

# Systematic Review of Universal Design Applied to Wayfinding Signage Systems for a University Campus.

Diego Joseph Villalon<sup>1</sup>, Andrea Mangiatordi<sup>1</sup>,

<sup>1</sup> "Riccardo Massa" Department of Human Sciences for Education  
University of Milano - Bicocca

**Abstract.** University campuses and educational facilities are places of diversity shared by people with different conditions and from different cultures. In this context signage is one of the most immediate tools people can use when navigating the complexity of these spaces providing access and usability to all users. This paper presents a systematic review of the literature referring to signage using a Universal Design (UD) approach. Out of 580 articles, 19 were considered the most relevant to understand the current state of knowledge about Universal Design in signage for wayfinding in university campuses. The key findings are a series of recommendations for designing a signage system considering Universal Design principles like prioritising centres of cultural gravity, emphasising convergence, providing flexible systems, using co-design from early stages, giving simple and relatable information presented according to user expectations, and the strategic placement of signage with progressive delivery of information to reduce cognitive load.

**Keywords:** Universal Design, Wayfinding, Signage, University, Accessibility, Inclusion

## 1 Introduction

Signage is a core component of any wayfinding system. Even when wayfinding is carried out using a navigation application, which could theoretically be sufficient to support orientation, signage is relevant both as confirmation of effective wayfinding and as a way of making sense of the environment. In this context, when it comes to accessibility and inclusivity of the built environment, signage plays a fundamental role, as it should be an ally in overcoming barriers, but it could also become a barrier in itself.

Firstly, this paper aims to explore the most promising approaches to accessible and inclusive wayfinding, using Universal Design (UD) as a theoretical framework. It can be defined as “the design of products and environments so that they can be used by all people, as far as possible, without the need for adaptation or specialised design” [1]. This design framework is often defined as utopian in the research literature, which mostly means that it could be the source of many concerns and scepticism, especially among academic faculty and staff, because of its risk of absolutism. This is balanced by positive aspects of utopias such as idealism, change and criticism [2]. Universal Design has been applied to signage and wayfinding studies in many different ways, and this study will attempt to summarise what exists in the literature. The first and most significant element that emerges from looking at accessible signage research from this perspective is a tendency - shared with many other areas where UD approaches have been used - to address the issues of different ‘categories’ of people

and users, and to try to bring them together to form an overarching picture of possible solutions.

The articles were classified according to their relevance to the central theme of the research question. Those where UD was referenced directly or indirectly were primarily included, but also those where accessibility solutions were presented in a way that, albeit not in line with UD principles, was considered useful to determine feasible and evidence based solutions for specific groups of people.

The signage system we want to develop will also consider the themes of orientation and disorientation, complex phenomena influenced by cognitive, cultural, and technological factors. Spatial disorientation is a key theme in our globalised world, raising questions about our relationship with space, technology, and our animal nature [3]. In a broader sense, disorientation is a geographical theme that concerns our relationship with space, places, the body, emotions, and time: it can be used as a metaphor for the time we live in, where finding points of reference is a key issue in many different ways. Understanding these factors can help develop more effective wayfinding support systems and improve our comprehension of human spatial cognition in various contexts.

The focus will be on a specific type of environment, namely “a university district”. This stems directly from the research project this work is part of, called MUSA, Multilayered Urban Sustainability Action. As we are evaluating and designing sustainable solutions to be tested in our own district, the focus on higher education spaces is central to our reflection. The accessibility of higher education environments remains a significant challenge for students with disabilities and for many other categories of people, requiring efforts on many levels. Some argue that a systemic approach to inclusion is needed, emphasising accessibility as a fundamental right rather than a luxury [4]. Urban design education has also incorporated wayfinding research, emphasising the importance of visual clarity and accessibility in multi-level environments. Previous systematic reviews have identified various factors affecting wayfinding behaviour in complex environments, including environmental complexity, familiarity, and cultural differences [5].

The aim of this article is hence to review the current state of the literature in order to answer the following specific research question:

“What are the most effective methods and best practices for implementing the principles of universal design in the development of an inclusive signage system for orientation and disorientation in a university district?”.

## 2 Related Work

Here we present some works that review the literature about related topics. Most of them are more focused on Wayfinding than Signage, because this topic can provide valuable insights into the needs of people with disabilities and other types of special needs. However, they do not offer specific solutions regarding the design of a signage solution.

Prandi et al. [6] present a literature review about devices and software applications for accessible wayfinding. The article analyses the literature considering different dimensions: a) Context of Use, b) Target Users, c) Technologies, d) Data sources, e) User Role. In the “Target Users” section, a section is dedicated to “All Users,” which specifically mentions projects that employ the Universal Design approach.

Gupta et al. [7] present a literature review regarding wayfinding for individuals with disabilities, summarising the findings of numerous studies and identifying similarities and contrasts in their wayfinding preferences. The study identifies several common points relevant across disabilities, while also demonstrating how preferences

regarding these points may differ. Furthermore, the study revealed that the majority of existing research focuses on visual impairment. As the authors note, “While we can (...) see some overlapping needs across users with vision impairments and users with mobility disabilities, there are relatively few studies documenting the needs of the latter, not to mention the needs of people with other disabilities, like hearing or cognitive impairments.”

### 3 Methodology

#### 3.1 Research Question

The initial step was to define a research question that would serve as a framework for selecting articles for review:

“What are the most effective methods and best practices for implementing the principles of universal design in the development of an inclusive signage system for orientation and disorientation in a university district?”.

#### 3.2 The Initial Query

The review started from a search in Scopus, using the following query: ((accessib\* OR inclusiv\*) AND (signage OR wayfinding)).

We limited the research database to Scopus database, which was selected because of its recognition on indexing peer-reviewed journals across relevant disciplines including design, architecture and accessibility studies. Scopus offers strong editorial standards and broad international coverage, which helped ensure a consistent methodological quality of the selected articles. To mitigate the limitations of a single-source search we complemented the screening with rigorous relevance classification and thematic coding.

This search returned 579 results. All articles were then screened by title, with the objective of evaluating their relevance to answer the above defined research question. In light of the aforementioned objective, we permitted ourselves some flexibility in the evaluation of the articles, given that the terms “Universal Design”, “Accessibility”, “Inclusiveness”, “Wayfinding”, “Signage” and “University District” can be interpreted in different ways and may also share numerous points with other terms and contexts.

The term “Universal Design” was not included in the search query as it is a relatively new and not very commonly used term. This would have led to a limited number of results, including only articles that refer to this specific theory, but excluding many other articles that could adopt the same principles without giving them this specific name. Instead, we opted to search for the keywords “(accessib\* OR inclus\*)” as these two terms are very likely to be present in any article pertaining to “Universal Design.” The results of these two keywords would include a significant number of articles relevant to the inclusion of people with different needs. This can be corroborated by the search of “(Universal Design) AND (Wayfinding OR Signage)” which yielded only 47 results, with only three of these not already included in the original query.

Finally, we used the aforementioned definition of “Universal Design” to identify the articles that respond to these principles, even if some of them do not use this specific term.

Referring to “Signage” and “Wayfinding”, the main goal of this review is to find Signage Systems applied to Wayfinding (orientation and disorientation). We classified as partially relevant some articles that refer to Signage in other contexts, considering they can give some hints for inclusive design of signage, but we mostly excluded articles dedicated only to marketing strategies or other totally unrelated areas. On the Wayfinding side, we discarded most articles that didn’t refer to Signage systems, as wayfinding opens too many doors leading to mobile apps, mapping systems, interior beacon-based orientation systems, etc. Some of these articles were still considered partially relevant, but only when they addressed Universal Design or when their knowledge could still be applied to the design of a signage system.

Finally, we chose to leave out of the search query all terms related to the scale of the environment or the university context. We planned to classify articles on a case by case basis, as different contexts or scales can still give important hints for the Signage System on a University District scale. For example, wayfinding systems designed for hospitals or airports are considered here to be similar in scale compared to University Campuses. In the same way, the best practices for designing the Signage System for a whole city can also be relevant in this specific context.

### **3.3 Relevance Classification:**

The articles were analysed in terms of their relevance to the research question proposed, with four levels of relevance identified:

R3: Very Relevant (Universal Design Applications) - These articles discuss the principles of Universal Design in the context of inclusive signage and wayfinding without focusing on a specific disability or group.

R2: Partially Relevant (Barrier Removal) - Partially address the issue from a more specific perspective (Examples: just for blind people; just about signage, but not inclusive). They can be useful to assess specific cases. All the articles in this category were also classified by specific topics (see next section)

R1: Little Relevance (Assistive Technologies and Local/Personal Solutions) - Articles that study very specific products, technologies or territories - Address Wayfinding Apps or Technologies for the individual (not aimed for collective or public interventions) - Address wayfinding or signage in a different scale or unrelated environment (grocery stores, islands, etc) - They indirectly refer to signage or wayfinding as part of a broader topic (Ex. Urban planning for people with disabilities)

R0: Irrelevant - Articles about unrelated topics (Example: “Group cycling safety behaviours: A systematic review”) - Articles about wayfinding systems that don’t involve signage (Mobile Phone Apps, Maps, etc. Example: “Accessible smartphones for blind users: A case study for a wayfinding system”) - Articles that focus on design and architecture best practices for an accessible environment (not oriented to signage or wayfinding) - Medical studies regarding specific conditions, symptoms or rehabilitation processes (Example: “Successful wayfinding in age: A scoping review on spatial navigation training in healthy older adults”) - Articles that talk about assistive technologies for specific types of disabilities

### **3.4 Categories Classification**

For every article considered Relevant (excluding R0), category tags were assigned, divided in two main groups:

#### **Key Topics:**

The tags in this group are included in the Search Query helping us understand the distribution of results based on key topics. Accessibility and Inclusion were integrated into one tag, however were considered alternative terms in the search query. On the other hand, signage and wayfinding are related topics, yet cannot be considered alternatives.

As explained in the Initial Query section, “universal design” was not part of the initial query. We decided to add the tag #universal to distinguish the articles that take a more universal design approach from those that only discuss a specific type of #accessibility.

- #universal: Articles that mention the topic Universal Design or address accessibility for a wide range of users.
- #accessibility: Articles that address accessibility and/or inclusion in general or for a specific type of user.
- #signage: Articles that address signage systems
- #wayfinding: Articles that address wayfinding, and not specifically signage.

### **Inclusion Target:**

These tags help us to understand the focus of the articles in terms of inclusion. This group also includes the tag #universal to differentiate the articles that refer specifically to universal design or inclusion for a wide range of users. Most articles focus on a specific type of user, for which we have created the following categories:

- #universal: Articles that mention the topic Universal Design or address accessibility for a wide range of users.
- #visual: Includes all types and levels of visual impairment.
- #hearing: Includes all types and levels of hearing impairment.
- #mobility: Includes all types of mobility impairment.
- #psychological: Includes all types of mental health issues, cognitive and intellectual impairment, etc.
- #multicultural: Articles that address Cultural or Social inclusion.
- #gender: Articles that address gender equality, gender identity and LGBT+ inclusion.
- #elder: Articles that address ageing issues and the inclusion of the elderly.

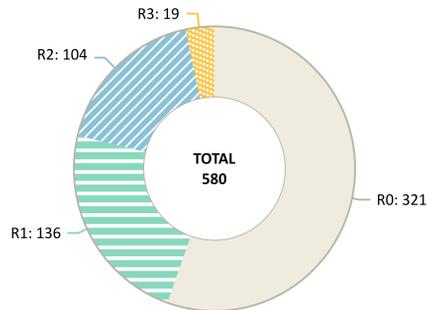
It's important to note that these tags have been selected for classification purposes, to quickly identify the general categories of topics covered within each article. The words chosen do have a limitation, and in some cases they may not be semantically representative of the specific topics. For example, the word “Psychological” may not perfectly describe certain types of “Intellectual Impairment”, but the best fitting category we still found to be “Psychological”.

Each article can be assigned as many tags as the topics that it is relevant for. This allows us to understand if the article is focused on a very specific topic (e.g., Signage design considerations for a hospital), if it addresses a specific type of user (e.g., Signage for people with visual impairments), or if it employs a more Universal Design approach (e.g., A Universal Design approach for Signage and Wayfinding). 2

## **3.5 Review**

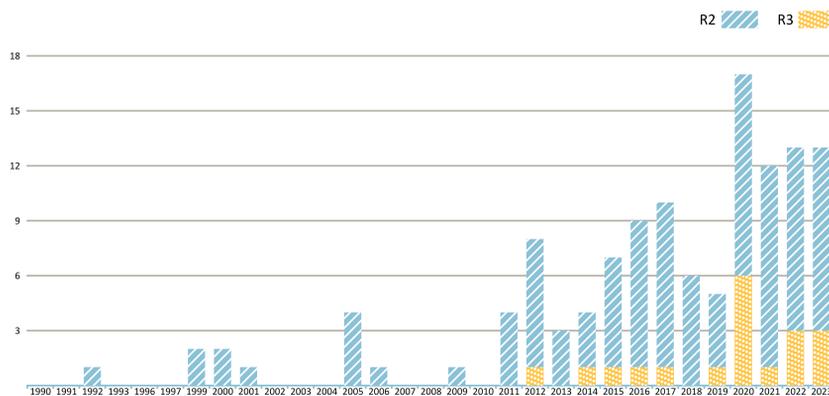
The process of tagging and relevance categorisation was very useful to identify the most relevant articles and understand how the topics relate to each other. For the scope of this study we confined our analysis to the articles designated as R3 (Very Relevant), as our objective was to gain a comprehensive understanding of the body of knowledge pertaining to the subject of Universal Design and Signage. All other relevant articles (R2, R1) were not reviewed in detail, but they are used for statistics,

and remain in an internal database that will be taken as reference for specific cases in the future.



**Fig.1** – Relevance Distribution of the whole set of research results

In Fig. 1 we can see the Relevance Distribution of the initial query. Out of 580 articles, 19 were classified as R3, Very Relevant (3,28%); 104 as R2, Partially Relevant; (17.93%), 136 as R1, Little Relevance (23,45%) and 321 as R0, Irrelevant (55,34%).



**Fig.2** - Articles by year with Relevance 2 and 3

As seen in Fig.2, the analysis of the most relevant articles (R2, R3) showed a significant increase in the amount of publications regarding inclusive wayfinding and signage beginning in 2011. All R3 articles are published after year 2012.

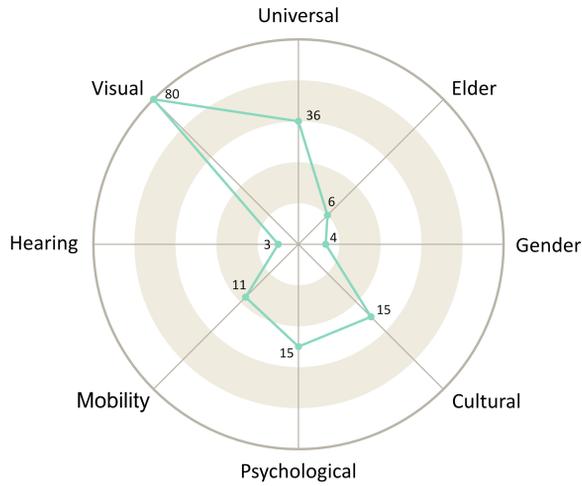


Fig.3 – Overall Distribution of Inclusion Target tags for all relevant articles (R1, R2, R3)

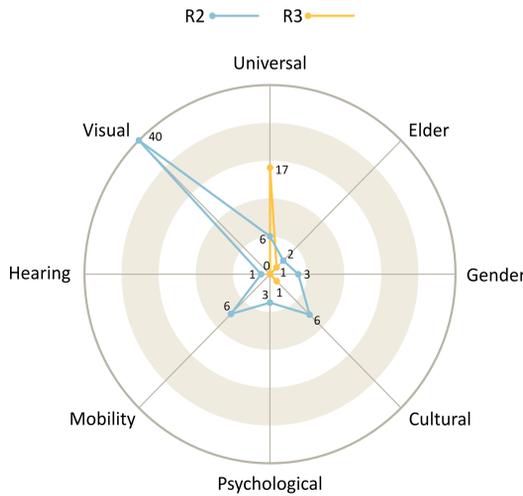
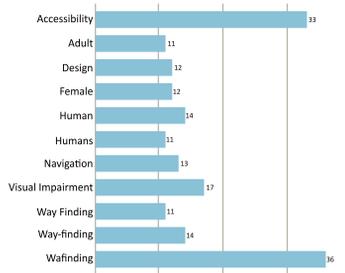


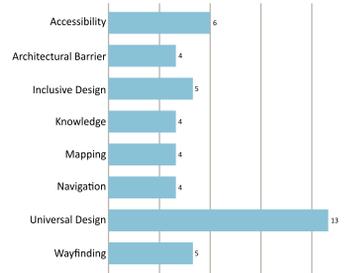
Fig.4 – Distribution of Inclusion Target tags separated by Relevance (for R2 and R3)

Fig. 3 and Fig. 4 show the distribution of the Inclusion Target tags of the relevant articles. Because of the methodology used for evaluating the Relevance, most of the R3 articles (17 out of 19) are tagged as “Universal”, while just 2 are tagged with other categories: “Elder” and “Multicultural”. It’s important to notice that there is a big majority of articles dedicated to Visual Impairments. Especially in the R2, out of 104 articles, 40 articles are tagged with “Visual”. Instead “Universal”, “Mobility”, and “Cultural” have just 6 articles each, followed by “Psychological” and “Gender” with

3, and finally “Elder” with 2 and “Hearing” with 1. As one might predict from signage relying largely on visual elements, the number of articles contained in the visual category was significantly larger than others. The remaining categories help us understand the relevance and development of other topics in the literature about signage. Taking this into consideration, we can conclude that Inclusive signage largely consists of the topics of visual impairments, mobility, and multicultural inclusiveness.



**Fig.5** - Top Keywords in Articles with Relevance 2



**Fig.6** - Top Keywords in articles with Relevance 3

Regarding Keywords, the most frequent in R2 was found to be different variations of “Wayfinding” (way finding, way-finding, wayfinding) followed by “Accessibility”, and “Human/humans” which all constitute general topics. After that we find “Visual Impairment” as the most frequent keyword confirming there is a larger number of articles dedicated to this group. Finally we find “Female” as another important Keyword, indicating the possible emergence of Gender equality as a relevant topic.

On the other hand, articles in R3 reveal “Universal Design” as the most frequent keyword followed by “Accessibility”, “Wayfinding” and “Inclusive Design” reflecting the focus of this study. More importantly, we found “Architectural Barrier”, “Mapping”, “Navigation” and “Knowledge” as the next most frequent keywords. With exception of “knowledge”, the other three give as an idea of the most relevant topics developed in current literature regarding Universal Design and Signage.

It is interesting to note that “signage” is not present in the most frequent keywords, indicating a lack of studies regarding this topic. This could be a consequence of the vast diffusion of new wayfinding technologies accessible to everyone in the last few decades. We can clearly see that most studies prioritise Mapping and Wayfinding Technologies instead of Signage, even though Signage continues to be very important for orientation, especially indoors, where there is still no unified technology that can work on every building.

### 3.6 Data Extraction

After the initial tagging and relevance classification process, we proceeded to read and analyse those articles that were evaluated as R3 (Very Relevant). During this phase, we applied a thematic coding process to extract useful content related to Universal Design and signage systems.

This coding was based on two main elements: the categories already identified through the tag system (e.g., #universal, #signage, #visual, etc.), and additional topics that emerged during the reading of the articles. Each R3 article was reviewed and annotated with these specific topic codes to help identify the most frequently discussed themes.

The findings were then grouped into broader categories that helped us identify recurring topics, observations and principles across the literature, therefore setting the base title structure of the “Findings” chapter.

## 4 Findings

### 4.1 Main Areas of Development

When analysing the literature about wayfinding, it becomes clear that there are very few studies and projects that take a Universal Design approach. Most of them are focused on a single type of user, and there is a majority of studies focused on Visual Impairment and Mobility Impairment, especially people with wheel chairs, as stated by Han, Yoon, and Cho [8],

Similar numbers were found by Prandi et al. [6] were out of 111 papers, 54 are dedicated to visual impairment, 25 to mobility, 19 to all users, 10 to visual and mobility, 2 to visual & cognitive impairments, 1 just to cognitive and 1 to hearing impairment.

### 4.2 Barriers, Preferences, Priorities & Information: Focus on the Function

Identifying barriers for different types of users is key for the implementation of Universal Design in a project. Allowing the user to set their own preferences on any type of interactive technology can help eliminate these barriers. Fogli, Arenghi, and Gentilin [9] proposed a mobile app that is able to “propose and guide users on paths that best fit their characteristics and preferences; for example, if a user declares some motor and/or visual impairment, the app proposes paths that avoid the architectural barriers related to such impairments”. This approach is interesting when used for adapting a system to different users but it can be limited in terms of “categorising” users according to their difficulties.

In contrast to this, Hedvall et al. [10] talk about a cultural shift to a new idea of Nonclusive design, meaning a “design that resists categorisations of bodies/roles and that does not come with predefined or presupposed limits in terms of who it is meant for”. This shift passes through seven themes:

1. From included to undefined users
2. From person to function.
3. From adaptism to variation
4. From separation to convergence
5. From reactive to proactive
6. From unaware to aware
7. From explicit to tacit

From these seven principles, the first two points are specially interesting, as they demonstrate the need of not focusing on a specific type of user and focus more on the “functions” that can better satisfy the needs of a wide range of people.

Other studies actually reinforce this idea by not focusing on the type of disability, but acknowledging the fact that the same environmental features can become either barriers or facilitators depending on the user group or even as personal preferences within the same group.

According to Gupta et al. [7], “people across disabilities want to plan their routes around common features, like carpet, stairs and crowds. However, they did not universally want to avoid or seek such features. Rather, needs varied from person to

person”. Under this perspective, the study suggests that wayfinding and navigation should be personalised not based on the user disability type, but around the user preferences regarding the different types of environmental features identified.

Regarding space layouts, most users agree that a Grid layout facilitates wayfinding both indoors and outdoors rather than one with curves and circles.

Some observations about the preferences of different groups of users based on certain features of the building as: - Carpeted areas, which are frustrating for people in wheelchairs and deafens the echo of the white cane for blind people - Stairs were preferred by some users with visual and cognitive impairments due to their efficiency, and even though the majority would avoid stairs, the reason to avoid them varied across disabilities. - Most users would avoid crowds, but some would actually prefer crowded routes in order to have the option to ask for assistance - Most users prefer to navigate using landmark based directions instead of distance, including landmarks that make sound

Finally the study proposes four pairs of opposing traits that differentiate the various “personas” encountered: - Technology (familiar vs. latest) - Route (planned vs. spontaneous) - Assistance (human vs, technological) - Experience (enjoyable vs. efficient).

Also Upadhyay et al. [11] mention the importance of “notifying users about changes in surface level, light intensity, etc. which can be considered as landmarks for people with visual impairment”.

Following this trend, Han, Yoon, and Cho [8] proposes the idea of “Geospatial Information for All”, creating a “Typology of accessibility Information integrated with universally designed spacial information”, which gives a good idea of the indoor and outdoor barriers that need to be identified for an accessible route planning. For example, in case of the sidewalk, it would be important to identify the width, the material, and the gradient of the path and the location of boundary stone. On this regards, they later identify how each of these elements become barriers or facilitators for users with different types of disabilities and the prioritisation of each by groups. The main groups reviewed in the research are mobility, visual and hearing impairment.

**Table 1.** User Group Accessibility Priorities by Han, Yoon, and Cho [8] Creative Commons Attribution License (CC BY)

<b>User Group</b>	<b>Barriers</b>	<b>Facilitators</b>
People with mobility impairments	- Sidewalk width less than 90 cm.	- Sidewalk separate from street
	- Gradient over 8%	- Lowered curb at crosswalk
	- Uneven surface	- Elevators
	- Misplaced street trees	- Lowered main entrance threshold
	- Crosswalk with curbstone	- Ramp
	- Stairs, escalator	- Automatic door
	- Overpass	- Wheelchair-accessible restrooms
	- Threshold at the main entrance	- Feeding/nursing rooms
	- Revolving door	- Diaper changing table
	- Main entry width less than 90 cm	- Restroom with children’s toilet
People with visual impairments	- Mixed traffic street	- Sidewalk separate from street
	- Uneven surface	- Braille block
	- Crosswalk	- Accessible pedestrian signal (APS)
	- Lowered sidewalk curb	- Handrail on stairs
	- Revolving door	- Braille sign on handrails

User Group	Barriers	Facilitators
People with hearing impairments	- Mixed traffic street	- Help button - Elevator braille buttons - Automatic door - Tactile and auditory information on signs and kiosk - Flashing emergency lights
	- Voice assistance	- Sign language services - Pictograms on signs

**Table 2.** User Group Barriers and Facilitators by Han, Yoon, and Cho [8] Creative Commons Attribution License (CC BY)

	People with mobility impairments	People with vision impairments	People with hearing impairments
<i>Pedestrian Path</i>	Gradient Width	With Braille block	
<i>Pedestrian Crossing</i>	Crossing type	With acoustic signal	
<i>Curb</i>	Height	Missing	
<i>Stairs</i>	With ramp Ramp gradient Ramp width	With handrail With Braille sign Number of steps	
<i>Elevator</i>	Wheelchair-accessible	With help button With Braille sign button	With strobe light
<i>Corridor</i>	Gradient Width	With Braille block	With strobe light
<i>Door</i>	Width With threshold Threshold height	Opening type Opening direction	
<i>Room</i>	Wheelchair-accessible		With strobe light
<i>Restroom</i>	Wheelchair-accessible With nursing room With changing table	Distinction of gender	With strobe light

Adding also the age variable, Wu and Wang [12] made an extensive study using Surveys and Statistical Analysis regarding the different aspects of a Signage system and the preferences of different types of users including age groups and different types of impairment.

For their model, they identified four dimensions of “wayfinding behaviour and users’ application of the signage system:

- Mind-map recognition
- Sign layout & design
- General needs & safety
- Capabilities & perception.

Regarding “wayfinding behaviour and signage systems”, few differences were found between groups of similar ages regardless of their ability or disability condition.

With regard to the dimensions of “Mind-map recognition” and “Sign layout & design”, little disparity was observed among groups.

Opinions in the dimensions of “General needs & safety” and “Capabilities & perception” in the design of urban parks were very different between young and elder users, independent of their ability or disability conditions.

These conclusions seem to show that age has a much bigger influence on user preferences than the specific disabilities when talking about wayfinding behaviour, preferences and needs in a signage system.

### 4.3 A Unified System of Wayfinding and Information Design

Sometimes, as Prandi et al. [6] state at the beginning of their review, “the same devices and software applications can represent a different form of barrier: if their user interface is not accessible or not suitable for assistive technologies, they fail in reaching the goal”. This reminds us that, if we’re designing a Universal Design wayfinding system we need to look at all the different layers that affect the wayfinding experience as a whole in order to correctly solve the problem.

Harper et al. [13] made a three phased research project about the lack of usability of multiple wayfinding interfaces in a multi-building hospital. Their findings regard not only the need of inclusion of the final user as a key element for the development of a user centred design, but also *the need to view wayfinding tools (kiosks, signage, apps, etc) and the actual design of the buildings as a unified system, and not as isolated tools*. From this point of view, “The wayfinding kiosk and application information should complement environmental information such as color coding, graphics, landmarks, room and elevator labelling and signage.” The conclusion of the study is a list of design guidelines for the design of wayfinding interfaces including the principles of Universal Design to accommodate to different users according to their preferences.

The recommended design guidelines for wayfinding interfaces are: - Be consistent with the physical environment, i.e. labels, icons, colours and signage - Use physical landmarks as a directional aid - Consider accessibility in the placement of touchscreen systems and on-screen interactions - Classify information and wording according to user expectations - Include a universal search feature - Use simple and relatable instructions - Minimise unnecessary on-screen information - Adhere to platform standards - Present visual aids effectively through the interface - Orient navigation information effectively from the user’s viewpoint - Provide a way for users to receive help from another human - Use a systems approach

Upadhyay et al. [11] discuss the types of wayfinding strategies for different types of users. While studying hospitals in low-income countries, they explain how many people rely on human assistance for wayfinding. Even though they proposed a digital app and a signage system to help users, they acknowledge human assistance as part of the system making specific recommendations on how to address the users and give directions to people in the hospital.

They also recommend to include 3 layers of information: - A layer of wayfinding with key services and landmarks - A layer of healthcare with essential information on service points associated with these functions - A customised information layer that is based on visitor’s preferences as well as the functionality of the hospital

*If extracted from the hospital context, these 3 layers show us the importance of guiding users not only on their geographical wayfinding, but also on the tasks and functions they most likely need to perform, reinforcing the idea of wayfinding as part of a system.*

Gupta et al. [7] add also another layer to the equation by showing that many people with disabilities obtain information about the planned route and the accessibility of the location before visiting the place by calling building personnel, searching online, but many times the information is not available.

#### 4.4 User Centered Design and Co-Design

In tune with the idea of including the final user on the design proposed by Han, Yoon, and Cho [8], also Rocha, Lima, and Brito [14] states that “considering the participation of the visually impaired user with the intention of proposing improvements in existing methodologies or in the process of creating the solution gains more and more strength as a strategy to promote intelligent and accessible environments.”

Kowaltowski, Bernardi, and Martin [15] arrive to a similar conclusion stating that “to increase the sensitivity of professional designers to issues concerning UD, potential users with disabilities should participate early in the design process, to provide input as the proposal is developed.”

Also Prandi et al. [6] acknowledge the importance of involving the user on the design process dedicating an entire section to the user’s role on the studies of their literature review. Out of 111 papers 36 had no users involved, 34 involved users in design & evaluation, 25 only in evaluation and 16 only in design. This idea was previously put into practice by Prandi et al. in a previous article [16], by involving a blind developer on the project “based on the idea that some of the best UI and the best interaction systems are obtained when there are people with disabilities on the design and development team, contributing to all aspects of the design and implementation, not just as participants in user studies.”

Another way of involving users is crowdsourcing information about the environment. This is a relatively common thing to do in wayfinding apps as done by [9], while also including the users with disabilities on previous stages of the development of their project.

One possible way of continuous co-design the possibility of crowd-sourcing information about the environment for something like PAM (Personalized Accessibility Map), analysed by Karimi, Zhang, and Benner [17], where users can contribute with data for a wayfinding system. This data not only reflects the users’ needs but also helps keeping the system updated with temporary or new data (as a construction that blocks a road, or a new entrance to a building).

One of the biggest challenges with this kind of systems is that there is no standard way of gathering accessibility data. Another interesting challenge is that most maps rely on visual landmarks, but they are of no use for people with no vision.

Chesser et al. [18] use the “Our Voice” framework, developed by the Stanford University to gather information related to Age-Friendliness in the University of Manitoba. Their findings suggest that a collaborative approach to citizen science that include users in data collection, analysis and mobilisation process can be useful to identify and address barriers. They therefore suggest that “institutions approach their own investigative processes in a manner that acknowledges the unique programming and service needs of the community populations that they serve.”

#### 4.5 User Awareness and Familiarity with the Systems

Katada [19] developed an AI chat bot as a digital signage capable of giving facility information, guidance, assistance and answer questions to people, including the visually impaired. Even though the system managed to correctly respond to prompts by users, the system faced challenges such as users’ lack of familiarity with this type of digital signage. To solve the initial obstacle of unfamiliarity with the system, the digital signage was equipped with prompts, mainly those that encourage voice input, positioned around its surroundings. For example, the signage displayed a prompt such as “Talk to me about where is xxx location?” to encourage voice input from users. These prompts were designed to make users aware of the system’s capabilities,

thereby “fostering” their “proper” use of the chat bot, as well as stimulating their interest in the chat bot’s functionality.

Let’s just notice that, even though Familiarity with the System is a value for most users, according to Gupta et al. [7], a specially innovative system can also be appreciated by certain users.

#### 4.6 Universal Design Assessment

Some studies focus on finding a way to evaluate and assess the application of the principles of Universal Design. Yang, Kao, and Lin [20] propose a modified Universal Design assessment to accommodate signage related features. Even though the assessment is designed for a hospital, it could help identify ways to redesign the signage also in other contexts.

- Principle 1. Equitable Use: The signage design is useful to people with diverse abilities.

- 1A. Provide the same means of signage use for all users: identical whenever possible; equivalent when not.

- 1B. Make the signage design appealing to all users.

- 7A. Provide a clear line of sight to important elements for any seated or standing user.

- Principle 2. Flexibility in Use: The signage design accommodates a wide range of individual preferences and abilities.

- 2A. Provide choice in methods of signage use.

- 2C. Facilitate the user’s accuracy and precision.

- 2D. Provide adaptability to the user’s pace.

- Principle 3. Simple and Intuitive Use: Use of the signage design is easy to understand, regardless of the user’s experience, knowledge, language skills, or education level.

- 3A. Eliminate unnecessary complexity.

- 3B. Be consistent with user expectations and intuition.

- 3C. Accommodate a wide range of literacy and language skills.

- Principle 4: Perceptible Information. The signage design communicates necessary information effectively to the user, regardless of ambient conditions or the user’s visual abilities.

- 4B. Provide adequate contrast between information in signage and its surroundings.

- 4C. Maximize “legibility” of essential information.

- 4D. Differentiate elements in ways that can be described(i.e., make it easy to give instructions or directions).

- 4E. Provide compatibility with a variety of techniques or devices used by people with visual limitations.

- 5A. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.

- 5D. Discourage unconscious action in signage that require vigilance.

Mosca and Capolongo [21] developed an evaluation framework to assess UD in public buildings based on specific performance criteria and their key indicators that represent the main objectives to develop environments universally usable and enjoyable for a wider number of users. In this framework wayfinding is just one of the points, but one could also extrapolate these principles to evaluate the Signage and Wayfinding design within a space.

Here is a selection of the identified principles that could be applied in this specific case:

1. Usability

- Equal use of the environment
- 2. Functionality
  - Flexibility/Personalization
  - Low physical effort
  - Flows/Distribution
- 3. Safety/Security
  - Minimize risk situations
  - Maximize security perception
- 4. Wayfinding
  - Visual information (signs, colors, map, landmark)
  - Perceptible information (tactile, sound)
- 5. Understanding
  - Information easy to understand (symbols, language, color contrast)
  - Communication (awareness, ICT)
- 6. Environmental factors
  - Illumination (natural/artificial)
  - Acoustics
- 7. Well-being
  - Health promotion and Physical activity
  - Aesthetic quality (colors, materials)
- 8. Social Inclusion
  - Cultural appropriateness
  - Social relation (integration and privacy)
  - Inclusive design process

#### 4.7 Signage Recommendations

Regarding the design Upadhyay et al. [11] make a series of specific recommendations about “Physical Interfaces”, referring specifically to signage, advising to have good illumination (over 100 lux) and following a standard for colours and fonts.

As for the contents, the study states that signage should not increase the cognitive load. Therefore one should pay attention to: - Strategic placement - Progressive disclosure of the information - All decision points in physical space must have adequate wayfinding signage - Reassurance of the information on all intersections is critical in progressive disclosure

By analysing digital wayfinding/signage solutions in hospitals Harper et al. [22] make a series of recommendations for these systems:

- Classification of information according to user expectations.
- Inclusion of a universal search
- Minimise unnecessary on-screen information.
- Adhere to platform UI standards
- Present visual aids effectively

Wan [23] makes a study about Universal Design principles applied to Tourist signage and takes as reference for their evaluation the seven UD principles and how these principles are applied in designing universally accessible tourist signage according to the standards of the “Center of Universal Design”, the “World Tourism Organization” and “Tourism Western Australia”.

For the first principle, “Equitable in use”, the same means of use should be offered to all users, offering privacy and safety, avoiding stigmatisation, and making the design appealing for everyone. Specifically for signage, international or universally recognised symbols should be used.

For the second principle “Flexibility in Use” users should be offered with choice and adaptability enhancing the user’s accuracy. For signage, it is recommended using text together with symbols.

For the third principle “Simple and intuitive” unnecessary complexity should be removed in order to be accessible to people with different literacy and language skills. Information should be presented according to its importance. In signage this translates in using signs and colors in a consistent way, choose an easy to read font (avoiding long and narrow forms) and simple wordings, using familiar abbreviations, arabic numbers (instead of roman), text aligned to the left. It’s also important to avoid giving different directions on the same sign, reduce the use of composite signs.

For the fourth principle of “Perceptible Information” it’s recommended to use pictorial and tactile for conveying essential information, using good contrast between information and backgrounds, make it easy to give instructions and offer different supports for people with sensory limitations. Also for signage, using arrows, using a font size according to the viewing distance, using non-reflective surfaces, using upper and lower case letters avoiding BLOCK CAPITALS. Signs should be positioned at important points along routes considering the effects of the surrounding environment on their visibility.

For the fifth principle “Tolerance for error” it’s necessary to minimise hazards by offering properly positioned warnings and avoiding signs with sharp edges.

For the sixth principle “Low physical effort” users should be enabled to stay in a neutral body position reducing sustained physical effort or repetitive actions. For signage this means positioning the signs in a way they can be viewed without any obstruction or special efforts and that tactile and braille signs can be easily reached.

For the seventh principle, “Size and space for approach and use” it is mainly recommended to pay attention to the position of the signs and the size of the elements within them.

Even though the study focuses on site specific interviews for evaluating the use of UD principles in tourism signage, the principles and recommendations found can be of use for developing almost any kind of Signage under the UD principles.

#### **4.8 Cultural Inclusivity**

Few studies focus on the Cultural aspect of the Universal Design. Specially when talking about Signage, it can really make a difference to understand how to design and communicate the wayfinding information.

Kim and Kang [24] analyse a multicultural society and their need to identify themselves with the territory through signage. The study shows how the cultural preservation field has been overly focused in architectural heritage, giving much more visibility to elite and property owning cultures.

To counter this effect there’s a need to shift focus to recognise places of interest for different groups living in a city, but at the same time one must be careful as these groups will compete for space because the city treats symbolic cultural space as exclusive property rights over land.

The most important take-away is that “contemporary ethnic urbanism patterns have called for an alternative spatial concept and mapping that does not emphasise borders, but rather the centers of cultural gravity, and acknowledges the reality of physically interwoven communities” in order to avoid competition and conflict.

#### 4.9 Future Work and Development

Prandi et al. [16] state that “As future work, we just started to investigate the use of conversational user interfaces (such as the Amazon Alexa) in combination with our system, to understand if it can be useful in assisting users during wayfinding tasks”. This statement is even more relevant now with the massive adoption of generative AI.

Even though accessibility and signage has been addressed from many different perspectives, the Universal Design approach is still lacking on development as studies focus mainly on specific types of users.

Regarding wayfinding, many studies are currently focused on more technological solutions, as apps and navigation assistants, but there is still a lot of space for development in the traditional signage field where best practices and recommendations could be updated under the light of newer approaches, as Universal Design, and the new social and cultural realities like globalisation, international mobility, gender equity and LGBT activism.

Regarding signage for universities and educational facilities, there are very few studies focused on this specific scenario and most of them are dedicated to evaluate specific projects instead of studying the problem from a more generic point of view. In this study we summarised some joint general recommendations from a diverse set of studies which focus on spaces with a similar scale, but more in depth studies could be made assessing the specific needs and requirements in the context of universities and educational facilities.

### 5 Discussion

This literature review about Universal Design applied to Signage has brought to light several themes and considerations that must be taken into account to create an inclusive environment through signage systems.

The first consideration is that the concept of Universal Design applied to this context is a relatively new tendency that started to gain interest during the years 2010's. Still, most of the literature that talk specifically about Universal Design for Wayfinding uses it more as an evaluation framework than as a Design approach.

As stated in other parts of this article, when talking about Signage and Wayfinding most of the literature focus on finding solutions for one specific type of user, with high priority for users with Visual Impairment followed by users with Mobility impairment and Intercultural solutions.

When talking about Universal Design, there seems to be a consensus on the fact that we should not focus on tackling problems for specific user groups or types of disabilities, but instead we should focus on identifying the common features and functions that define the users' needs and that influence their decisions. For example, we know users will program their routes based on the presence of a crowded area, but while some users will find the crowd a benefit, others will try to avoid it. We should therefore focus on making users aware of the possibility to find a crowded area on the road and let them choose by themselves whether this is a barrier or a facilitator, instead of unilaterally suggesting the path based on our assumptions about the user abilities.

For Signage, this principle is easier said than done. Just a few studies identify specific features that help users decide their wayfinding preferences. Also most of these strategies are easier applied in digital wayfinding apps (like google maps), which allow a certain degree of personalization, but they are more difficult to apply to static physical signage. Digital Signage seems to open some possibilities on this, but

these systems are usually not interactive enough to allow personalization of the information.

There is some common agreement on some of the key features that people across disabilities use for deciding their ideal paths: path width, stairs, ramps and elevators, floor types and materials (such as carpet or uneven surfaces), the presence of certain types of signals (as braille blocks, audio signals, strobe lights, etc), or the presence of a crowd. Still this approach is limited due to the fact that every space and situation can have different features and a different set of users with their own set of requirements: For example, while on the streets we need to assess Curbs in the sidewalks and special signals at the crossroads and traffic lights, while in a building we need to identify certain types of doors or lighting systems. From this point of view, many studies regarding user expectations for a wayfinding system are limited to the specific context in which the system is used based on its architecture, its design features and on its potential users.

It is also demonstrated that a good Signage System Design should be consistent with the environment and with any other system with which it is related. If a space, for example, has a wayfinding App, an illustrated Map and a Signage System, all these systems should use a unified code in order to help the user get oriented using the combination of tools that better satisfies their needs without having to understand 3 different information systems.

Another important aspect to consider is the relationship between the User and the Signage / Wayfinding System. On this topic we can analyse user's preferences in terms of technological innovation vs less technological solutions, route planning vs spontaneous wayfinding, in efficient vs enjoyable experience, in human vs technological assistance. Ageing seems to be a key Factor on determining the different approaches in this relationship.

At this point, considering all the possible combinations of users and possible contexts, it's important to notice that most studies agree in the necessity of involving users early in the design process. Keeping in mind the previous concepts of "Focusing in the Features" and "Being Consistent with the Environment", User-centered design and co-design seems to be also accepted as a key process in order to arrive to a Universal Design wayfinding system. The involvement of users should be implemented from an early stage of the design process and can be extended even after the project is completed by implementing a crowdsourcing system that allows users to contribute on keeping the information updated in the system. One of the challenges on this regard is that there is no standard way of gathering accessibility data, a topic that could be interesting for further studies.

Regarding the use of Universal Design for Signage and Wayfinding systems, different frameworks and recommendations exist, but most of them are just a practical application of the seven principles of Universal Design: 1. Equitable Use, 2. Flexibility in Use, 3. Simple and Intuitive, 4. Perceptible Information, 5. Tolerance for Error, 6. Low physical effort, 7. Size and space for approach and use.

Regarding specific recommendations for signage, beside the basic graphic design recommendations, Some important principles are the "strategic placement" of the signs using a "progressive disclosure" of the information with the objective of "reducing cognitive load". All the "decision points should have adequate signage" and there should be "Reassurance of the information" on all intersections.

In general, for wayfinding systems, it is recommended to use physical landmarks as a directional aid, use simple and relatable instructions, minimise unnecessary information, classify information according to user expectations, orient navigation information to the user's point of view and adhere to platform standards.

Another interesting aspect to consider is the different layers of information where we can identify mainly three layers: First, the basic places and physical landmarks that can serve as a reference for orientation (E.g. a sculpture, an open space, an office

number or name). Second the functions and services these places can provide to the user (E.g. Student services, administrative tasks, relax and entertainment). Third, a customised information layer based on the user's preferences for navigation (E.g. Stairs, Ramps, Sound Signals, Braille Block, etc).

As a final consideration, Universal Design is not just about users with disabilities, but should also consider other aspects as Social and Intercultural inclusion and Gender Equity. A few studies focus on these topics recommending to move away from categorisations, working for "undefined" users, focusing more on the system functions instead of the user categories, moving from separation to "convergence" and from explicit to "tacit" in order to shift the focus from the differences between users.

Another relevant topic is the importance of recognising places of interest for different groups sharing the same space, but warns about the risk of competition and conflict between groups that feel like they "own" a specific area. To avoid this, they recommend to use an alternative spatial concept that doesn't emphasise borders, but rather the "centers" of cultural gravity.

As we've seen on this review, there is a growing interest in applying Universal Design in Wayfinding and Signage, but it's still a relatively new approach. Most studies are limited to assess the level of "Universal Design" by getting inspiration from its seven principles, but there are very few examples of real-world applications of this approach in a Signage System.

Probably because of the quick democratisation of wayfinding technologies in the last two decades most studies have focused on "Wayfinding Technologies" using mobile phones and digital devices, while very few have focused on "Signage". Even though wayfinding apps have taken a central role on our everyday lives for orientation, Signage systems are still omni-present in almost any context so it would be important to expand the research in this area also considering new technologies.

As a designer making this review, I can also say that many "findings" or recommendations regarding specific advice for accessible signage come from studies done by non-designers and end up being very basic graphic design recommendations as "using an easy to read font" or "Good contrast between the text and the background color". Still, I believe some important principles have been identified that are at the base of the design process and can set a starting point for future research and development in Signage and Wayfinding systems.

## 6 Conclusions

After this review, we can say that Universal Design for Signage and Wayfinding is a relatively new tendency that is gaining interest through the latest years. Most studies propose some kind of interpretation of the seven principles of Universal Design as a tool for assessing accessibility and a few of them propose specific strategies for implementation.

Many sets of recommendations were encountered in the analysed literature, allowing to identify at least four different important areas of reflection and intervention. The first one is directly related to UD and its applications: we gathered many suggestions towards prioritising convergence over separation, providing users with flexible systems that value their choice, in a consistent and interconnected way. A second area is represented by co-design and user participation, with a stress on early user involvement and on continuous collaboration, as updates to a system pose great threats to its accessibility if not well managed. As a third area we can name the specific field of wayfinding, which relies on using physical landmarks for orientation and providing guidance tailored to users' functional objectives and preferences.

Instructions should be simple, relatable, and aligned with the user's point of view. Information should be classified according to user expectations and presented in line with platform standards to ensure clarity and consistency. The fourth and final area was related to signage itself: to be effective it requires strategic placement, with signs positioned at every decision point and intersections to reassure users. Information should be presented progressively to reduce cognitive load, ensuring clarity and ease of navigation.

Regarding the theme of orientation in a multicultural space, we found out that emphasising borders can create competition or conflict, so focusing on centers should be something to be prioritised in order to represent "cultural gravity", but leaving space for intercultural exchange.

For future development we found that research on accessibility and signage often focuses on specific user groups, leaving Universal Design underdeveloped. While current development in wayfinding studies emphasise technological solutions, traditional signage still needs updates to reflect modern social changes like globalisation and gender equity. For universities, limited studies exist, mostly evaluating specific projects rather than broader needs. This study compiles general recommendations but highlights the need for tailored research on university signage requirements.

**Acknowledgments.** This work was founded by University of Milano Bicocca through a Research Grant to DV within the MUSA – Multilayered Urban Sustainability Action – project (ECS 000037), funded by the European Union – NextGenerationEU, under the National Recovery and Resilience Plan (NRRP) Mission 4 Component 2 Investment Line 1.5: Strengthening of research structures and creation of R&D "innovation ecosystems", set up of "territorial leaders in R&D".

#### **CRedit author statement.**

**Diego Joseph Villalon:** Conceptualization, Methodology, Formal analysis, Writing – original draft preparation, Visualization. **Andrea Mangiardi:** Supervision, Validation, Writing – review and editing.

## **References**

1. Mace R.: Universal Design : Barrier Free Environments for Everyone Designers West, 33, pp. 147–152 (1985) DOI:
2. Steinfeld E., Tauke B.: Universal Design: 17 ways of thinking and teaching. pp. 165–189. Husbanken, Oslo (2002)
3. Schmidt Müller Di Friedberg M.: Geographies of Disorientation, Routledge, (2017) <https://doi.org/10.4324/9781315584683>
4. Chiwandire D., Vincent L.: Wheelchair users, access and exclusion in South African higher education African Journal of Disability, 6, (2017) <https://doi.org/10.4102/ajod.v6i0.353>
5. Iftikhar H., Asghar S., Luximon Y.: The efficacy of campus wayfinding signage: A comparative study from Hong Kong and Pakistan Facilities, 38, pp. 871–892 (2020) <https://doi.org/10.1108/F-04-2020-0035>
6. Prandi C., Barricelli B.R., Mirri S., Fogli D.: Accessible wayfinding and navigation: A systematic mapping study Universal Access in the Information Society, 22, pp. 185–212 (2023) <https://doi.org/10.1007/s10209-021-00843-x>
7. Gupta M., Abdolrahmani A., Edwards E., Cortez M., Tumang A., Majali Y., Lazaga M., Tarra S., Patil P., Kuber R., Branham S.M.: Towards More Universal Wayfinding Technologies: Navigation Preferences Across Disabilities Conference on Human Factors in Computing Systems - Proceedings (2020) <https://doi.org/10.1145/3313831.3376581>

8. Han S.R., Yoon S., Cho S.: Smart Accessibility: Design Process of Integrated Geospatial Data Models to Present User-Customized Universal Design Information *Frontiers in Psychology*, 10, (2020) <https://doi.org/10.3389/fpsyg.2019.02951>
9. Fogli D., Arengi A., Gentilin F.: A universal design approach to wayfinding and navigation *Multimedia Tools and Applications*, 79, pp. 33577–33601 (2020) <https://doi.org/10.1007/s11042-019-08492-2>
10. Hedvall P.-O., Price M., Keller J., Ericsson S.: Towards 3rd Generation Universal Design: Exploring Nonclusive Design Studies in Health Technology and Informatics. vol. 297. pp. 85–92 (2022) <https://doi.org/10.3233/SHTI220824>
11. Upadhyay V., Bhatnagar T., Holloway C., Balakrishnan M.: A Case Study on Improving Accessibility of Healthcare Care Facility in Low-resource Settings *Conference on Human Factors in Computing Systems - Proceedings* (2022) <https://doi.org/10.1145/3491101.3503557>
12. Wu K.-C., Wang H.: Inclusive design thinking for accessible signage in urban parks in Taiwan *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. vol. 10279 LNCS. pp. 335–347 (2017) [https://doi.org/10.1007/978-3-319-58700-4\\_28](https://doi.org/10.1007/978-3-319-58700-4_28)
13. Harper C., Duke T., Avera A., Crosser A., Jefferies S., Klisans D.V.: Exploring Hospital Wayfinding Systems: Design Guidelines for Wayfinding Interfaces *Advances in Intelligent Systems and Computing*. vol. 1205 AISC. pp. 30–36 (2020) [https://doi.org/10.1007/978-3-030-50838-8\\_5](https://doi.org/10.1007/978-3-030-50838-8_5)
14. Rocha L., Lima T.S., Brito L.C.: Universal signaling based on the articulation between the ergonomic practices and the perception of the visually impaired *Advances in Intelligent Systems and Computing*. vol. 954. pp. 35–43 (2020) [https://doi.org/10.1007/978-3-030-20444-0\\_4](https://doi.org/10.1007/978-3-030-20444-0_4)
15. Kowaltowski D.C.C.K., Bernardi N., Martin C.: A universal design Charrette conducted in an educational setting to increase professional sensitivity *Journal of Accessibility and Design for All*, 5, pp. 47–76 (2015) <https://doi.org/10.17411/jaccess.v5i1.91>
16. Prandi C., Delnevo G., Salomoni P., Mirri S.: On supporting university communities in indoor wayfinding: An inclusive design approach *Sensors*, 21, (2021) <https://doi.org/10.3390/s21093134>
17. Karimi H.A., Zhang L., Benner J.G.: Personalized accessibility map (PAM): A novel assisted wayfinding approach for people with disabilities *Annals of GIS*, 20, pp. 99–108 (2014) <https://doi.org/10.1080/19475683.2014.904438>
18. Chesser S.A., Porter M.M., Barclay R., King A.C., Menec V.H., Ripat J., Sibley K.M., Sylvestre G.M., Webber S.C.: Exploring University Age-Friendliness Using Collaborative Citizen Science *Gerontologist*, 60, pp. 1527–1537 (2020) <https://doi.org/10.1093/geront/gnaa026>
19. Katada Y.: Development of a Signage-type AI Chat Bot that Supports Universal Design *Kyokai Joho Imoji Zasshi/Journal of the Institute of Image Information and Television Engineers*, 73, pp. 1030–1034 (2019) <https://doi.org/10.3169/itej.73.1030>
20. Yang C.-M., Kao C.-H., Lin C.-H.: A preliminary study on applying UD principles for signage assessment in hospital environment *Advances in Usability Evaluation Part II*. pp. 307–315 (2012)
21. Mosca E.I., Capolongo S.: Universal Design-Based Framework to Assess Usability and Inclusion of Buildings *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. vol. 12253 LNCS. pp. 316–331 (2020) [https://doi.org/10.1007/978-3-030-58814-4\\_22](https://doi.org/10.1007/978-3-030-58814-4_22)
22. Harper C., Avera A., Crosser A., Jefferies S., Duke T.: An exploration of interactive wayfinding displays in hospitals: Lessons learned for improving design *Proceedings of the Human Factors and Ergonomics Society*. vol. 2017-October. pp. 1119–1123 (2017) <https://doi.org/10.1177/1541931213601884>
23. Wan Y.K.P.: Accessibility of tourist signage at heritage sites: An application of the universal design principles *Tourism Recreation Research*, (2022) <https://doi.org/10.1080/02508281.2022.2106099>
24. Kim A.M., Kang K.H.A.: We Are Here: City Signs and Maps in Ethnic Placemaking *Journal of the American Planning Association*, 89, pp. 2–15 (2023) <https://doi.org/10.1080/01944363.2022.2030785>