

Article

Enhancing Accessibility: A Comprehensive Study of Current Apps for Enabling Accessibility of Disabled Individuals in Buildings

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Abstract: In today's digital age, mobile applications have become invaluable tools for enhancing accessibility and inclusivity, especially for individuals with disabilities. This study focuses on the landscape of accessibility apps designed to facilitate inclusivity for disabled individuals in buildings. By investigating current trends, strengths, weaknesses, and their impact on independence and quality of life, the research aims to shed light on the state of these apps and identify areas for future development. To achieve these objectives, a multi-faceted approach was employed, encompassing a literature review and app categorization. The study emphasizes the necessity for a common evaluation and certification framework to ensure consistency, reliability, and transparency in assessing the effectiveness of accessibility apps in the built environment. Such a framework would instill user trust, support informed decision-making, and stimulate innovation in this field. The findings of this research contribute to the advancement of inclusive design practices, serving as a valuable resource for developers, policymakers, and disabled individuals seeking effective tools to enhance accessibility. By fostering an inclusive society where disabled individuals can fully navigate and participate, this study aligns with the broader goal of creating a more inclusive and equitable world.

Keywords: accessibility apps; disabled individuals; design for all; inclusive design; building accessibility; mobile applications



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1. Introduction

In today's rapidly evolving digital age, mobile applications have revolutionized various aspects of our lives, enhancing convenience, connectivity, and productivity. From communication to entertainment, these apps have transformed the way we interact with the world. One crucial area where mobile apps have immense potential is in enabling accessibility for disabled individuals, particularly in buildings. Buildings play a pivotal role in shaping our communities, but they often pose significant challenges for people with disabilities. To bridge this gap, various mobile applications have emerged, aiming to enhance accessibility and empower disabled individuals to navigate and interact with buildings more effectively. People with disabilities often encounter barriers when accessing public and private buildings, limiting their participation in various aspects of life, such as education, employment, and social activities. While architectural modifications and building codes have made significant progress in recent years, the power of technology, specifically mobile applications, holds immense potential for addressing these challenges. Mobile apps designed to enable accessibility in buildings offer features and functionalities that empower disabled individuals to navigate spaces more independently. These apps provide information about accessible entrances, elevators, ramps, and other facilities within a building. They may also offer real-time navigation assistance, accessible routes, and other personalized features to cater to different types of disabilities. Moreover, these applications can provide valuable information regarding building accessibility ratings

and user-generated reviews, enhancing decision making for disabled individuals when choosing accessible destinations.

Design for All is a powerful principle that strives to create an inclusive and equitable society where everyone can participate fully and independently [1]. By embracing the principles of equality, accessibility, usability, flexibility, safety, aesthetics, and user involvement, Apps for disabled people have demonstrated positive effects on navigation, access to information, empowerment, and inclusion. Overcoming challenges such as data accuracy, technical limitations, and interface design will contribute to the continued improvement and effectiveness of accessibility apps. Incorporating emerging technologies and fostering collaboration are potential avenues for enhancing these apps' functionality and impact in the future. Inclusive smart buildings and smart cities have the potential to revolutionize the accessibility and quality of life for people with disabilities. By integrating universal design principles, assistive technologies, real-time information, accessible infrastructure, and inclusive planning, we can create environments that empower individuals with disabilities to fully participate in and contribute to urban life.

The research question that this study addresses is how can the current apps designed to enable accessibility for disabled individuals in buildings be comprehensively investigated to identify their strengths, weaknesses, and potential areas for improvement, while assessing their impact and effectiveness in facilitating inclusive environments?

The aim of this research study is to conduct a comprehensive investigation of the current apps available for enabling accessibility for disabled individuals in buildings. By exploring the existing landscape of such applications, we seek to identify their strengths, weaknesses, and potential areas for improvement. Additionally, we aim to assess the impact and effectiveness of these apps in facilitating inclusive environments and empowering individuals with disabilities.

The primary objectives of this study are as follows:

- (a) To identify and cluster the range of mobile applications currently available for enabling accessibility in buildings.
- (b) To assess the trends of these apps in terms of improving accessibility for disabled individuals.
- (c) To identify potential areas for improvement and future directions for the development of accessibility-focused apps.

The research question that this study addresses is: How can the current apps designed to enable accessibility for disabled individuals in buildings be comprehensively investigated to identify their strengths, weaknesses, and potential areas for improvement, while assessing their impact and effectiveness in facilitating inclusive environments?

To achieve the research objectives, a multi-faceted approach will be employed. Firstly, a literature review will be conducted to gain insights into the existing body of knowledge surrounding accessibility apps for disabled individuals in buildings. Emphasis will be placed on the Design for All concept, the needs and challenges for the apps for disabled people and the inclusive smart buildings and smart cities. This will help establish a theoretical framework and identify key variables for evaluation. Following the literature review, a comparative analysis of different accessibility apps will be conducted, examining their features. The findings of this study will provide an in-depth understanding of the current landscape of mobile applications designed for enabling accessibility in buildings. The research will identify the strengths of these apps and present potential areas for future app development. The study's outcomes will contribute to the advancement of inclusive design practices and serve as a valuable resource for developers, policymakers, and disabled individuals seeking effective tools for enhancing accessibility. By facilitating a more comprehensive understanding of the current state of accessibility-focused apps, this research study aims to promote an inclusive society where disabled individuals can navigate and participate.

The innovative elements of the study include the exploration of the existing landscape of accessibility apps, the assessment of their trends, the effectiveness in improving acces-

sibility for disabled individuals, and identify potential areas for future app development. Additionally, it aims to incorporate the principles of Design for All and explore the potential of inclusive smart buildings and smart cities in revolutionizing accessibility and quality of life for people with disabilities. The multi-faceted approach, combining a literature review and comparative analysis of different accessibility apps, contributes to a comprehensive understanding of the current state of accessibility-focused apps and promotes inclusive design practices.

2. Theoretical Background

2.1. The Design for All Concept

Design for All, also known as Universal Design, is a fundamental principle that advocates for creating products, environments, and services that are accessible and usable by all individuals, regardless of their age, abilities, or disabilities [1]. It aims to eliminate barriers and ensure equal opportunities for everyone to participate fully in society [2]. The Design for All principle goes beyond mere compliance with accessibility standards and seeks to integrate inclusivity as an inherent aspect of design from the outset [3]. In this description, we will explore the key principles and elements of Design for All and highlight its significance in creating a more inclusive and equitable world.

- (a) At the core of Design for All is the principle of equality, recognizing that every individual has the right to participate in all aspects of life on an equal basis [4]. It acknowledges and celebrates diversity, encompassing a wide range of abilities, disabilities, age groups, cultural backgrounds, and personal preferences. By incorporating inclusivity into the design process, barriers are removed, and the needs and preferences of all individuals are considered.
- (b) Design for All places great emphasis on accessibility and usability [5]. Accessibility ensures that individuals with disabilities can access and use products, environments, and services independently and without barriers. This includes considerations such as wheelchair access, tactile signage, visual and auditory aids, and alternative communication methods. Usability focuses on creating designs that are intuitive, user-friendly, and cater to a diverse range of user abilities, ensuring that everyone can interact effectively with the designed object or environment.
- (c) A key aspect of Design for All is flexibility and adaptability [6]. It recognizes that people have different preferences, needs, and abilities, and designs should accommodate these variabilities. Flexibility allows for customization and personalization, enabling individuals to adjust the design to meet their specific requirements. Adaptability ensures that designs can be modified or reconfigured over time to accommodate changing needs, technological advancements, and societal shifts.
- (d) Design for All prioritizes safety and comfort for all users [7]. It considers factors such as ergonomics, stability, and sensory comfort to ensure that designs do not pose risks or discomfort to any user. Safety measures are implemented to protect individuals from potential hazards, and designs are created to minimize physical and psychological strain.
- (e) Design for All recognizes the importance of aesthetics and emotional well-being in creating inclusive designs [8]. It acknowledges that individuals have different sensory preferences and emotional responses to their surroundings. Therefore, designs should be aesthetically pleasing, stimulating positive emotions, and promoting well-being for all users.
- (f) Technology plays a significant role in advancing Design for All principles [9]. Innovative technologies can be harnessed to create inclusive designs that cater to diverse needs. For example, assistive technologies, smart devices, and digital interfaces can enhance accessibility, facilitate communication, and provide personalized experiences. Integrating technology effectively ensures that designs remain relevant and adaptable in a rapidly evolving digital landscape.

- (g) Design for All encourages collaboration and user involvement throughout the design process [10]. It recognizes that the expertise and insights of individuals with disabilities and diverse user groups are invaluable in understanding their needs and preferences. User-centered design approaches involve actively engaging users in the design process, gathering feedback, and incorporating their input to create more effective and inclusive designs.

Designing with consideration for diverse requirements is of paramount importance, especially when it comes to individuals with disabilities or other vulnerabilities who may have specific indoor needs [11]. The built environment must be adaptable and accommodating to cater to the unique requirements of each person [12]. This includes considerations such as accessibility features, lighting conditions, temperature control, acoustics, and spatial layout. By addressing these diverse needs, indoor environments can be optimized to support the comfort, safety, and well-being of all individuals, including those who are more vulnerable or fragile [13]. Designing with an inclusive mindset ensures that everyone can access and navigate indoor spaces comfortably, fostering a sense of belonging and enabling them to thrive in their environments. Through thoughtful design, indoor spaces can be transformed into inclusive and empowering environments that meet the diverse requirements of all individuals [14].

Design for All promotes universal design practices that benefit individuals of all abilities and characteristics. It encourages designers, architects, policymakers, and stakeholders to incorporate inclusivity as an integral aspect of design, ultimately fostering a more accessible and inclusive world for everyone.

2.2. Needs and Challenges in the Development of Apps for Disabled Individuals

Studies have explored the development process of accessibility apps and highlighted key considerations:

- (a) User-Centered Design: Many successful apps employ a user-centered design approach, involving disabled individuals throughout the development process. Engaging users in requirements gathering, usability testing, and feedback sessions helps ensure that the app meets their specific needs and preferences [15].
- (b) Integration of Accessibility Standards: App developers often adhere to established accessibility standards, such as the Web Content Accessibility Guidelines (WCAG). Compliance with these standards ensures that the app is accessible to users with various disabilities and follows best practices for inclusive design [16].
- (c) Collaboration with Building Owners: The literature emphasizes the importance of collaboration with building owners and management to obtain accurate information about building accessibility. Building partnerships allow app developers to access floor plans, identify accessible routes, and gather relevant data for app integration [17].

Research studies have also examined the effectiveness and impact of accessibility apps on disabled individuals in buildings:

- (a) Improved Navigation and Independence: Accessibility apps have demonstrated their effectiveness in improving navigation and wayfinding for disabled individuals. Users reported increased independence and confidence when accessing buildings, leading to enhanced participation in activities [18].
- (b) Enhanced Access to Information: Apps provide valuable information about accessible entrances, elevators, restrooms, and other facilities within buildings. Users appreciate having this information readily available, which allows them to plan their visits more effectively [19].
- (c) Empowerment and Inclusion: Accessibility apps contribute to the empowerment and inclusion of disabled individuals. By overcoming physical barriers and providing access to building facilities, these apps enable users to participate more fully in social, educational, and employment activities [20].

The literature also identifies several challenges associated with accessibility apps for disabled individuals in buildings:

- (a) **Data Accuracy and Timeliness:** Maintaining up-to-date and accurate data about building accessibility poses challenges. App developers need mechanisms to ensure data accuracy and timely updates, especially in dynamic environments where changes occur frequently [21].
- (b) **Technical Limitations:** Technical limitations, such as limited GPS accuracy indoors, can affect the performance of accessibility apps [22]. Developers must explore alternative positioning technologies, such as Bluetooth beacons or Wi-Fi positioning, to enhance location accuracy indoors.
- (c) **Usability and Interface Design:** Designing an intuitive and user-friendly interface for accessibility apps is crucial. Developers need to consider the diverse needs and preferences of disabled individuals, ensuring that the app is easy to navigate and understand for users with varying abilities [23].

The literature review highlights potential areas for improvement in accessibility apps:

- (a) **Integration of Emerging Technologies:** Exploring the integration of emerging technologies, such as artificial intelligence, machine learning, and augmented reality, can enhance the functionality and user experience of accessibility apps [24]. These technologies can provide personalized recommendations, real-time information, and interactive guidance.
- (b) **Gamification and Incentives:** Incorporating gamification elements and incentives within accessibility apps can encourage engagement and motivate users to utilize the app regularly [25]. Rewards, challenges, and social features can create a more engaging and interactive experience.
- (c) **Enhanced Collaboration and Data Sharing:** Building stronger collaborations between app developers, building owners, disability organizations, and users can facilitate the sharing of accurate and comprehensive data [26]. This collaboration can contribute to more robust and up-to-date information within the app.

User-centered design plays a crucial role in the development of applications for disabled people to enhance their accessibility to the built environment [27]. It involves actively involving disabled individuals in the design process, ensuring their needs, preferences, and capabilities are considered. By conducting user research and usability testing, designers can gather valuable insights to create inclusive and intuitive interfaces. User-centered design also emphasizes the importance of iterative design and continuous improvement based on user feedback, ultimately leading to more effective and empowering applications for disabled individuals to navigate and participate fully in the built environment [28].

The needs and challenges for apps for disabled individuals are summarized in Figure 1.

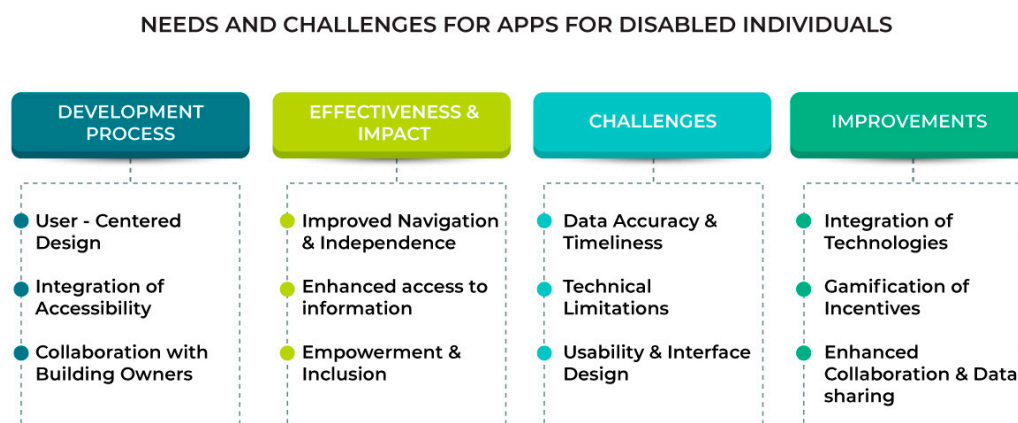


Figure 1. Needs and challenges for apps for disabled individuals.

2.3. Inclusive Smart Buildings and Smart Cities: Enhancing Accessibility for People with Disabilities

In recent years, the concept of inclusive smart buildings and smart cities has gained significant attention, aiming to create environments that are accessible and supportive for all individuals, including those with disabilities. The integration of technology and infrastructure can play a crucial role in enhancing accessibility and enabling smooth mobility for people with disabilities.

The inclusive elements of smart buildings include:

- (a) Inclusive smart buildings should incorporate universal design principles, ensuring that the physical environment, infrastructure, and technologies are usable by all individuals, regardless of their abilities [29]. This includes features such as ramps, accessible entrances, wide doorways, adjustable-height counters, and tactile indicators for individuals with visual impairments.
- (b) Integrating assistive technologies within smart buildings can greatly enhance accessibility [30]. For example, voice-activated controls, smart lighting systems, and automated doors can assist people with mobility impairments. Braille signage, audio guidance systems, and accessible touchscreen interfaces can facilitate navigation for individuals with visual impairments.
- (c) Smart buildings should provide real-time information and communication services to assist people with disabilities [31]. This can include digital signage with visual and auditory information, mobile applications with accessible interfaces, and communication systems that support multiple modalities, such as text, voice, and video.
- (d) Addressing sensory needs is crucial for individuals with disabilities. Smart buildings should incorporate features such as acoustic treatments to reduce noise levels, tactile surfaces for individuals with visual impairments, and lighting systems that account for different sensitivities. Educational buildings are a good example of the application of these practices [32]. The evolution of inclusive design in architecture for individuals on the autistic spectrum, highlighting the use of smart sensor systems to achieve independent living and ensure safety, privacy, and proper support for relatives and caregivers, has already been highlighted [33].

Shifting from the scale of smart buildings to smart cities, the needs for inclusiveness at that level include:

- (a) Smart cities should prioritize the development of accessible infrastructure, including well-designed sidewalks, ramps, and crosswalks that cater to the needs of individuals with disabilities [34]. Accessible public transportation systems, with features such as low-floor buses, audio and visual announcements, and wheelchair-friendly vehicles, are also essential.
- (b) Ensuring digital inclusion is vital for people with disabilities [35]. Smart cities should offer accessible online platforms, mobile applications, and digital services that can be easily navigated and utilized by individuals with various disabilities. This includes accessible websites, screen reader compatibility, and captioning for audio and video content.
- (c) Data-driven Accessibility Planning: Smart cities can leverage data analytics and real-time monitoring to identify areas of improvement for accessibility [36]. By gathering data on foot traffic, transportation patterns, and accessibility issues, city planners can make informed decisions to enhance accessibility and allocate resources effectively.
- (d) Smart cities should foster inclusive public engagement by involving people with disabilities in the planning and decision-making processes [37]. Engaging with disability advocacy groups, conducting accessibility audits, and seeking input from individuals with disabilities can lead to the creation of more inclusive urban environments.

All major aspects of inclusive smart buildings and smart cities are depicted in Figure 2.

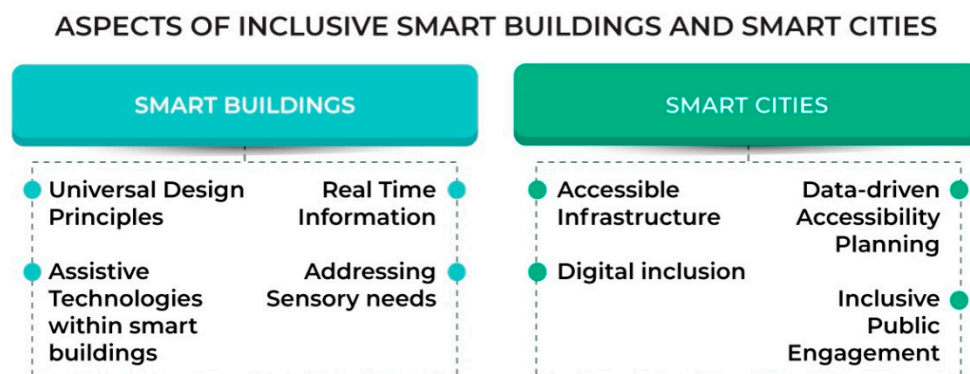


Figure 2. Aspects of inclusive smart buildings and smart cities.

Inclusive smart buildings and smart cities have the potential to revolutionize the accessibility and quality of life for people with disabilities. By integrating universal design principles, assistive technologies, real-time information, accessible infrastructure, and inclusive planning, we can create environments that empower individuals with disabilities to fully participate in and contribute to urban life.

2.4. Research Initiatives for an Inclusive Built Environment

The European Union has recognized the importance of inclusiveness in the built environment and has actively invested research grants to develop expertise in this area. These grants aim to advance knowledge and understanding of creating accessible spaces for individuals with disabilities. The EU's commitment to promoting inclusiveness highlights its dedication to improving the quality of life and equal opportunities for all individuals within the built environment. In this section, we will present some of the research initiatives supported by these grants, shedding light on the progress made towards enhancing inclusiveness in the built environment. In this section, we will present remarkable advancements achieved through EU-funded research projects aimed at enhancing inclusiveness and accessibility of the built environment for disabled individuals. These pioneering initiatives have revolutionized assistive technologies, ensuring equal opportunities and independence for all. From innovative accessibility features in public spaces to inclusive housing designs and smart solutions for mobility, these projects showcase the EU's commitment to creating inclusive societies.

- (a) The Web Accessibility Directive Decision Support Environment (WADcher) project featured a large-scale accessibility assessment infrastructure, incorporating a robust framework for assessing the accessibility of web content [38]. Developers and designers were able to leverage the tool's advanced decision support features to create accessible assets. The tool also combined automatic and expert reviews on a web accessibility observatory platform, providing comprehensive accessibility insights.
- (b) The project ICT for smart and personalized inclusion included user profiling standards and tools, capturing individual needs and preferences to ensure personalized accessibility solutions [39]. Cloud, crowd, game, and smart technologies were leveraged to involve a diverse range of stakeholders in the development and delivery of accessible solutions.
- (c) The cloud platforms Lead to Open and Universal access for people with Disabilities and for All (CLOUD4all) project adopted the concept of the Global Public Inclusive Infrastructure (GPII), providing accessibility solutions tailored to each individual's unique requirements [40]. The tool automatically matched and modified mainstream and specialized technologies to cater to users' specific needs.
- (d) The Virtual and Augmented Environments and Realistic User Interactions To achieve Embedded Accessibility DesignS (VERITAS) project incorporated an Open Simulation Platform (OSP), which served as an open framework for simulation-based testing and

compliance with accessibility guidelines [41]. Detailed virtual user models and simulation environments were developed to simulate users' physical, cognitive, behavioral, and psychological characteristics for testing accessibility.

- (e) Open Accessibility Everywhere: The Groundwork, Infrastructure, Standards (ÆGIS) project integrated the Open Accessibility Framework (OAF), making accessibility open, configurable, and applicable in various contexts [42]. The project followed a user-centered design (UCD) approach, prioritizing user needs and interaction models to ensure inclusivity.
- (f) The Accessibility Assessment Simulation Environment for New Applications Design and Development (ACCESSIBLE) project incorporated a harmonized accessibility methodology for assessing accessibility in software design and development [43]. It provided an assessment simulation environment with a suite of accessibility analyzing tools and developer-aid tools for efficient evaluation of software applications.

In conclusion, recent research activities focused on key areas such as web content accessibility assessment, personalized accessibility solutions, and tailoring accessibility to individual needs. They introduced innovative approaches such as decision support features for developers, user profiling for personalized solutions, and the utilization of the Global Public Inclusive Infrastructure (GPII) concept. Additionally, these projects emphasized the importance of user-centered design, open accessibility frameworks, and harmonized methodologies to ensure inclusivity in software development and evaluation. Collectively, they have contributed to advancing accessibility and fostering an inclusive digital environment.

3. Methodology

This research study employs a mixed-methods research design to achieve its objectives. The study incorporates both qualitative and quantitative approaches to provide a comprehensive understanding of the current landscape of mobile applications designed for enabling accessibility in buildings. The qualitative component includes a literature review and comparative analysis of different accessibility apps, while the quantitative component involves analyzing user feedback and app ratings.

A systematic literature review was conducted to gain insights into the existing body of knowledge surrounding accessibility apps for disabled individuals in buildings. The literature review encompassed scholarly articles, conference papers, reports, and relevant publications in the field. Emphasis was placed on the Design for All concept, the needs and challenges for the apps for disabled people, and the inclusive smart buildings and smart cities. The literature review provided a theoretical framework for the study and helped identify key variables for evaluation.

A comparative analysis was performed to evaluate different accessibility apps available for enabling accessibility in buildings. A diverse range of apps was selected based on their popularity, user ratings, and relevance to the study objectives. The analysis focused on assessing the strengths and weaknesses of these apps in terms of features, user experience, navigational capabilities, and accessibility-related functionalities. User reviews, and official app documentation was analyzed to understand user satisfaction and app effectiveness. Data for the comparative analysis was collected from various sources, including user reviews, and official app documentation. App store ratings and reviews were collected from popular platforms. User feedback and reviews provided valuable insights into the user experience, effectiveness, and impact of the accessibility apps. Official app documentation, including app descriptions and features, was analyzed to understand the capabilities of each app.

The apps were selected through a systematic approach that involved several steps. Initially, a comprehensive search was conducted to identify a wide range of accessibility apps designed for enabling accessibility in buildings. The search included app stores, academic databases, and relevant online resources. The identified apps were then screened based on predefined inclusion and exclusion criteria. These criteria may have considered

factors such as relevance to the research objectives, popularity, user ratings, availability, and functionality. The final selection of apps included in the review was determined through consensus among the research team. The aim of the selection process was to include a diverse and representative set of applications that cover various aspects of enabling accessibility in buildings. However, it is important to note that the representativeness may depend on the specific criteria and availability of apps at the time of the study. While efforts were made to include a broad range of apps, it is possible that certain apps or categories may have been underrepresented or omitted. The limitations and generalizability of the selected apps should be discussed in the manuscript to provide a clear understanding of the sample. The selection of these applications was primarily driven by their relevance to the research objectives and the aim of assessing the current landscape of accessibility apps for enabling accessibility in buildings. The chosen apps were expected to provide insights into the strengths, weaknesses, and potential areas for improvement in existing accessibility-focused apps. Additionally, the selected apps may have represented different features, functionalities, target user groups, or innovative approaches in enhancing accessibility. A more detailed rationale for selecting these specific applications should be provided in the manuscript to provide transparency and justify the choices made.

The collected data were analyzed using qualitative and quantitative methods. Qualitative data from user reviews and app documentation were thematically analyzed to identify common patterns, strengths, and weaknesses of the accessibility apps. Quantitative data, such as app store ratings, were analyzed to evaluate user satisfaction and app effectiveness. The data analysis provided a comprehensive understanding of the strengths, weaknesses, and impact of the accessibility apps. Ethical considerations were adhered to throughout the research process. The study prioritized user privacy and confidentiality by anonymizing user feedback and not disclosing any personally identifiable information. App store ratings and reviews, which were publicly available, were used for analysis in an ethical manner. Additionally, the research study followed ethical guidelines and regulations regarding data collection and analysis.

There were several limitations to consider in this study. Firstly, the evaluation of accessibility apps was limited to the apps available in the selected app stores. Not all apps were included in the analysis due to availability or compatibility issues. Secondly, the study's findings were influenced by the subjective nature of user reviews and app store ratings. Thirdly, the study's scope focused on mobile applications for building accessibility and did not encompass all aspects of accessibility for disabled individuals. Despite these limitations, the study aims to provide valuable insights into the current landscape of accessibility apps and their impact on enhancing accessibility in buildings.

4. Results and Discussion

4.1. Exploring the Landscape: Apps for Inclusive Living and Support

In the scope of this study, a comprehensive review was conducted on 25 apps that facilitate open accessibility for individuals with disabilities. The 25 apps listed below are designed to assist individuals with chronic conditions and disabilities in various aspects of their lives. These apps cover a wide range of functionalities, including task management, accessibility information, health and fitness tracking, communication, medication management, mindfulness and mental well-being, navigation, assistance with daily activities, and more.

1. Access Now [44]: App to find accessible places for people with physical disabilities.
2. Assistive Touch: App for individuals with physical disabilities to perform device functions with customized gestures.
3. Audible [45]: Audiobook and podcast app for reading or listening to books.
4. Be My Eyes [46]: App connecting blind or visually impaired individuals with sighted volunteers for assistance.
5. Cognifit [47] Cognifit (2023), <https://www.cognifit.com/> Last accessed 23 May 2023: Brain training app with exercises to improve cognitive functions like memory and logic.

6. Curable [48]: Virtual pain coach app that offers exercises and resources to manage chronic pain.
7. Flaredown [49] Flaredown (2023), <https://flaredown.com/> Last accessed 23 May 2023: App for tracking symptoms, treatments, and triggers related to chronic illnesses.
8. Fuel Service [50]: App to assist drivers with disabilities in finding gas stations that provide assistance.
9. Glimmer [51]: Inclusive dating app that promotes transparency and welcomes people with disabilities.
10. Google Maps [52] Google Maps (2023), <https://www.google.com/maps/> Last accessed 23 May 2023: Navigation app with accessibility features, including information on wheelchair accessibility and routes.
11. Google Voice [53]: Hands-free accessibility app for voice commands and phone operation.
12. Happify [54]: App promoting happiness through mindfulness and positive psychology techniques.
13. ICE [55] ICE (2023), <http://icecontact.com/> Last accessed 23 May 2023: In Case of Emergency app to store personal and medical information for first responders.
14. IFTTT [56]: App for automating tasks and connecting different apps and devices.
15. Instacart [57]: Grocery delivery app for convenience and accessibility.
16. Lyft [58] Lyft (2023), <https://www.lyft.com/> Last accessed 23 May 2023: Ride-hailing app with wheelchair-accessible vehicle options and assistance for people with disabilities.
17. Medisafe [59]: Medicine reminder app for managing medications and tracking prescriptions.
18. My Fitness Pal [60]: App for tracking nutrition, water intake, and workouts for overall health management.
19. ReLeaf [61] Releaf (2023), <https://releafapp.com/> Last accessed 23 May 2023: App for tracking and sharing results of medical cannabis treatments for pain relief.
20. Remember The Milk [62]: Task management app for better organization and memory assistance.
21. Roger Voice [63]: App enabling real-time transcription of phone conversations for individuals who are deaf or hard of hearing.
22. Sleep Cycle [64] Sleep Cycle (2023), <https://www.sleepcycle.com/> Last accessed 23 May 2023: Sleep tracking app that monitors sleep patterns and wakes users during their lightest sleep phase.
23. Stop, Breathe, Think [65] Mindfulness and meditation app for emotional well-being.
24. Sworkit [66]: Fitness app offering a variety of workout routines with options for modification.
25. Think Dirty [67]: App to determine the toxicity level of personal care products based on ingredients.

Categorizing the apps based on their main functions, we can cluster them into the following categories:

- (a) Task Management and Organization (Access Now, Remember the Milk): This cluster includes apps that assist users in managing tasks, lists, and improving productivity.
- (b) Health and Well-being (Cognifit, Curable, Flaredown, Happify, My Fitness Pal, ReLeaf, Sleep Cycle, Sworkit, Think Dirty): The apps in this cluster focus on various aspects of health and well-being, such as managing chronic pain, tracking nutrition and exercise, monitoring sleep patterns, promoting positivity, assessing product safety, offering customizable workouts, and improving cognitive function.
- (c) Accessibility and Communication (Be My Eyes, Fuel Service, Google Maps, ICE, Lyft, Roger Voice): This cluster comprises apps that enhance accessibility and facilitate communication for individuals with disabilities. They assist in finding accessible gas stations, provide real-time transcription for deaf individuals during phone conversations, connect blind or low vision individuals with sighted volunteers for assistance,

store personal and medical information for emergency situations, offer accessibility features in navigation apps, and provide accessible transportation options.

- (d) **Daily Living and Assistance** (Assistive Touch, Glimmer, Google Voice, IFTTT, Instacart): Apps in this cluster aim to simplify daily tasks and provide assistance in various areas of life. They include apps for grocery shopping, performing smartphone functions with customized gestures, automating tasks, and connecting various apps for enhanced accessibility and convenience, operating smartphones through voice commands, and an inclusive dating app that welcomes individuals with disabilities.

An overview of the classification of apps for disabled individuals is presented in Figure 3.



Figure 3. Apps for disabled individuals.

The trends in apps used for enhanced accessibility to the built environment can be categorized as follows:

- Accessibility:** A significant focus is placed on apps that provide accessibility information, navigation assistance, and transportation services to support individuals with disabilities in navigating the built environment.
- Health Tracking and Management:** Many apps are dedicated to helping users track and manage their health conditions. These apps allow individuals to monitor chronic pain, symptoms, medications, and overall well-being, empowering them to take control of their health.
- Mindfulness and Mental Health:** The recognition of mental well-being as a crucial component of overall health is reflected in the prevalence of apps dedicated to mindfulness, meditation, and promoting positive thinking. These apps aim to foster mental resilience and well-being.
- Personal Assistance and Automation:** Apps like Instacart and IFTTT offer personal assistance and automation, simplifying daily tasks and processes. These apps enhance convenience and accessibility for individuals with disabilities, providing support and streamlining various aspects of their lives.

4.2. Expanding Horizons: Innovations in Apps for Inclusive Accessibility

The current landscape of apps catering to individuals with disabilities encompasses a wide array of functionalities. However, there are still notable gaps and untapped potential in several areas that present opportunities for the development of new applications. These areas include assistive technologies, social support and community building, personalized healthcare management, employment and career support, accessibility in public spaces, and education and learning. The apps for inclusive accessibility can be clustered as follows:

- One area that holds immense potential for innovation is assistive technologies. While existing apps have made significant strides in improving accessibility, there remains room for the development of innovative assistive technologies tailored to specific

disabilities or conditions. For instance, smart devices that cater to individuals with motor impairments can greatly enhance their ability to navigate and interact with their environment. Similarly, communication tools for nonverbal individuals can facilitate their expression and interaction with others. By focusing on these specific needs, developers can create apps that address the unique challenges faced by individuals with disabilities, ultimately improving their quality of life.

- (b) Social support and community building is another critical area where apps can make a substantial impact. These apps can serve as platforms that foster connections among individuals with disabilities, enabling them to form supportive communities. By providing a space for sharing experiences, offering support, and exchanging valuable information, these apps can help combat social isolation and promote a sense of belonging. Through features like forums, chat functionalities, and events, individuals with disabilities can connect with others who share similar experiences and find comfort in a supportive network.
- (c) Personalized healthcare management is an area where apps can greatly contribute to improving the well-being of individuals with disabilities. By leveraging data and user input, these apps can offer personalized health management plans and recommendations. For example, an app could track and monitor vital health indicators, provide reminders for medication intake, and offer tailored exercise routines. By taking into account individual conditions, treatments, and responses, these apps can empower individuals to take an active role in managing their health and well-being.
- (d) Employment and career support is another crucial aspect that can benefit from app development. Apps focused on providing career guidance, job search assistance, and accommodations for individuals with disabilities can help bridge the gap between employers and prospective employees. These apps can offer resources such as job listings that specifically cater to individuals with disabilities, guidance on navigating the recruitment process, and information on workplace accommodations. By facilitating access to employment opportunities and empowering individuals with disabilities to showcase their skills and talents, these apps can contribute to greater inclusivity in the workforce.
- (e) Improving accessibility in public spaces is a pressing concern for individuals with disabilities. Apps can play a vital role in providing comprehensive information on the accessibility of public spaces, including buildings, public transportation, and recreational areas. These apps can offer real-time updates on accessibility features, such as ramps, elevators, and accessible restrooms, enabling individuals to plan their activities and navigate their surroundings with greater ease. By promoting awareness and advocating for improved accessibility standards, these apps can contribute to creating more inclusive and accommodating environments for everyone.
- (f) Education and learning opportunities for individuals with disabilities can also be enhanced through the development of specialized apps. These apps can facilitate accessible education by providing interactive learning materials, customizable accessibility features, and tailored learning plans. By leveraging multimedia elements, such as audio descriptions and closed captions, these apps can cater to diverse learning styles and accommodate various disabilities. Additionally, features like progress tracking and personalized feedback can support individuals in their educational journey and foster a more inclusive learning environment.

4.3. The Need for a Common Evaluation and Certification Framework for Accessibility and Inclusiveness in the Built Environment

The results of the study examining the characteristics of mobile applications aimed at improving accessibility for individuals with disabilities, emphasize the necessity of establishing a universal framework for evaluating and certifying the inclusiveness and accessibility of physical spaces. While these apps demonstrate potential in enhancing

accessibility, their effectiveness varies greatly. Therefore, it is crucial to adopt a standardized method for assessing and certifying their impact.

Firstly, a common evaluation and certification framework would address the current lack of consistency and reliability in assessing the accessibility features of these apps. The study's findings may reveal inconsistencies in terms of features, user experience, and effectiveness among the analyzed apps. A standardized framework would provide clear criteria and guidelines for evaluating the accessibility and inclusiveness of the built environment, enabling developers and policymakers to ensure that the apps meet minimum standards and provide meaningful support to disabled individuals.

Furthermore, a common framework would facilitate transparency and trust in the evaluation process. Currently, users rely heavily on app store ratings and user reviews, which may not always reflect accurate or comprehensive assessments of accessibility features. With a standardized evaluation and certification framework, users could have access to reliable and verified information about the accessibility of the apps. This would empower disabled individuals to make informed decisions about which apps to use based on their specific needs and preferences.

Additionally, a common framework would foster innovation and improvement in the development of accessibility apps. By establishing a baseline of evaluation criteria, developers would have a clear understanding of the essential features and functionalities required to enhance accessibility. This would encourage the creation of more inclusive and user-friendly apps, leading to continuous advancements in the field.

4.4. Limitations of the Study

The study, nevertheless, has some limitations that should be considered. Firstly, its scope and generalizability may be limited since it focuses on a specific subset of accessibility apps designed for buildings, potentially restricting its applicability to other contexts or types of disabilities. Secondly, there might be an app selection bias in the comparative analysis of different apps, as the researcher's selection criteria could influence the evaluation process, introducing potential bias. Additionally, the study may not fully explore the long-term impact of accessibility apps on users' independence and quality of life, which is essential for understanding their sustained benefits. Rapid advancements in technology could also pose a challenge, as certain app assessments may become outdated over time, potentially making some of the study's findings less relevant. Additionally, the number of apps included in the study is relatively small, which may affect the robustness of the findings. Although the research proposes the need for a common evaluation and certification framework, it may not thoroughly delve into the challenges and potential limitations associated with implementing such a framework. Furthermore, ethical considerations should be addressed, especially if the study involves the privacy of app users or sensitive data. If the literature review primarily focuses on studies published in specific languages or regions, there may be potential language or geographic bias in the findings, limiting the study's inclusivity and representation. Depending solely on the existing literature may be a limitation as well, as it could restrict the identification of emerging trends or novel insights not yet documented in previous studies. Lastly, the study may not explicitly mention involving disabled individuals in the design or evaluation process of accessibility apps, potentially missing out on valuable perspectives that could enhance the research.

5. Conclusions and Future Work

This research study aimed to investigate the landscape of mobile applications designed to enhance accessibility for disabled individuals in buildings. The study identified trends, evaluated existing accessibility apps, and assessed their impact on inclusivity and empowerment for disabled individuals. Through a multi-faceted approach including a literature review and comparative analysis, several key findings emerged. The literature review provided valuable insights into the main aspects of the Design for All concepts, as well as for the development, effectiveness, challenges, and potential areas for improvement

of accessibility apps for disabled individuals in buildings. User-centered design, integration of accessibility standards, and collaboration with building owners were defined to be crucial for successful app development. The article also discusses the essential features required in inclusive smart buildings and smart cities to ensure a seamless experience for individuals with disabilities, fostering their full participation in urban life. A collection of remarkable advancements implemented through EU-funded research projects, focusing on enhancing inclusiveness and accessibility of the built environment for disabled individuals was also implemented. The methodology of this research study combined qualitative and quantitative approaches to investigate the current landscape of mobile applications designed for enabling accessibility in buildings. The research findings will contribute to the advancement of inclusive design practices and serve as a valuable resource for developers, policymakers, and disabled individuals seeking effective tools for enhancing accessibility.

While the current landscape of apps for individuals with disabilities is extensive, there are still opportunities for growth and improvement. By focusing on areas such as assistive technologies, social support and community building, personalized healthcare management, employment and career support, accessibility in public spaces, and education and learning, developers can create innovative apps that address specific needs and enhance the lives of individuals with disabilities. These apps have the potential to foster inclusivity and empower people with disabilities.

The findings of the study analyzing the features of apps for disabled accessibility in buildings, highlight the importance of developing a common evaluation and certification framework for the accessibility and inclusiveness of the built environment. While mobile applications have shown promising potential in enhancing accessibility, their effectiveness can vary significantly, and there is a need for a standardized approach to evaluate and certify their impact.

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