion within the urban environment and (2) evaluate how the historical features of a city impact on it.

The setting of the survey parameters (Figure 1) in the previous research phases focused on measurable data, also able to give a more complete perspective on inclusion by overcoming the limited concept of architectural barriers and considering absent qualities.

2.1. Direct experience: methodology and results illustration

The first performed analysis was of quality kind, based on the direct fruition and observation of the city streets.

The outcome of the survey was a set of photographs, video recordings and annotations of different nature, which required a visual representation to account for the various data. The arrangement of the graphic proposal for the report on the investigation took into consideration three main objectives: (1) to render the spatial extension of the conditions observed in the urban environment; (2) to convey the complexity of the components that contribute to the definition of inclusion and how exclusion features can arise from the interaction between the latter; (3) to understand whether certain situations of inaccessibility correspond to peculiar characters of the historical city.

Based on these premises, the graphic solution represents a linear abstraction of the same path and the public spaces it crosses. Subsequently, the assessment of public space was made with an illustration of each parameter through symbols (Figure 2), used singularly or reproduced in a line or surface. In addition to the use of a single colour, this choice was intended to give a direct depiction, through the amount of colour, of the consistency of the many constraints that are still present in a historic site as Sabbioneta.

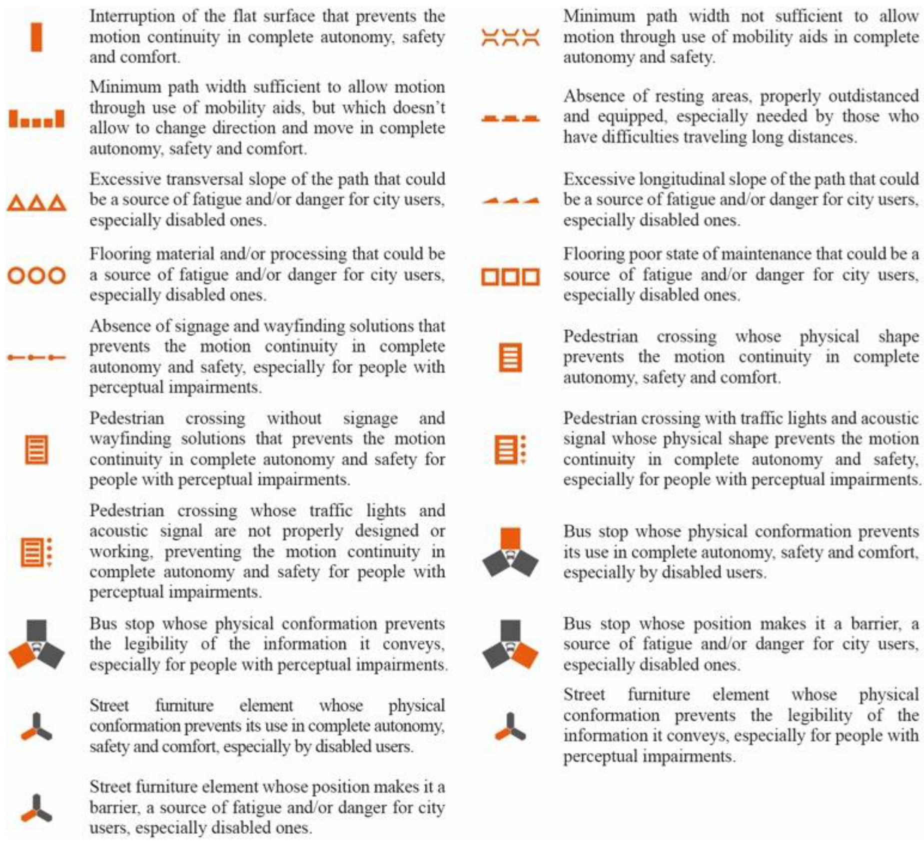

Figure 1. Graphic representation and description of the parameters used for the evaluation of the level of accessibility in the built environment © S. Marconcini

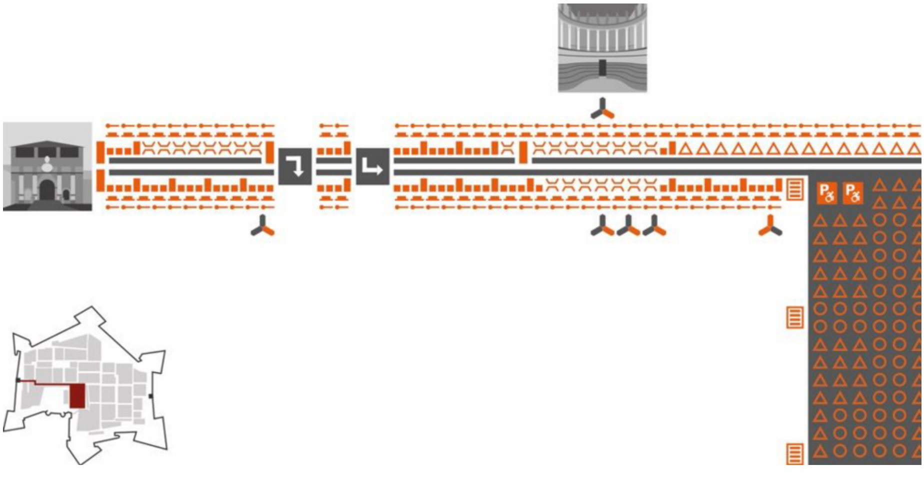

Figure 2. A section of the graphic outcome of the on-site survey in Via Vespasiano Gonzaga in Sabbioneta (in red in the general plan on the left) © S. Marconcini

2.2. Semi-automatic method: workflow and results

The aim of the AI method was the inventory of sidewalk attributes, through a semi-automatic method, implementing Artificial Intelligence. First of all, a 3D digital survey of Sabbioneta was conducted using a Mobile Mapping System: Leica Pegasus:Two. The resulting point cloud had a great density of points on ground surfaces (more than 1000 points per square meter) so that it was suitable for subsequent data processing techniques.

Then, through a knowledge-based and a Machine Learning approach, it was possible to semantically segment the point cloud and identify the points that pertain only on sidewalk surfaces [5]. Then the sidewalks areas were analysed, computing portions of sidewalks (of 2 meters wide along the road trajectory) one at a time. Basing on points attribute it was possible to compute several geometric attributes pertaining to the sidewalk portion analysed. The attributes included the width, the height respect the road, the transverse and longitudinal slopes, the material of the paved surface.

The computation was conducted for the whole dataset, and the results were stored in a vector layer (i.e. a shapefile) containing the sidewalk network of the city [4]. Each portion of sidewalk analysed was converted into a point in the vector file, then edges were generated to connect the nodes and to create a proper network. Together with the spatial position, also the attributes were linked to the corresponding edge in the network. From the vector network was then possible to generate thematic maps and to compute accessible routes within the city.

The semi-automatic approach was able to generate a shapefile with specific data automatically computed from a geometric survey of the city. The generated shapefile was then a proper basis for further analysis. An important step in this method was the definition of which attributes to compute and how to retrieve and convey those data to the final users.

2.3. Comparison of the two approaches

On the basis of the results obtained from the two methods (empirical evaluations and a set of measurements), it was possible to compare them in terms of the reliability of the measured data and the usefulness of its interpretation.

Referring to the first case, among the computed parameters, it was decided to focus on the sidewalk width. While for the direct experience, the width was measured by hand with a tape measure on specific zone of the city, for the semi-automatic method the analysis was carried out focusing on several portions of sidewalk and the width was retrieved as the difference between the farther away point and the closer one to the road centreline. To take care of possible errors, computed values were then rounded to the closer 0.05 m.

A simple analysis of the two methods was based on the comparison of the sidewalk width in several zones of Sabbioneta. Figure 3 shows the 10 points where the comparisons were done, while Table 1 provides the values of the measures and the differences.

Figure 3. Spatial position of the 10 check points on the city, selected for the comparison between sidewalk widths, measured on-site (DE method) and resulting from the automatic computation (AI method). The background is the city map with the sidewalk network thematized according to widths @ D. Treccani

Table 1. Comparison of sidewalk widths, computed by the AI method and measured on-site within the DE method. The position of the check points on the city are reported in Figure 3 @ Daniele Treccani

Check Point	Computed width (m) AI method	Measured width (m) DE method	Difference (m)
1	1.55	1.53	+0.02
2	1.30	1.37	-0.07
3	1.20	1.16	+0.04
4	1.25	1.20	+0.05
5	1.00	0.99	+0.01
6	1.38	1.31	+0.07
7	0.85	0.83	+0.02
8	1.25	1.25	0.00
9	0.70	0.73	-0.03
10	0.75	0.68	+0.07

The average difference is 0.04 m, with a maximum peak of 0.07 m. basing on the width attribute it was interesting to note that both the semi-automatic and the direct experience method were capable of underlying several problematic areas of the city.

An example is provided by Figure 4, where a sudden reduction in sidewalk width was detected by the computations (the red and green lines were generated relying on the shapefile produced by the automatic method). The same sudden change in width was also observed by the on-site survey developed within the DE method.

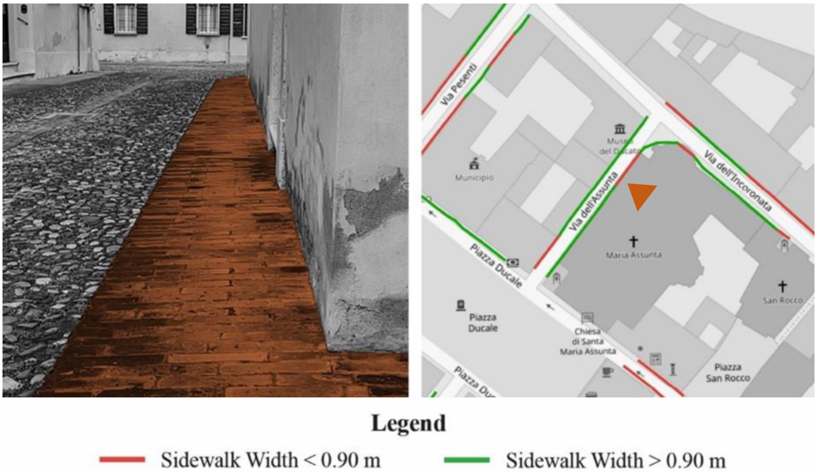

Figure 4. A photo (left) of a sidewalk of Sabbioneta with a sudden change in width. The change was also detected by the automatic method and graphically displayed by the map (right) with sidewalk network coloured according to sidewalk widths, defined accessible or not accessible according to Italian law. The orange arrow on the map marks the position where the situation occurs @ S. Marconcini, D. Treccani

A second interesting fact to observe was related to the attribute " transverse slope ". In this case, analysing the map, it was noted that in some specific positions there was a sudden change in the computed value of this parameter. To better understand these situations, comparing them with the data collected on-site, it was noted that in these positions there were entrances to public buildings and therefore the sidewalks have ramps that allow access from the street. An example is given in Figure 5, where the portion of the pavement with the ramp in front of a bank entrance was shown.

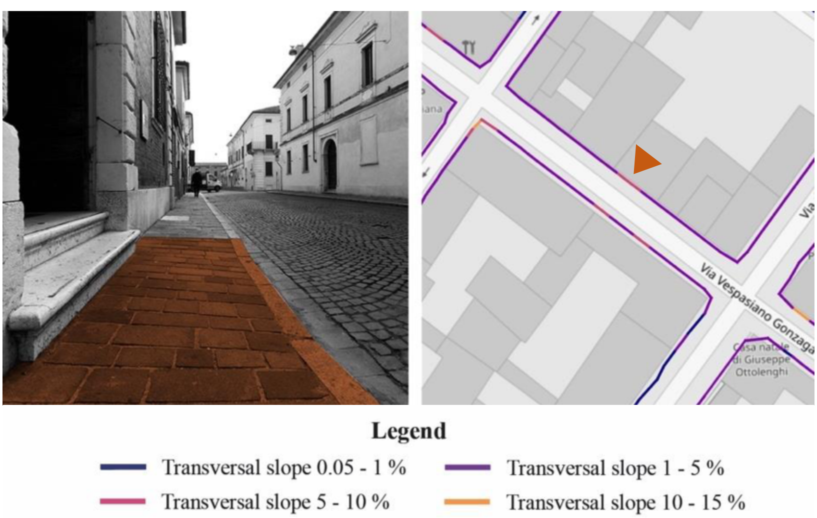

Figure 5. A photo (left) of a sidewalk of Sabbioneta with a change in transversal slope. The change was also detected by the automatic method and graphically displayed by the map (right) with sidewalk network coloured according to sidewalk transversal slope, defined in percentage (>1% is considered inaccessible by Italian law). The orange arrow on the map marks the position where the situation occurs @ S. Marconcini, D. Treccani

3. Discussion and conclusions

In this paper two approaches to study the physical accessibility of historic urban environments were presented and compared, the Direct Experience one, made on-site, and the Artificial Intelligence one. In both cases, the results of the measurements, the criticalities examined, and the analyses carried out were conveyed in different ways to represent the results obtained, one more graphic, using symbols and colour as interpretive tools, and one linked to a spatial representation of measurement data on the city map.

From the analysis and comparison of the two methods, it is easy to observe how both are reliable in collecting information, while presenting some peculiarities through which they can complement each other.

Stemming from the previous examples on the analysis of the paths width and their transversal slope, the AI method makes it possible to collect geometric data that are objective and reliable, with a high density of information (in this case, the data relate to sections of sidewalk every 2 meters). It is precisely the objectivity and rigorousness typical of a method that uses Artificial Intelligence that represent its positive aspect: the data collected are objective and all consistent with each other, since they are measured according to the same rule applied systematically to each section analysed.

It can be deduced, therefore, that if the AI method allows to obtain reliable data, for design purposes the measurements carried out need to be understood. This interpretation of the data collected, closely linked to what is occurring in situ, is a characteristic and fundamental facet of the presented DE method. Particularly, the latter makes possible to determine the reasons underlying the geometric variations in space that lead to a state of inaccessibility, in addition to the opportunity to display the absent qualities of the built environment. Finally, for the specific purpose of interpreting data, the graphic outcome provides already processed information which can be compared to further data, like cultural heritage features, and can be used quickly, without additional effort by decision makers, in planning inclusive design strategies.

From these results, the will for further developments is the elaboration of a methodology that integrates both the approaches, exploiting the fast data processing capability of ICT and the interpretive skills of experts in the field. As discussed at length, the two are deemed to be complementary and not successive stages in a process, as shown by the following first methodological proposal: 1) Development of a direct experience, on-site, to read the main features of the environment; 2) Interpretation of the data of the first investigation and definition of the parameters to be used by the AI for the survey; 3) Data gathering with the semi-automatic method and reports processing; 4) Final interpretation and systematisation of information for the implementation of inclusive design strategies. Finally, it is possible to conceive a subsequent use of ICT to track the constant changes, both positive and negative, in the built environment, amid this constant interaction between technology and expertise.

The experience gained in the work presented in this article has shown how interdisciplinary approaches, including the use of ICT, are fundamental for the achievement of quality results in the field of physical accessibility (in this case the historic urban context). This opens the way for future projects where teams of researchers and professionals with different experiences could work together to reach tangible and effective results.

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