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Analysis of the Accessibility Improvement Index in Urban Areas through Heritage Buildings Used as Museums—Case Studies in the Region of Murcia (Spain)

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Abstract: Equality of opportunity for all people, regardless of their abilities, is a fundamental principle in contemporary society. This includes the ability to use any object, service, or environment. The analysis of universal accessibility in the built environment is a requirement to achieve the full inclusion of society as a whole, both in the urban and architectural spheres. This study is based on the analysis of the current and potential states of accessibility, which makes it possible to obtain the accessibility improvement index, a parameter that identifies how much the accessibility of a physical environment can be improved by removing architectural barriers. The methodology is applied to a sample of 25 heritage buildings used as museums to observe how they function. The results show that the feasibility of barrier removal is higher than 75% in all the buildings in the sample, reaching 100% in some cases. The results obtained are contrasted with other works and highlight the potential of expanding the analysis developed to other urban and built environments to ensure full equality of access to the physical environment.

Keywords: accessibility; person with disabilities; physical disability; cultural heritage; universal design; building information modelling; sustainable construction; urban environment; museum

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1. Introduction

Currently, there is a strong interest in inclusivity. This interest is linked to the Sustainable Development Goals (SDGs) established by the United Nations (UN) for the year 2030. The aim of the SDGs is to fight poverty, protect the planet, and ensure prosperity for the whole society. [1]. Several SDGs are directly related to the idea of guaranteeing equality for all people in society. Without excluding the benefits of others, SDG 10 and SDG 11 are the most directly related to the inclusiveness of any person, regardless of their abilities. SDG 10, "reduction of inequalities," intends, through its target 10.2, to "promote social inclusion [. . .] of all people, regardless of their age, sex, disability, race, ethnicity, origin, religion, or economic or other condition" [2]. Focusing this goal on the built environment, SDG 11, "sustainable cities and communities," addresses accessibility and inclusivity in the built environment, from urban and natural public spaces to housing, including public-use buildings, as stated in its targets 11.3 (related to the enhancement of the inclusivity and sustainable urbanisation of human settlements) and 11.7 (focused on providing universal access to safe, inclusive, and accessible public spaces). The goal is, therefore, to ensure the equality and full inclusion of all members of society. SDG 11 also directly refers to the need to protect and preserve cultural heritage, as reflected in target 11.4 [3].

Within inclusivity, accessibility in the built environment affects a considerable part of society. The number of people considered "persons with disabilities" (PwD) depends directly on the concept of disability. This concept has evolved throughout history, gradually expanding in connection with the evolution of the model of disability [4–7]. The latest data published by the World Health Organisation [8] estimate that the global population with disabilities ranges from 10% to 15%, totalling 1 billion people. Additionally, between 2.2% and 3.8% would be in a situation of severe limitation, which would account for between 110 and 190 million people worldwide.

Currently, the accepted model is the biopsychosocial model of the International Classification of Functioning, Disability, and Health by the World Health Organization [8]. This model considers "disability" as a combination of personal and contextual factors, including impairments, activity limitations, and participation restrictions. Therefore, there is a part of disability that depends on the context, which includes the built environment.

Legally, the UN Convention on the Rights of Persons with Disabilities ensures "the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities" [9]. At this time, 186 countries have ratified this document [10], demonstrating their commitment to equality for people with disabilities. The countries with the strongest progress in accessibility policies and disability rights are located in Europe, North America, and East Asia [11,12].

The "European Accessibility Act: Improving Accessibility of Goods and Services in the Internal Market" is a legislative initiative introduced by the European Parliament in 2019. Its intention is to draw public attention to potential strategies and facilitate accessibility for people with disabilities. The document was designed to assess the possible socio-economic implications of prospective new EU policies to increase the accessibility of products and services for people with disabilities, with a focus on the effects on market dynamics under the economic expansion of a territory. By identifying the limits of the people in front of the possible access to the essential goods and services for market participants, including industry and consumers with impairments, especially older people, the challenges and effects of providing accessible goods and services that assist the realisation of such a full and productive participation in society were analysed [13].

The concept of accessibility cannot be limited to specific elements or aspects; rather, it should encompass the entirety of the experience. As defined by the UNE 170001-1 standard, the accessibility chain refers to the "set of elements that, in the process of user interaction with the environment, enables the realisation of the intended activities within it" [14]. Breaking a link in the chain prevents moving on to the next link. Therefore, a building cannot be accessible without considering its surroundings (the previous link). This includes how access occurs, encompassing the urban environment [15–18] or transportation [19,20]. A fundamental link in this chain is building access, serving as a connection between the external and internal environment. An inaccessible entrance renders the entire building inaccessible, regardless of its interior features.

The social and technical significance of the discrimination caused by architectural barriers is evident in the extensive existing scientific literature, which addresses the topic across different physical environments that surround us: the urban environment [17,18,21–27], residential architecture [18,28–32], public buildings [33–36], transportation [19,20,37,38], and natural spaces [18,39].

Cultural heritage consists of any human creation with exceptional historical, artistic, scientific, aesthetic, ethnological, or anthropological value [40]. As it is universal, and therefore belongs to all of humanity [40–42], it must be accessible to everyone. Museums serve this purpose by exhibiting cultural heritage in a way that allows public access while ensuring its preservation. Museums are also centres for study and dissemination. Notably, heritage encompasses both tangible and intangible aspects, both of which require conservation and dissemination.

Numerous properties are also part of cultural heritage, which likewise needs to be preserved, considered, and disseminated. These often become museum buildings (prepared for contemplation), although at times they retain their original purpose, often concurrently serving as cultural attractions. Frequently, heritage buildings are adapted for use as museums, showcasing additional pieces and becoming monuments themselves. In these cases, the conditions necessary for collection contemplation and exhibition are augmented by the building's museumization and the requirements for its maintenance and preservation. Thus, the building becomes both container and content simultaneously. This can also occur in the context of contemporary buildings [43].

The current definition of a museum was established by the International Council of Museums (ICOM) in 2022. It describes a museum as a "non-profit, permanent institution at the service of society that acquires, conserves, researches, interprets, and exhibits tangible and intangible heritage. It is open to the public, accessible, and inclusive, and museums promote diversity and sustainability [. . .]" [44]. Contrasting with the previous definition, made in 1974 [45], the current definition includes intangible heritage and places significant emphasis on the concepts of accessibility, inclusion, diversity and sustainability. Museums act as custodians and disseminators of cultural heritage. Therefore, they need to be available to the entire society, regardless of their abilities, as access to and enjoyment of heritage belonging to all is a right of every member of the society.

There is abundant literature on the characteristics a museum should have for the proper conservation and exhibition of its collections [43,46–51]. Aspects such as lighting, placement of pieces, educational value, security, etc. are taken into account. In addition to the collection, it is also necessary to exhibit and preserve the building. Thus, the constraints multiply as all that is necessary for the musealisation of the objects contained must be applied to the continent itself.

The definition of museum encompasses two main aspects: conservation and exhibition [42]. Most studies consider the first aspect [46,48,51], discussing the different conservation approaches and their implications on the materiality of the piece. Other articles cover the second [43,49], although targeting the general public without a holistic approach that includes all PwD.

Museums and heritage buildings receive large numbers of visitors. For example, in 2022, the Prado Museum (Madrid, Spain) received 2,456,724 visitors [52]. The Louvre Museum (Paris, France) had 7.8 million visitors in 2022 [53]. The MET Museum (New York, NY, USA) received 7.35 million visitors in the 2019 fiscal year [54], and the British Museum (London, UK) had 4,105,115 visitors in 2022 [55]. These visitor numbers highlight the need to address the special needs of any user in an accessible environment.

While in environments such as urban areas, residential buildings, or public buildings, the focus on accessible design centres on physical (and to a lesser extent, sensory) disabilities, in museums, the focus is particularly on sensory and cognitive accessibility. Most existing works specifically address visual impairment [56–61]. To a lesser extent, there are also references to other groups of people with disabilities, such as hearing impairment [61,62] or cognitive impairment [63]. This predominant interest in sensory and cognitive disabilities corresponds to the particularities of these buildings, because seeing and understanding the exhibits is a fundamental aspect of museum use. However, studies with a holistic approach that includes the wide range of different abilities observed in society are less common [64]. Occasionally, the use of ICT (Information and Communication Technology) is proposed as an accessible means [65–67].

Regarding accessibility in heritage buildings, which often house museum use, the idea that they cannot be made accessible because they were not originally designed that way is still prevalent, and their adaptation is deemed unfeasible [68–70]. This point of view is based on the premise that historic buildings were built with different design criteria and requirements than today, and this does not allow for the incorporation of accessibility criteria [70]. However, there are numerous examples of studies and interventions in monuments to improve their accessibility [68,70–77]. These interventions can enhance accessibility without damaging the building. The difference is that intervention in historic buildings requires a detailed case-by-case study, such as the one carried out by Tutal [68], making it difficult to generalise actions. In this regard, authors such as [78] propose that historic buildings can not only be made accessible but can also be adapted more easily than more recent structures due to being designed under comfort parameters similar to those dictated by a barrier-free design.

These previous works used different methodologies. Some used ICT for data collection through laser scanning [70], whereas others used PwD experience through semi-structured interviews and go-along interviews [74,75]. Most focused on barrier detection, with few proposing solutions. Those that proposed solutions focused on specific cases [68,71]. In numerous cases, they focused on a few different existing disabilities [72,74,76], but without a holistic approach. Therefore, it is necessary to develop a methodology that includes all disabilities, contributes to the removal of barriers to knowledge of the potential accessibility level of the building, and whose application does not require, at least in the first phase, specific technologies or experts.

The challenges of intervening in heritage buildings for the improvement of accessibility contrast with the greater permissiveness concerning actions that enhance comfort, such as introducing installations.

Lastly, it is worth highlighting the tourism sector as a driver of accessibility in museums and monuments, fostering the development of the concept of accessible tourism, which stems from an economic model of disability [5,6]. Considering data on the global population with disabilities from the World Health Organization [8], individuals with disabilities become a pool of potential customers, leading tourist environments to adapt to their needs. Accessible tourism is not limited to overcoming barriers that exclude certain people and can be defined as a "form of tourism that [...] enables people with access requirements, including mobility, vision, hearing and cognitive dimensions of access, to function independently and with equity and dignity through the delivery of universally designed tourism products, services and environments" [79]. Its relevance is evident in studies on accessibility in various tourism resources, such as hotels [80,81], commercial and leisure environments [82,83], or museums and monuments [64,76,79,84–86]. Countries where a large percentage of their gross domestic product (GDP) is derived from tourism could increase their economy through accessible tourism by developing initiatives such as the MEDRA Project [86].

Based on the above, the objectives of this study are:

- The design of a methodology for the study of the current and potential accessibility of buildings that does not negatively affect the heritage aspects of the building.
- The qualitative and quantitative study of the accessibility improvement index of a representative sample of musealised heritage buildings to obtain their current level of accessibility and their potential level of accessibility.

2. Object of Study

The study sample consists of 25 heritage buildings located within the geographical area of the Region of Murcia in south-eastern Spain. All selected buildings have been classified as Cultural Heritage Sites of Interest, in accordance with current legislation [41]. In the architectural context, a "Cultural Heritage Site of Interest" refers to monuments, groups of buildings or sites with exceptional historical, artistic, scientific, aesthetic, ethnological, or anthropological value [40]. This designation applies to both movable and intangible properties. The quantity, typology, use, and distribution of heritage buildings in this area are similar to those in the rest of Spain and other Western European countries [87]. Figure 1 shows some examples of the analysed architecture.

The analysed buildings range in age from the 11th to the 20th century, with representative examples from each century. Most of them, 8 buildings, belong to the 16th century. The remaining centuries have between 1 and 3 buildings each.

It is common for heritage buildings to undergo changes in their use. In the case of buildings converted into museums or museum spaces, their original use is lost, although in certain cases, both uses coexist. The conversion into a museum involves interventions for adaptation and conservation. Regarding the studied buildings, 9 of them have an original military use, 7 religious, 5 residential, 2 public-use, 1 library, and 1 museum, with only 1 building retaining its original use. Among the 25 analysed buildings, 5 (20%) combine museum use with their original or other use, while 20 (80%) are solely museums or museum-converted buildings.

Figure 1. Examples of buildings analysed. (**A**): Punic wall (Cartagena, Spain), (**B**): Palace of the Fajardo Family (Cehegín, Spain), (**C**): Castle of Jumilla (Jumilla, Spain), (**D**): Church of San Juan de Dios (Murcia, Spain), (**E**): Archaeological Museum (Murcia, Spain), (**F**): Charity hospital (La Unión, Spain), (**G**): Huerto Ruano (Lorca, Spain), (**H**): Calahorra tower (Aledo, Spain) and (**I**): Saint Francis Convent (Mula, Spain).

In terms of location, the majority of the buildings (22) are situated in urban areas, while only 2 are in natural environments and 1 in a rural area. In all cases, they are in urbanised surroundings, with vehicular access nearby and pedestrian connections to the entrance.

The wide range of type, age, use (both original and current), and location of the buildings in the sample shows the effectiveness of the method not only in particular circumstances but in a variety of situations. In addition, the environment, the use, and the architectural characteristics of the analysed buildings are analogous to those of any present-day non-heritage construction, making the methodology used, the results, and the conclusions derived from this study applicable to any other building and its urban environment.

3. Materials and Methods

The methodology employed in this study is organised into seven phases: documentation, accessibility audit, building division into analysis zones and allocation of values and barriers, determination of the current level of accessibility, study of removable barriers, determination of the potential level of accessibility, and determination of the accessibility improvement index. Each phase includes an independent action of the methodology that could be executed by an autonomous work group. Data collection takes place in phases 1, 2, 4, and 6, while the results are generated in phase 7. Figure 2 schematically depicts the followed methodological process.

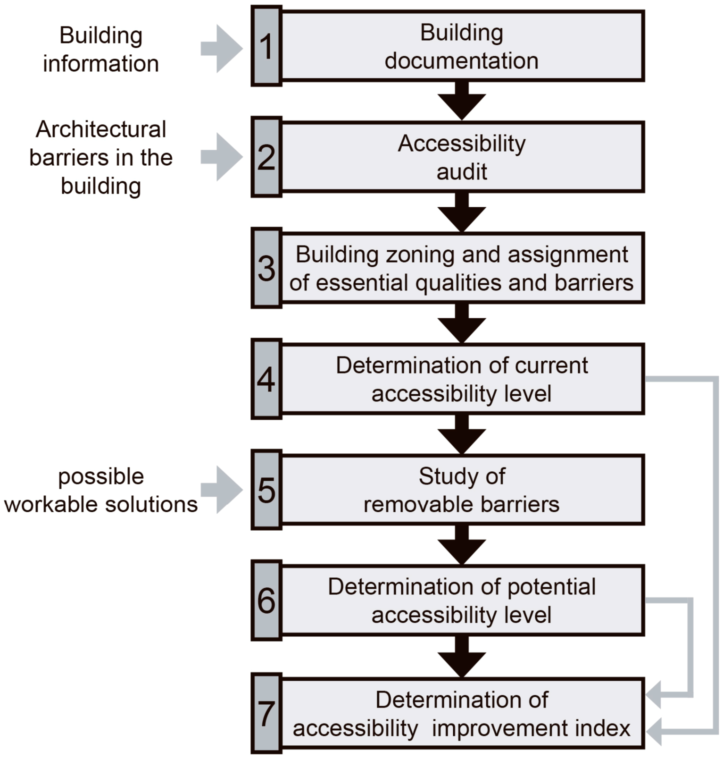


Figure 2. Methodology.

3.1. Phase 1: Building Documentation

Phase 1 involves the documentation of the analysed building. Documenting a building is a necessary step for proper intervention, as emphasised in various restoration charters, such as the Athens Charter (1931), Rome Restoration Charter (1932), Venice Charter (1964), Norms of Quito (1967), or the Charter on the Built Vernacular Heritage (1999) [88–92], to name a few examples. It is a constant assertion that any action should be preceded by a detailed study of the building. In this work, the following information is obtained:

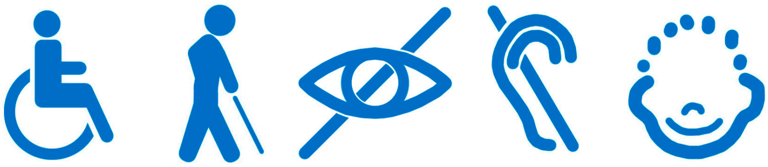
- Architectural, historical, and artistic information about the building, including its history, heritage characteristics, displayed collections, etc.
- Functional information about the building. This includes activities conducted, schedules, types of visits (guided, self-guided. . .), information provided to users, resources for user accessibility, etc.
- Building plans to understand the layout and relationship between its spaces.

Due to the uniqueness of heritage buildings, their building documentation has multiple sources, such as bibliographic reviews, analyses of historical documents, or interviews with managers.

3.2. Phase 2: Accessibility Audit

An accessibility audit involves on-site data collection to identify existing architectural barriers within the building [34,70,83,93]. Two types of references are distinguished: user experience studies and direct observation of the environment. In this study, the accessibility audit corresponds to the latter type.

The accessibility needs of the group of users with disabilities are diverse. To make space accessibility specific, understandable, and useful for both users and managers, based on the analysis of the disparity of terms used and the disabilities considered in the extensive existing literature [32,67,68,77,94–106], five groups of People with Disabilities (PwD) are considered, encompassing various specific situations: wheelchair users, cane or crutch users, visually impaired users, hearing impaired users, and cognitively impaired users (Figure 3). These groups include not only all PwD who may have accessibility problems in the built environment but also other similar circumstances, such as elderly people or people with baby carriages.



1 2 3 4 5

Figure 3. Groups of People with Disabilities considered: 1 wheelchair users; 2 cane or crutch users; 3 visually impaired users; 4 hearing impaired users; 5 cognitively impaired users.

To carry out the audit, a catalogue of 238 potential architectural barriers is defined, encompassing all the difficulties that can arise in the physical environment related to mobility, grasping, orientation, and communication [14]. The list of barriers is obtained from state regulations on accessibility in the built environment [107,108] and complemented by regional regulations, with the barriers derived from legal parameters [73].

To facilitate barrier identification, 20 analysis zones are defined: elements connecting the urban environment and the interior of a building or isolatable building areas for intervention (e.g., stairs, doors, restrooms, etc.). These defined analysis zones are applicable to any building type, whether heritage or contemporary. The barriers are distributed across these zones. Table 1 displays the 20 analysis zones and the number of catalogue barriers situated in each.

Table 1. Analysis zones. The code relates each barrier/solution in the following tables with the analysis zone in which it is located.

Analysis Zone and Code	Catalogue Barriers
Parking space (AP)	7
Access (AC)	5
Door (PU)	17
Horizontal circulation (CI)	12
Flooring (PV)	6
Step with risk of falling (DE)	6
Information point (PA)	8
Staircase (ES)	26
Ramp (RA)	23
Lift (AS)	24
Escalator (EM)	8
Moving walkway (TR)	7
Step lift (PEV)	12
Stair lift (PEI)	6
Auditorium space (EA)	10
Furniture (MO)	8
Mechanisms (ME)	3
Wc (WC)	29
Signs (SE)	12
Musealisation (MU)	9

Each barrier can affect one or more groups differently. Each barrier is assigned a Limitation Coefficient (C.L.) for each group, indicating if it does not affect, slightly affects, moderately affects, or hinders usage. To determine the impact of each barrier on each group of PwD, the research group responsible for this task interviewed 15–20 members of each group analysed, pointing out each barrier and asking about the level of impact, and then compiling and analysing the results. This consultation follows the WHO's recommendation [4]. This recommendation calls for involving PwD in matters that directly concern them, not only because they have the right to exercise control over their lives but also because they often have a more accurate perception of their situation. Table 2 illustrates the different possibilities for each barrier, along with the corresponding Limitation Coefficients.

Table 2. Possibilities for each barrier and the corresponding Limitation Coefficients.

Barrier	Does Not Affect	Slightly Affects	Moderately Affects	Hinders Usage
Barrier 1	C.L. = 0	C.L. = 0.2	C.L. = 0.5	C.L. = 1

After the comprehensive definition of the catalogue of architectural barriers, an accessibility audit is conducted for each building, identifying and recording the present architectural barriers.

3.3. Phase 3: Building Zoning and Assignment of Essential Qualities and Barriers

Conceptually dividing a building into zones facilitates its analysis. Numerous prior examples propose similar strategies [70,71,109,110]. The analysed building is divided into spaces corresponding to rooms or spatially isolated zones to which identified barriers and essential qualities are later assigned. Figure 4 provides an example of building zoning.

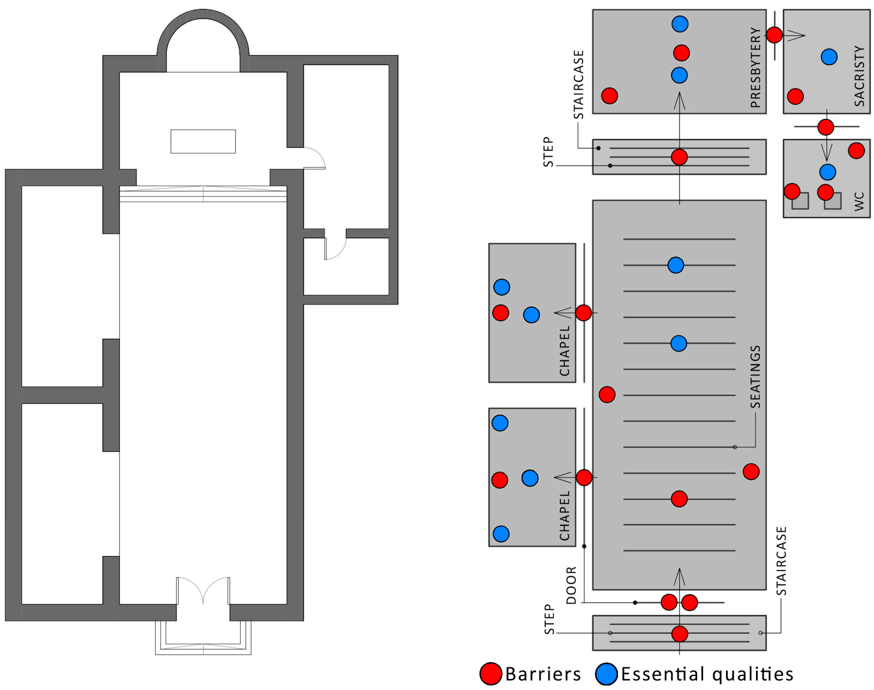


Figure 4. Example of building zoning. (**Left**): plan of the analysed building. (**Right**): diagram of the zoning of the building, indicating the barriers and the essential qualities.

A building has different essential qualities depending on its use, its architecture, its history, etc. Essential qualities are attractive aspects of a building that motivate individuals to access and use it. For this analysis, the following essential qualities are considered: usage (need to use a space for its intended purpose); typological (importance of a space for understanding architectural typology); and historical-artistic. These three essential qualities were selected for this study as they are the most relevant in the study sample (museums). The essential qualities are identified in each space of the building based on the information obtained in phase 1. The value of a space's essential qualities is the sum of these three considered qualities. A higher sum of essential qualities in a space involves a higher relevance in the building.

3.4. Phase 4: Determination of Current Accessibility Level (C.A.L.)

For each space, the Limitation Coefficients are summed, and the threshold values are established. In a space in which the sum of Limitation Coefficients is less than or equal to 0.2, all essential qualities of the analysed space are considered accessible. If the result is greater than 0.2 and less than or equal to 0.5, some essential qualities of that space are considered accessible. If it is greater than 0.5, none of the essential qualities are considered accessible. These threshold values have been established based on previous empirical studies and have proven to be reliable and in accordance with the accessibility of people with disabilities.

If a space or element analysed is necessary to access another space (e.g., stairs), and it is considered non-accessible, all spaces accessed through it as the sole route are also considered non-accessible. This approach aligns with the concept of an accessibility chain [13].

The accessible qualities of a building for each group of PwD are the sum of accessible essential qualities of each space. Table 3 shows the established levels of accessibility. A building is classified as accessible if the percentage of accessible essential qualities is equal to or greater than 90% and partially accessible if the percentage of accessible essential qualities is greater than or equal to 50% and less than 90%. If accessible essential qualities are below 50%, the building is considered non-accessible.

Table 3. Levels of accessibility and % of accessible essential qualities.

% Accessible Essential Qualities	Level of Accessibility	Colour
90% $\leq$ accessible essential qualities	Accessible	Green
50% $\leq$ accessible essential qualities < 90%	Partially accessible	Yellow
Accessible essential qualities < 50%	Non-accessible	Red

3.5. Phase 5: Study of Removable Barriers

For each of the 238 architectural barriers identified in phase 1, one or more possible solutions are established. Solutions are designed based on the following criteria:

- Eliminate the barrier for affected groups;
- Avoid creating new barriers for other groups;
- Avoid causing harm to the heritage building.

Different proposed solutions address the barrier from various perspectives: eliminating the feature that constitutes a barrier, modifying that feature, creating an alternative to the barrier-causing element, and the possibility for an alternate service [93].

Each barrier is assessed for technical and heritage viability. Technical feasibility is established due to the fulfilment of national construction regulations, whereas heritage feasibility depends on compliance with national regulations and international documents, such as the Venice Charter, Norms of Quito, or the Charter on the Built Vernacular Heritage [90–92], accepted by the International Council on Monuments and Sites (ICOMOS). A solution can always be applied if both viabilities are assured.

Table 4 provides an example structure of the proposed solutions for a barrier.

Table 4. Example structure of the proposed solutions for a barrier.

Zone	Barrier	Solution	Technical Viability	Heritage Viability
Door	PUXX	PU-I01 PU-I02 PU-I23	Assured Awaiting Assured	Awaiting Assured Assured

3.6. Phase 6: Determination of Potential Accessibility Level (P.A.L.)

After studying the feasibility of barrier removal, phase 3's analysis is repeated, excluding barriers considered removable (assigning a limiting coefficient of 0). At the phase's end, the building's potential level of accessibility is obtained for each considered group of PwD.

3.7. Phase 7: Determination of Accessibility Improvement Index (A.I.I.)

With the current and potential accessibility levels known for each building, its accessibility improvement index is calculated, representing the difference between the potential and current accessibility levels:

$$\text{A.I.I.} = \text{P.A.L.} - \text{C.A.L.} \quad (1)$$

where:

A.I.I.—accessibility improvement index;
P.A.L.—potential accessibility level;
C.A.L.—current accessibility level.

4. Results

Architectural barriers with a higher prevalence are shown in Table 5. Most of the barriers with a prevalence exceeding 75% of the sample (19 buildings) are found in analysis zones related to ambulation and vertical movement between levels (circulation, doors, stairs, or ramps). Barriers related to visual perception in access, musealisation, and signage also stand out.

Table 5. Architectural barriers with higher prevalence.

Zone	Barrier	Description	% Buildings
Access	AC02	Access without accessibility signage	100%
	AC04	Access without accessible directory	84%
Horizontal circulation	CI05	Undetectable obstacle	100%
	CI12	Isolated step with no accessible alternative	100%
	CI11	There is no accessible vertical communication	84%
	CI01	Width < 1.20 m	80%
	CI09	Insufficient lighting	76%
	CI03	Height < 2.20 m	76%
Door	PU01	Width < 0.80 m	96%
	PU07	Insufficient clearance between door and mechanism	84%
	PU03	Door without turning space	80%
Staircase	ES10	Step without edge signalling	100%
	ES13	Stair landings without signalling	100%
	ES15	Staircase without continuous handrail	96%
	ES17	Short handrail ends	96%
	ES25	Handrails without braille orientation plates	92%
	ES03	Width < 1.20 m	88%
	ES05	Inadequate step height	80%
Ramp	RA05	Excessive longitudinal slope	80%

Table 5. *Cont.*

Zone	Barrier	Description	% Buildings
Furniture	MO01 MO03	Insufficient provision of accessible seats Armless seat	84% 88%
Musealisation	MU04	Element exposed at elevated height or on the ceiling	76%
Signs	SE06	The signal produces reflections	76%

Figure 5 shows the architectural barriers detected with higher prevalence and the percentage of buildings in the sample where they are located.

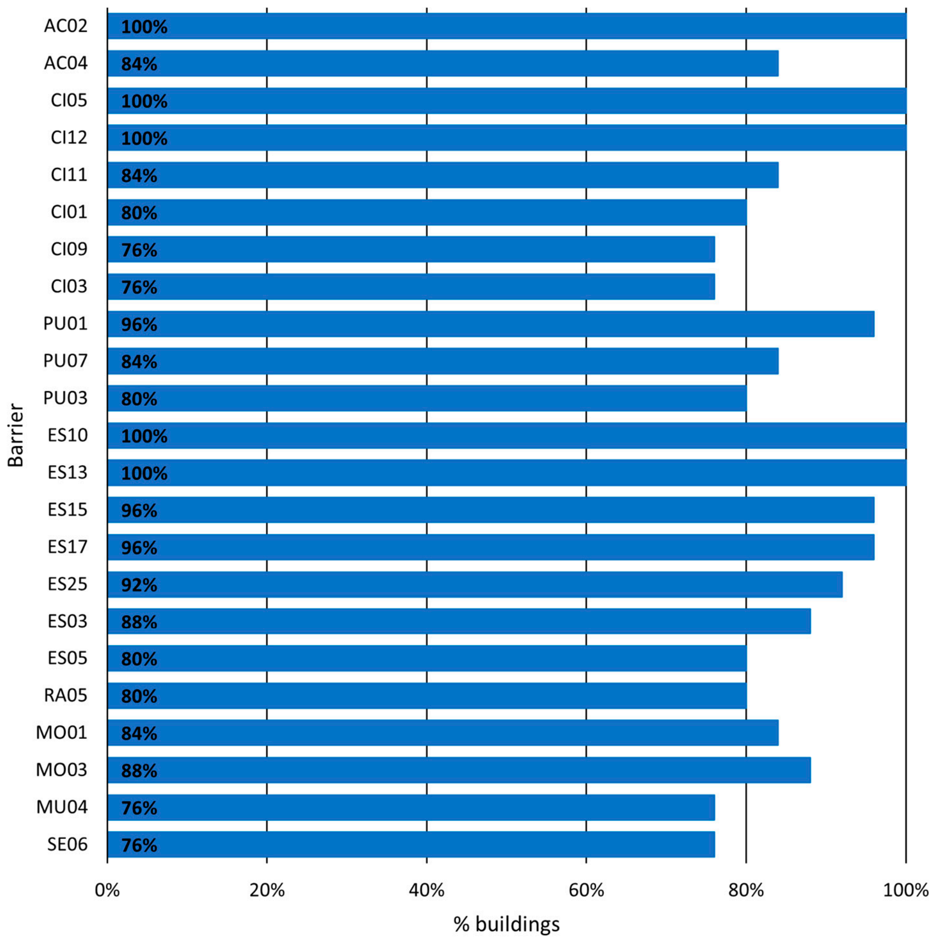


Figure 5. Architectural barriers with higher prevalence. The description of each barrier is shown in Table 5.

Building access constitutes a crucial link in the accessibility chain, connecting the urban environment and interior space. Figure 6 illustrates the types of barriers detected in the sample's entrances. Colours relate each barrier to the type of action they hinder: ambulation, apprehension, location, and communication. Problems related to inadequate signage (96% of buildings) stand out, as well as issues generated by doors (88%) or elements for overcoming level differences (stairs and ramps). In general, problems identified with doors have an impact on wheelchair users and cane or crutch users.

Data obtained in phase 4 provide insights into the current level of accessibility for each building in the study sample for each analysed group of PwD, expressed as a percentage of accessible essential qualities. Table 6 displays the accessibility level for each considered group in each building, along with the arithmetic mean of the sample and the standard deviation. Figure 7 shows graphically the current accessibility level of each building by PwD group. It shows large differences between groups (hearing impaired users and cognitively impaired users have a higher current accessibility level in all buildings) and between buildings for the same group. This is a consequence of the uniqueness of the heritage building.

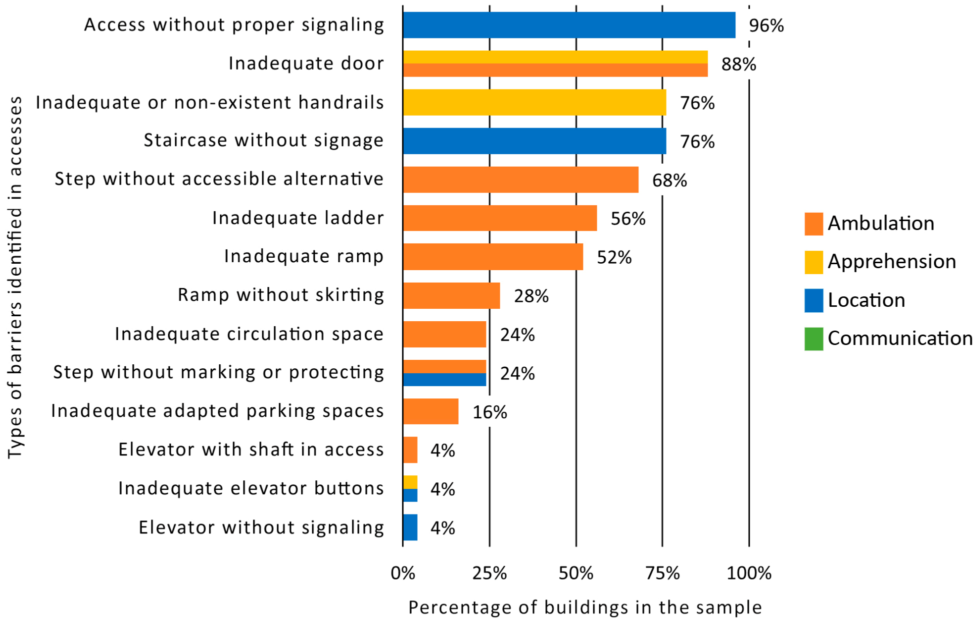


Figure 6. Types of barriers detected in the accesses to the buildings analysed. Colours relate each barrier to the type of action they hinder: ambulation, apprehension, location, and communication. A barrier with two colours means that is related with both actions.

Table 6. Current accessibility level (C.A.L.) of the buildings in the sample and mean value and standard deviation, by group of PwD.

Building (Ref)	Current Accessibility Level (C.A.L.)				
	Wheelchair Users	Cane or Crutch Users	Cognitively Impaired Users	Hearing Impaired Users	Visually Impaired Users
01	2%	7%	16%	88%	9%
02	0%	15%	51%	63%	31%
03	10%	8%	40%	82%	8%
04	8%	45%	50%	69%	19%
05	0%	14%	32%	93%	16%
06	4%	34%	36%	62%	14%
07	1%	8%	30%	82%	9%
08	1%	25%	48%	81%	16%
09	43%	69%	33%	90%	22%
10	0%	25%	16%	65%	2%
11	0%	10%	24%	97%	26%
12	0%	65%	75%	97%	25%
13	0%	12%	55%	90%	31%
14	24%	34%	42%	81%	19%
15	16%	27%	37%	85%	29%
16	0%	43%	51%	77%	28%
17	0%	0%	30%	96%	9%
18	1%	74%	66%	84%	28%
19	1%	10%	11%	90%	6%
20	2%	57%	57%	85%	33%

Table 6. *Cont.*

Building (Ref)	Current Accessibility Level (C.A.L.)				
	Wheelchair Users	Cane or Crutch Users	Cognitively Impaired Users	Hearing Impaired Users	Visually Impaired Users
21	6%	62%	37%	90%	21%
22	4%	53%	31%	93%	22%
23	14%	55%	37%	86%	10%
24	0%	16%	13%	67%	3%
25	0%	57%	15%	96%	14%
Average	6%	33%	37%	84%	18%
Standard deviation	10%	23%	17%	11%	9%

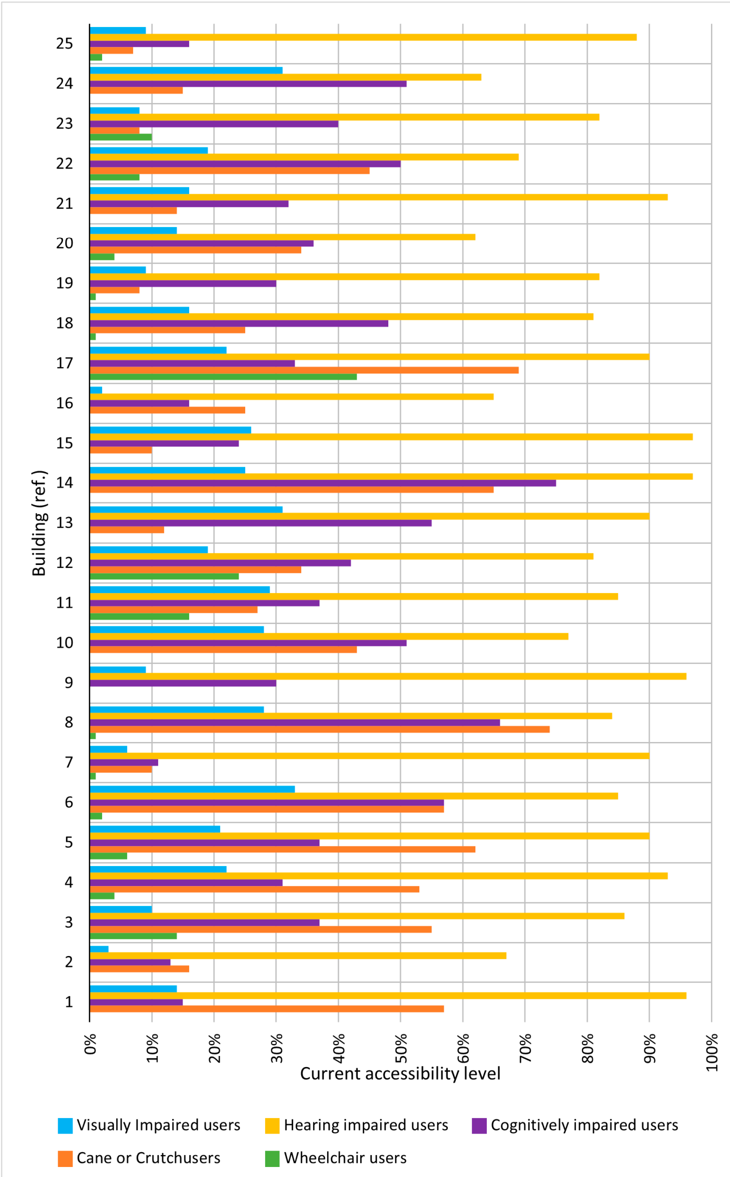


Figure 7. Current accessibility level of the buildings in the sample by group of PwD.

The current level of accessibility for all analysed buildings is generally low, except for the hearing-impaired group, for which the current level of accessibility is medium-high, with an average of 84%. The remaining groups have an average below 40%, with two distinct groups: first, the groups of physically disabled individuals using canes and cognitively disabled individuals, with averages of 33% and 37% respectively. Second, the visually impaired and physically disabled individuals using wheelchairs, with notably lower averages of 18% and 6%, respectively.

The current accessibility level does not reach 50% for all groups in any of the buildings in the sample. Three of the buildings show a current accessibility level equal to or greater than 50% for three groups: cane or crutch users, cognitively impaired users, and hearing-impaired users. A total of 36% of buildings have a current accessibility level equal to or greater than 50% for two groups (20% for cane users and the hearing-impaired, and 16% for cognitively disabled and hearing-impaired individuals).

The hearing-impaired group is the only one that displays an accessibility level equal to or greater than 50% in all buildings (among which, 10 buildings, 40% of the total, have an accessibility level equal to or greater than 90% and are considered accessible). At the opposite end, the groups of cane users and visually impaired individuals are assessed as not accessible (accessibility level below 50%) for all buildings.

In phase 6, the potential accessibility level of the buildings in the sample is determined. Table 7 presents the potential accessibility level and the current accessibility level for each group in each building, along with the average of the sample and the standard deviation.

Table 7. Potential accessibility level (P.A.L.) and current accessibility level (C.A.L.) of the buildings in the sample and mean value and standard deviation, by group of PwD.

Building (Ref)	Wheelchair Users		Cane or Crutch Users		Cognitively Impaired Users		Hearing Impaired Users		Visually Impaired Users	
	C.A.L.	P.A.L.	C.A.L.	P.A.L.	C.A.L.	P.A.L.	C.A.L.	P.A.L.	C.A.L.	P.A.L.
01	2%	14%	7%	14%	16%	100%	88%	100%	9%	99%
02	0%	45%	15%	47%	51%	99%	63%	100%	31%	98%
03	10%	33%	8%	32%	40%	100%	82%	100%	8%	99%
04	8%	39%	45%	98%	50%	100%	69%	100%	19%	95%
05	0%	83%	14%	99%	32%	100%	93%	100%	16%	100%
06	4%	98%	34%	99%	36%	100%	62%	100%	14%	99%
07	1%	89%	8%	89%	30%	100%	82%	100%	9%	100%
08	1%	50%	25%	58%	48%	100%	81%	100%	16%	90%
09	43%	84%	69%	97%	33%	100%	90%	100%	22%	96%
10	0%	87%	25%	77%	16%	100%	65%	100%	2%	99%
11	0%	63%	10%	94%	24%	100%	97%	100%	26%	97%
12	0%	0%	65%	87%	75%	100%	97%	100%	25%	98%
13	0%	34%	12%	41%	55%	100%	90%	100%	31%	98%
14	24%	95%	34%	93%	42%	100%	81%	100%	19%	93%
15	16%	36%	27%	89%	37%	99%	85%	100%	29%	96%
16	0%	57%	43%	57%	51%	96%	77%	100%	28%	96%
17	0%	31%	0%	32%	30%	94%	96%	100%	9%	87%
18	1%	96%	74%	100%	66%	100%	84%	100%	28%	100%
19	1%	54%	10%	56%	11%	100%	90%	100%	6%	98%
20	2%	98%	57%	100%	57%	100%	85%	100%	33%	99%
21	6%	88%	62%	100%	37%	100%	90%	100%	21%	100%
22	4%	91%	53%	93%	31%	100%	93%	100%	22%	100%
23	14%	78%	55%	98%	37%	100%	86%	100%	10%	98%
24	0%	67%	16%	73%	13%	100%	67%	97%	3%	63%
25	0%	100%	57%	100%	15%	100%	96%	100%	14%	100%
Average	6%	64%	33%	77%	37%	99%	84%	100%	18%	96%
Standard deviation	10%	29%	23%	27%	17%	1%	11%	1%	9%	8%

The potential accessibility level of the sample is medium or high in most cases. The average value of the potential accessibility level is 100% for hearing impaired users, 99% for cognitively impaired users, and 96% for visually impaired users.

Out of the 25 analysed buildings, 68% have a potential accessibility level equal to or greater than 50% for all groups. Among them, 6 buildings (24% of the total) are potentially accessible (accessibility level equal to or greater than 90%) for all groups. A total of 32% of buildings have a potential accessibility level below 50% for some groups. Among them, 5 buildings (20% of the total) pertain to two groups: wheelchair users and cane users, while the remaining 3 buildings (12% of the total) only show a potential accessibility level below 50% for wheelchair users (not accessible).

When analysing the sample by PwD groups, the hearing-impaired and cognitively disabled groups can potentially access all buildings. The visually impaired group has a potential accessibility level for 92% of buildings and a partial accessibility level (between 50% and 90%) for the remaining 8% of buildings. Regarding the groups of cane users and wheelchair users, the distribution of buildings across the three potential accessibility levels (accessible, partially accessible, and not accessible) is 48%, 32%, and 20% for the first group and 24%, 44%, and 32% for the second group.

The comparative analysis of data obtained in phases 4 and 5 provides the number of existing barriers in each building and the percentage of these that can be removed without negatively affecting the heritage building. When combined with data resulting from phase 6, the improvement index is calculated for each group. Table 8 summarises this data.

Table 8. Existing and removable barriers and accessibility improvement index (A.I.I.) by PWD group for each building in the sample, average and standard deviation.

Building (Ref)	Existing Barriers	Removable Barriers	Accessibility Improvement Index (A.I.I.)				
			Wheelchair Users	Cane or Crutch Users	Cognitively Impaired Users	Hearing Impaired Users	Visually Impaired Users
01	408	89%	12%	7%	84%	12%	90%
02	132	93%	45%	32%	48%	37%	67%
03	150	93%	23%	23%	60%	18%	91%
04	244	91%	31%	53%	50%	31%	75%
05	153	93%	83%	85%	68%	7%	84%
06	278	95%	95%	65%	64%	38%	85%
07	256	94%	87%	81%	70%	18%	91%
08	177	89%	49%	33%	52%	19%	74%
09	336	86%	41%	28%	67%	10%	74%
10	178	96%	87%	52%	84%	35%	97%
11	360	94%	63%	85%	76%	3%	71%
12	94	90%	0%	22%	25%	3%	73%
13	243	85%	34%	30%	45%	10%	67%
14	202	89%	71%	59%	57%	19%	74%
15	312	91%	20%	62%	62%	15%	66%
16	85	85%	57%	14%	44%	23%	67%
17	223	78%	31%	32%	64%	4%	78%
18	308	99%	95%	26%	34%	16%	72%
19	258	92%	53%	46%	89%	10%	92%
20	414	97%	95%	42%	43%	15%	66%
21	540	98%	82%	38%	63%	10%	79%
22	196	92%	87%	39%	69%	7%	78%
23	471	89%	64%	43%	63%	14%	88%
24	456	86%	67%	57%	87%	30%	60%
25	90	100%	100%	43%	85%	4%	86%
Average	N/A	91%	59%	44%	62%	16%	78%
Standard deviation	N/A	5%	29%	21%	17%	11%	10%

The percentage of removable barriers is high across all analysed buildings. The mean is 91%, with a standard deviation of 5%. All buildings exhibit a percentage of removable barriers exceeding 75%. These data imply the existence of a technically viable solution for each removable barrier in the sample heritage buildings. However, there remains a percentage of barriers for which there is no viable solution, mainly due to physical or technical limitations (e.g., insufficient space to install a ramp).

The improvement index varies considerably depending on the building and the analysed group. When considering groups, the mean is 78% for the visually impaired, followed by wheelchair users and cognitively disabled individuals, both around 60%. The mean of the improvement index for cane users is 44%, while for the hearing-impaired, it is only 16%. In terms of standard deviation, it ranges from 10% for the visually impaired to 29% for wheelchair users, reflecting significant dispersion.

When considering buildings, significant differences are observed, with some structures having very high improvement indices for certain groups while being much lower for other groups (building reference numbers: 1, 5, 11, 12, 17, 22, or 25). Other buildings exhibit fewer extreme values among groups, although with broad ranges, highlighting the uniqueness of each heritage building.

The variability of the accessibility improvement index is due to its dependence on two factors: the current accessibility level and the potential accessibility level. A high improvement index indicates a large gap between both levels and that a large number of removable barriers affect the PwD group. A low accessibility improvement index means that the number of removable barriers affecting this group of PwD is small.

5. Discussion

The applied methodology has allowed for the evaluation of accessibility and the potential for improvement in heritage buildings used as museums. In this regard, it is noteworthy that while most studies focus on sensory aspects [56–62], a significant number of barriers of a physical nature have been identified, necessitating continued research in this field. Comprehensive studies that consider all different abilities are more appropriate than sensory-focused studies.

Most accessibility studies traditionally emphasise the auditing process, primarily focusing on identifying and categorising barriers and problems without proposing actionable solutions [22,82,110]. This work, on the other hand, advances the proposal of solutions and the analysis of potential accessibility, emphasising the potential of the built environment to achieve full inclusion for People with Disabilities (PwD). Moreover, the determination of a parameter such as the improvement index allows for weighing the positive impact of each solution within a holistic view of the building.

The urban environment is constantly evolving to adapt to societal needs, including universal accessibility. The references we examined [17,18,21–27] not only support our findings but also highlight a growing scholarly interest in universal accessibility. Among the constraints of the urban environment are its size and features, such as the presence of slopes or level changes, as well as the fact that these areas were not designed with universal accessibility parameters in mind. To effectively tackle the complexities of the urban environment, our study, like prior research [70,71,109,110], advocates for subdividing it into more manageable zones or sectors for a targeted approach. Furthermore, the existence of constraints presents similarities between the urban environment and heritage buildings.

The analysis of the interior space of a building [33–36] is relevant for understanding its potential use by people with disabilities, while the study of urban accessibility [17,18,21,22] is key for the use of exterior space. However, one of the constraints that complicates intervention in the urban environment is the interface with the buildings, so the connection points between these urban and architectural realms, the entrances, must be highlighted, as the continuity in the accessibility chain depends on them.

While many sources [68–70] propagate the idea that heritage buildings inherently lack accessibility, our research challenges this perspective by unveiling potential intervention opportunities. While the current state may indeed be inaccessible, the potential analysis confirms that, with appropriate interventions, heritage buildings can be made accessible to the majority of society without compromising their essential qualities or heritage value.

In this line, the data obtained in the analysis of the current accessibility level (Table 6 and Figure 7) are highlighted. As mentioned above, there is a large difference between buildings, reinforcing the idea that heritage buildings are unique and that a general criterion cannot be established [68–70]. However, the approach of dividing the building into independent analysis zones and the proposal of specific solutions show that the intervention is feasible.

An important aspect is the significance of analysing the essential qualities of a museum-converted building beyond its displayed collections. In the case of heritage buildings, the inherent value of the structure is evident, but in modern constructions, the architectural interest of the building can be equally noteworthy, as seen in numerous contemporary museums with exceptional architecture [43].

The approach of this study highlights the amount of data obtained from the systematic study of accessibility. Other previous studies generated an equally significant volume of data [18–22,29,32,34,70,71]. In this regard, statistical analyses could provide more complete information.

Our findings align with the rising interest in accessible tourism [79], emphasising how accommodating the needs of the People with Disabilities (PwD) community can lead to significant economic benefits. Therefore, this study aligns with previous ones [76,80,84–86] as a tool to promote accessible tourism.

6. Conclusions

Our methodology offers a comprehensive and detailed insight into the various accessibility aspects of the physical environment, highlighting both existing barriers and areas for potential improvement. Its configuration allows for a detailed understanding of existing architectural barriers and their impact on each group of People with Disabilities (PwD). It informs about the current state of the building for different groups of PwD but, in addition, offers a potential accessibility level and, through their combination, the improvement index the building presents. All of this falls within a line of work aimed at supporting accessibility improvement, going beyond mere diagnosis.

This line of work is necessary in any built environment, whether urban or architectural. The needs of PwD and, in general, of any individual (since any citizen might temporarily experience a situation of disability) are analogous, revolving around mobility, grasping, orientation, and communication abilities. This similarity between environments allows the application of the developed methodology in urban areas with equal validity.

After all, the methodological apparatus indicates powerful potential to be used in conjunction with consolidated and often applicable economic evaluation procedures targeted at expressing the feasibility of an initiative, such as that on cultural property assets such as museums.

Highlighting the analysis of entrances as the link between the exterior and interior environments is crucial. While it is true that mere entry to a building does not guarantee its full use, it is essential for initiating an activity and holds significant symbolic value for individuals. Furthermore, as previously discussed, it is a pivotal link in the chain of accessibility; without it, the entire building cannot be considered accessible.

The information provided by the proposed methodology is useful for two major profiles related to the building experience. Firstly, managers who can identify the needs and lines of action for their building to achieve an accessible built environment that respects the rights of all individuals. Secondly, for users, it offers a reference level that is easily understandable and tailored to their characteristics, enabling them to plan their potential visits to the building.

Additionally, under the globally recognised objective of social justice and the equitable distribution of goods and services throughout communities, the information frame provided by the proposed assessment method is significant for private and public entities from the perspective of effectively allocating their own financial resources among several urban settings where there is a high prevalence of PwD needs.

The elements referred to as "essential qualities" capture the specificities of heritage and museum buildings. However, with minor adjustments, the methodology is easily applicable to any other context. Therefore, it becomes a tool aimed at universal accessibility in the built environment, regardless of its specific use. This encompasses not only the interior space but also the exterior, where the needs of PwD are analogous.

The use of indicators such as the one proposed proves valuable for developing elements such as accessibility labels, which, in domains such as tourism, are frequently used to highlight a tourist destination as accessible and to attract visitors with disabilities.

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