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Promoting accessibility and social inclusion in smart cities: a gamification approach

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Resumo

As pessoas com deficiência continuam a carecer de igualdade de acessibilidade e mobilidade nas cidades. Nem todas as instalações, rotas ou modos de transporte, como viajar de comboio, carro ou a pé, são acessíveis a pessoas com mobilidade reduzida. Rampas íngremes, degraus, pedregulhos e outras coberturas irregulares de vias são, por vezes, intransitáveis para pessoas com mobilidade reduzida ou de cadeiras de rodas, o que pode resultar em lugares inacessíveis e insatisfação ao tentar chegar a um local ou destino específico. Esta tese é um componente do tema "Smart Cities", cujo objetivo principal é incorporar os conceitos de mobilidade, sustentabilidade e digitalização, a fim de melhorar a qualidade de vida das pessoas em todo o mundo. Este estudo tem como objetivo criar uma ferramenta educacional que eduque e alerte os utilizadores sobre os obstáculos que as pessoas com deficiência experimentam diariamente. Somos levados a aprender com estímulos poderosos, envolventes e inovadores no mundo de hoje; assim, tentamos criar uma nova técnica para a educação de adultos. Quando comparado com abordagens tradicionais, o uso de jogos sérios melhora os resultados de aprendizagem de forma mais eficaz. Educando a população em geral sobre possíveis obstáculos, como um carro estacionado em cima da calçada que dificulta a mobilidade dos utilizadores de cadeiras de rodas, esta dissertação irá beneficiar pessoas com defeciências.

Esta solução gamificada visa sensibilizar a população em geral para a dificuldade de mobilidade e acessibilidade adotando comportamentos mais responsáveis no seu dia a dia. Contribuir para o desenvolvimento de "Smart Cities", criando uma cidade sem barreiras onde todos possam contribuir, melhorar a qualidade de vida de muitas pessoas com deficiência e considerar o futuro do planeamento urbano.

Para desenvolver esta solução, começamos com uma revisão sistemática da literatura, selecionando os registros relevantes e, em seguida, incluindo-os em uma lista para leitura adicional, ficando com um total de 22 documentos.

A definição do identificador de barreiras BarrierBeGone, foi baseada numa metodologia de Design Centrado no Utilizador, que consistiu num ciclo de três interações que abrangeu três fases distintas: recolha de requisitos, design e desenvolvimento, e avaliação. Esta metodologia enfatizou fortemente a interação entre o sistema e o seu utilizador final.

Este conhecimento foi complementado por uma investigação aprofundada sobre as variáveis que afetam a acessibilidade e inclusão social em cidades inteligentes, realizada através de entrevistas com um grupo de cinco indivíduos com mobilidade reduzida, o que levou à definição dos requisitos iniciais do sistema.

Posteriormente, o conceito de um sistema de identificação de barreiras foi desenvolvido e iniciou-se o processo de design e desenvolvimento do sistema. Para medir a usabilidade da plataforma proposta, foram aplicadas técnicas de avaliação de usabilidade, através de testes com nove utilizadores representativos.

No geral, os resultados da avaliação da usabilidade do identificador de barreiras BarrierBeGone são indiscutivelmente favoráveis. Todas as partes interessadas concordaram com a utilidade

e simplicidade da plataforma. O sistema foi disruptivo devido à sua utilidade e simplicidade, o que serviu como principal incentivo para o seu uso futuro.

Com base no sucesso dos objetivos desta dissertação, é possível alcançar o objetivo final de aumentar a acessibilidade e a inclusão social em cidades inteligentes, proposto para este projeto.

Abstract

People with disabilities continue to lack equal accessibility and mobility in cities. Not every facility, route, or mode of transportation, such as travel by train, car, or foot, is accessible to people with mobility impairments. Steep ramps, steps, bouldering, and other uneven pathway covering are sometimes impassable for mobility-impaired or wheelchair users, which might result in inaccessible places and dissatisfaction when attempting to reach a specific location or destination. This thesis is a component of the smart cities subject, whose major objective is to incorporate the concepts of mobility, sustainability, and digitization in order to enhance the quality of life for people throughout the globe.

This study aims to create an educational tool that educates and alerts players about the obstacles that disabled people experience on a daily basis. We are pushed to learn from powerful, engaging, and innovative stimuli in today's world; thus, we attempt to create a new technique for adult learning. When compared to traditional approaches, the usage of serious games improves learning outcomes more effectively. By educating the general population about potential obstacles, such as a car parked on top of the sidewalk hindering wheelchair users' mobility, this dissertation will benefit persons with disabilities. This gamified solution aims to make the general population aware of the difficulty of mobility and accessibility that people with wheelchairs have on a daily basis to adopt more responsible behaviors. Contributing to the development of smart cities, creating a city without barriers where everyone can contribute, enhancing the quality of life for many persons with disabilities, and considering the future of city planning.

To develop this solution, we start with a systematic literature review, selecting the relevant records and then including them in a list for further reading, finishing with 22 documents.

The definition of the proposed barrier identification was based on a User Centered Design methodology, which consisted of a cycle of three interactions covering three distinct phases: requirements gathering, designing and development, and evaluation. This methodology placed a strong emphasis on the interaction between the system and its end user.

This knowledge was supplemented by an in-depth investigation into the variables that affect accessibility and social inclusion in smart cities, applied through interviews with a group of five individuals with mobility impairments, which led to the definition of initial system requirements.

Subsequently, the concept of a barrier identification system was built and its design and development process started. system. To measure the usability of the proposed platform, the evaluation technique of usability tests was applied, with nine representative users.

Overall, the BarrierBeGone barrier identifier evaluation usability results are unquestionably favorable. The stakeholders all agreed on the platform's utility and simplicity. The system was disrupted by its utility and simplicity, which served as the primary driver of intended use in the future.

Reputing the success of the objectives of this dissertation, the final objective of increasing the accessibility and social inclusion in smart cities, proposed for this project, is achievable.

Acknowledgements

First and foremost, I want to thank Professor Marta Campos Ferreira, Professor Joana Campos, and Professor Carla Fernandes for serving as this dissertation's adviser and co-advisor, respectively. I appreciate their high standards and rigor as well as the opportunity, interest, understanding, and availability they have demonstrated during all phases of this project. I also want to express my gratitude to everyone who has supported the growth of this project by lending their expertise and availability to this research.

I want to extend a sincere appreciation to all of my friends for being there for me at every stage of my academic career and for their advice and support.

Last but not least, I would like to extend a very special thank you to my family, especially my parents and siblings, for their encouragement, compassion, and above all, for all of the possibilities they have given me throughout my journey.

"If the place does not allow access to all people, this place is disabled "

Thaís Frota

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Listings

Abreviaturas e Símbolos

PWDs	People with Disabilities
UCD	User Centered Design
GPS	Global Positioning System
SDK	Software Development Kit
3G	Third-Generation
4G	Fourth-Generation
Wi-Fi	Wireless Fidelity,

Chapter 1

Introduction

1.1 Context

The topic of accessibility for people with mobility disabilities is an important and timely one. Mobility disabilities can significantly impact an individual's ability to move around and participate in society, and it is essential that our cities and communities are designed and built to be inclusive and accommodating to the needs of all residents.

The concept of smart cities revolves around using technology and data to enhance the quality of life for residents, improve sustainability, and optimize urban services [16]. As cities become more digitally connected and data-driven, there is an opportunity to leverage these advancements to promote accessibility for all individuals, including those with disabilities. Smart city initiatives can integrate assistive technologies, accessible infrastructure, and inclusive design principles to create an environment that caters to the diverse needs of its inhabitants. Despite the potential benefits of smart cities for promoting accessibility and social inclusion, there are several challenges to overcome[38]. These challenges include addressing digital divides, ensuring affordability and accessibility of smart technologies, and considering the needs of marginalized or under served populations. Additionally, smart city initiatives must actively involve individuals with disabilities and other stakeholders to avoid unintentional exclusion and ensure that solutions meet real-world needs[38].

1.2 Problem definition and motivation

Cities are responsible for being more inclusive and accessible for all their residents, including people with mobility disabilities. The European Accessibility Act (Directive 2019/882) is a landmark EU law that requires some everyday products and services to be accessible for persons with disabilities[3]. This way, all the cities have a legal obligation to build their environments more accessible. Thus, they enable people with disabilities to participate fully in society and live with dignity and independence, providing more social justice [3]. Although renovating their environs might be costly, accessible cities can attract a greater range of enterprises and tourists, as well as maintain a highly qualified workforce, improving the quality of life for all people, not just those with disabilities, by promoting active and healthy lifestyles, decreasing traffic congestion, and improving the city's general livability.

Technological solutions are increasingly being used to address a variety of challenges faced by people with mobility disabilities, including technologies around navigation and transportation, generally mobile apps including GPS systems or crowdsourced based, providing real-time information on accessible routes and transportation options with tips and ratings[17]. In addition, there are accessibility information apps providing information about the accessibility of buildings and streets more focused on the faster path to a specific destination, not focusing on the city's accessibility or identifying barriers, and this way negatively affects people with disabilities.

The lack of solutions to identify barriers affecting people with disabilities is a significant issue in our society. People with disabilities face numerous challenges in their daily lives that can limit their ability to access their destinations[38]. Despite some efforts to address these issues, there is still a significant gap in identifying and solving the barriers that affect people with disabilities. This means that many people with disabilities face barriers preventing them from fully participating in society and achieving their full potential. It is crucial to raise awareness of the barriers in the population that impact people with disabilities and to create and practice effective ways to remove them to help cities to become more socially inclusive and accessible.

The problem at hand is the lack of effective solutions to identify and address barriers that hinder the full participation and inclusion of people with mobility disabilities in society, particularly within cities. Despite the existence of the European Accessibility Act (Directive 2019/882)[3], and other efforts to promote accessibility, there remains a significant gap in ensuring that cities are truly accessible for all their residents, including those with disabilities.

- **Inadequate Accessibility Information:** The current accessibility information apps and navigation technologies are insufficient in providing comprehensive data on the accessibility of cities. While some apps focus on the fastest route to a specific destination, they fail to highlight potential barriers and obstacles faced by people with disabilities, making it difficult for them to plan their journeys effectively[16].

- **Limited Barrier Identification:** Cities often lack systematic methods or technologies to identify and address physical and environmental barriers that impact people with mobility disabilities. This results in the persistence of inaccessible infrastructure, buildings, and public spaces, making it challenging for individuals with disabilities to move freely and participate fully in various activities[36].

- **Social Exclusion and Reduced Quality of Life:** The presence of barriers leads to social exclusion and limited opportunities for people with disabilities to engage in educational, employment, recreational, and social activities. As a result, they may face isolation, reduced quality of life, and limited access to essential services and resources[38].

The problem definition revolves around the need for comprehensive and innovative technological solutions that can effectively identify and address barriers faced by people with mobility disabilities within cities. These solutions should go beyond simple navigation and provide real-time accessibility information, route planning, and crowd-sourced data to create more socially inclusive and accessible urban environments.

In order to solve the problem defined in this project, its presented a mobile application BarrierBeGone, a system that identifies potential barriers for people with mobility disabilities.

1.3 Objectives

The goal of this dissertation is to explore the current state of accessibility for people with mobility disabilities in our cities, as well as to identify opportunities for improvement, by designing, developing and evaluating a mobile application, based on crowdsourcing and with game elements, that allow identifying barriers that affect the quality of life of people with mobility disabilities. The dissertation will focus on various aspects of accessibility, social inclusion, crowdsourcing, and smart cities. It will examine the challenges faced by people with mobility disabilities and will explore potential solutions for addressing these challenges. Additionally, this dissertation will also look at the role of technology in creating more inclusive and accessible cities for people with mobility disabilities. Through a combination of literature review, case studies, and qualitative research, this dissertation aims to contribute to the ongoing conversation about accessibility and to provide practical recommendations for creating more inclusive and equitable cities for people with mobility disabilities.

The main objective of this dissertation is to help the cities to become more inclusive and improve the quality of life of people with mobility disabilities. Accordingly, the research problem was segmented into four major objectives:

- **Literature Localization and Analysis:** Conduct a comprehensive review and analysis of existing research on the topics relevant to the project. This involves identifying and studying academic papers, reports, and relevant publications related to accessibility, mobility challenges faced by people with disabilities, and technological solutions implemented in smart cities.

- **Understanding Mobility Challenges:** Thoroughly comprehend the specific challenges encountered by people with limited mobility. This step requires gathering insights from the target user group, conducting interviews, surveys, and engaging with relevant stakeholders to gain a deeper understanding of the barriers they face in urban environments.

- **Design and Prototype Development:** Create and develop a barrier identifier focused on enhancing accessibility and social inclusion in smart cities. The design process should be guided by the insights gained from the research, aiming to address the identified mobility challenges effectively. The outcome is a functional prototype of the barrier identifier technology.

- **Evaluation with Potential Users:** Assess the developed prototype by engaging with its potential users. Conduct usability testing, user interviews, and gather feedback to evaluate the effectiveness and user-friendliness of the barrier identifier. This step is vital in refining the technology based on user inputs and ensuring its practicality and usability.

The first goal lays the theoretical groundwork for the project's fundamental ideas and establishes the overall development picture. Its goal involves a full theoretical grasp of the ideas behind social inclusion, accessibility, and reduced mobility in smart cities.

The second goal of this project grants the identification of factors that influence, in an active or passive way, the experiences of people with mobility limitations in their movements in their localities, content crucial for the initial definition of the prototype of a barrier identifier to be designed. This goal aims to fill the potential subjective nature of the collected theoretical framework, product of the previous design.

The third goal is to design and develop a mobile application, based on crowdsourcing and with game elements, that allow for identifying barriers that affect the quality of life of people with mobility disabilities. This way, by providing a platform, a mobile application, for people with mobility disabilities to share their experiences and challenges when navigating through their locations, making a more engaging and accessible process to identify and report barriers.

Therefore, another goal is to have people as an information resource through an introduction of game elements in order to increase people's engagement, empowering them to take an active role in advocating for their needs and promoting change in their communities.

In the end, the ultimate goal revolves around evaluating the feasibility of the proposed barrier identification system and analyzing the developed prototype's usability. .

Ultimately, the final objective of this project is to enhance the user experiences when faced with various obstacles, aiming to increase accessibility and promote social inclusion in smart cities. The focus lies on improving overall accessibility and inclusivity, allowing individuals to navigate the urban environment more seamlessly and fostering a sense of belonging for all community members.

1.4 Document Structure

This dissertation contains 7 chapters.

- In Chapter 1, the introduction, problem definition and motivation and the objectives of this dissertation.

- In Chapter 2, the state of the art is described and are related works have been submitted.

- In Chapter 3, the method is defined.

- In Chapter 4 is described the Requirements Definition.
- In Chapter 5 is covered the development and implementation of the BarrierBeGone mobile application.
- In Chapter 6 the usability testing process and discussion are presented.
- In Chapter 7 Conclusions and Future work are described here.

Chapter 2

Systematic Review of the literature

This Chapter, describes the primary accomplished results, addressing the formal qualities of the selected articles, and the category identification.

The PRISMA statement criteria and checklist were followed in this systematic review of the literature [29]. It was composed of three methodological steps: material selection, descriptive analysis, and category identification, which enabled the identification of relevant articles on mobility disabilities, accessibility and inclusivity of citizens, including people with and without physical disabilities, and the relationship with smart cities.

2.1 Material Selection

The following electronic data-bases were searched: MEDLINE (Medical Literature Analysis and Retrieval System Online) [6], SCOPUS [8] and sinalDB. In addition to the database descriptors, free keywords were utilized to make sure the search was as thorough as possible, in order to gather all peer-reviewed research articles written in English language from January 2012 until December 2022. These databases selected are three trustful global citation databases providing enriched data and linked scholarly literature across a wide variety of disciplines, including conference proceedings, academic journals and other pertinent documents. There were selected documents since 2012, in order to conduct a thorough examination of the phenomenon and take into account the great majority of recent studies in the area. In order to collect data, the following terms were searched: " disabled person "; " wheelchair "; " reduced mobility "; " physical impairment "; " wheeled mobility "; " mobility limitation "; " person with disability "; " game "; " game-based "; " mobile app "; " video game "; " accessibility "; " inclusion "; " smart city "; " barrier "; " sustainable city "; " resilient ". The following query was used to combine these terms: ("disabled person" OR wheelchair OR "reduced mobility" OR "physical impairment" OR "wheeled mobility" OR "mobility limitation" OR "person with disability") AND (gami* OR game OR game-based OR "mobile app*" OR "video game") AND (accessibility OR inclusion OR "smart cit*" OR barrier

OR "sustainable cit*" OR resilient). This query was defined following multiple exploratory experiments utilizing various combinations of topic-related keywords and Boolean operators while keeping the review's purpose in mind. Furthermore, given the nature of this assessment, the search was restricted to " Smart cities ". The final query returned 386 articles for assessment, which were reviewed independent by one researcher, in four stages, in accordance with the guidelines specified in Table 1. All articles that included accessibility, mobility disability and social inclusion, were included for the screening phase. The articles that did not address accessibility, social inclusion, not addressing users with physical impairments, were excluded from screening phase. Articles that did not fully meet the inclusion criteria or met any of the exclusion criteria were therefore deleted from the study.

The collected records were examined in the first step by reading the title and detecting and deleting the duplicates; after reviewing all titles,and deleting the duplicates 142 records were excluded. The remaining 136 papers were reviewed in step two by reading the abstracts, with 97 articles being removed. In the third step, 39 records were examined by reading the complete text, and 20 were eliminated.In the last stage, the 19 selected papers were cross-referenced, and one extra article was included following full-text analysis. As a result of the selection procedure, a total of 20 articles, referenced as [31], [18], [39], [42], [20], [33], were chosen for review and extensive analysis in the following stage. The following Figure 2.1 summarizes the process.

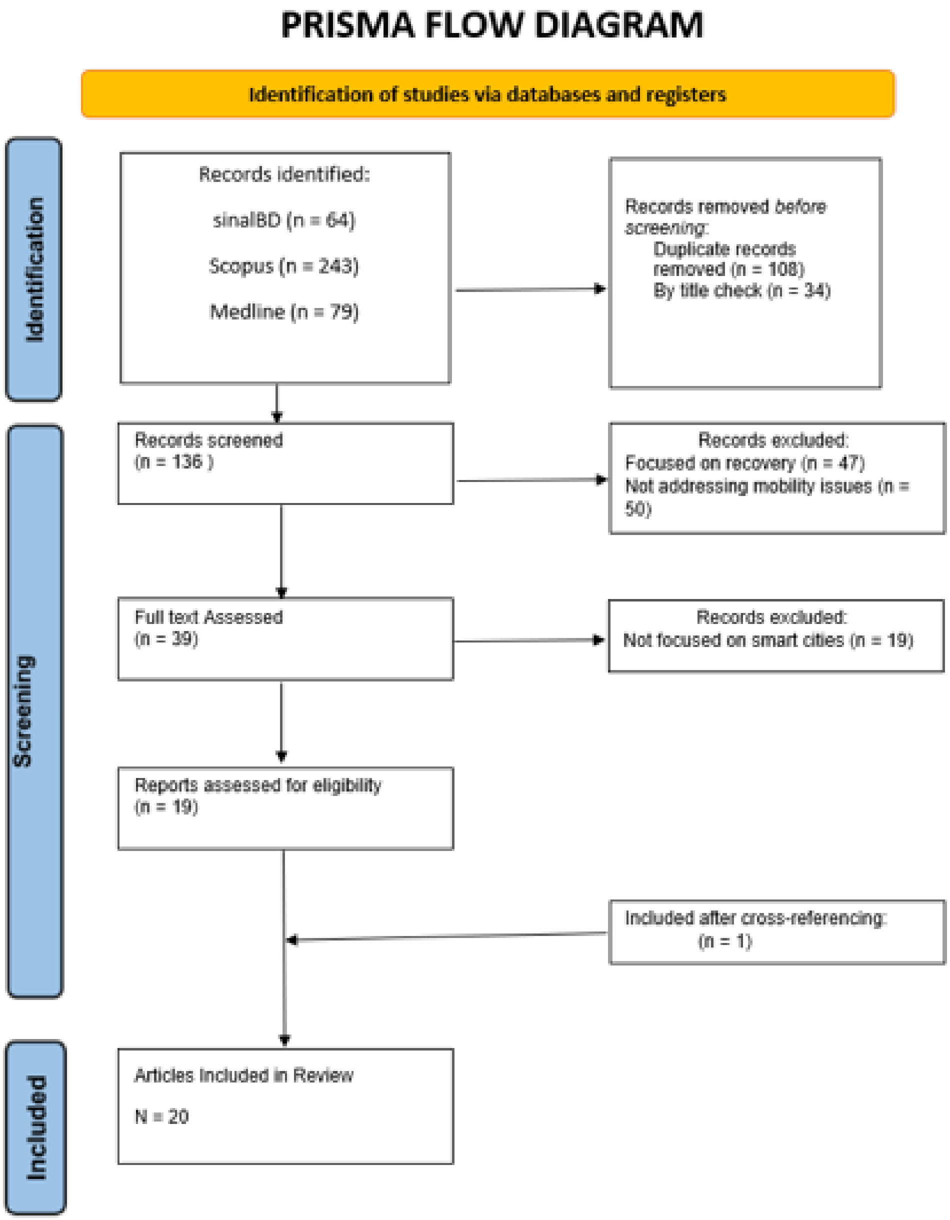


Figure 2.1: PrismaFlowDiagram

2.2 Descriptive Analysis

The RayyanQCRI platform (the Systematic Reviews web app) was employed throughout the initial stages of data selection. RayyanQCRI is a web-based platform and systematic review tool developed by the Qatar Computing Research Institute (QCRI)[28]. It is designed to assist researchers in efficiently conducting systematic reviews and managing the process of screening and selecting relevant research articles[28]. It provided an efficient screening process with an intuitive interface to manage and screen the researched articles. The following study traits were taken out: authors, year, country, study design, study aim, participants, game type, exclusion reason,and outcomes related to the barriers.

2.3 Category Identification

The last assessment process involved carefully analyzing the text of each article and extracting pertinent information, such as the dimension it addresses: barriers, inclusion, and/or smart cities. As the dimensions were determined, they were sorted into preliminary categories that were systematically refined and connected through the comparison of ideas and concepts gleaned from the literature research. Finally, the categories were combined and adjusted to produce high-level categories for each facet of barriers, social inclusion, and smart cities.

2.4 Selection Criteria

Inclusion criteria	**Exclusion criteria**
Articles addressing accessibility, barriers, or social inclusion	Articles that did not address accessibility, barriers, or social inclusion
Target primarily people with mobility disabilities	Did not primarily target people with mobility disabilities
Written in English	

Table 2.1: Selection Criteria

2.5 Descriptive Analysis

After the descriptive analysis, it was observed that most of the selected articles were published in 2019(6; 30%), 2011(1; 5%), 2012(3; 15%), 2014(1; 5%) 2016(2; 10%) 2020(3; 15%) 2021(2; 10%) 2022(1; 5%), Figure 2.2 .

Most of the studies took place in Portugal(4; 20%), Italy(3; 15%), Brazil(2; 10%), United Kingdom(2; 10%), France(1; 5%), Malaysia(1; 5%), Japan(1; 5%), European Union(1; 5%), Taiwan(1; 5%), Switzerland(1; 5%), Colombia(1; 5%), with a majority of all studies being conducted in developed countries, Figure 2.3.

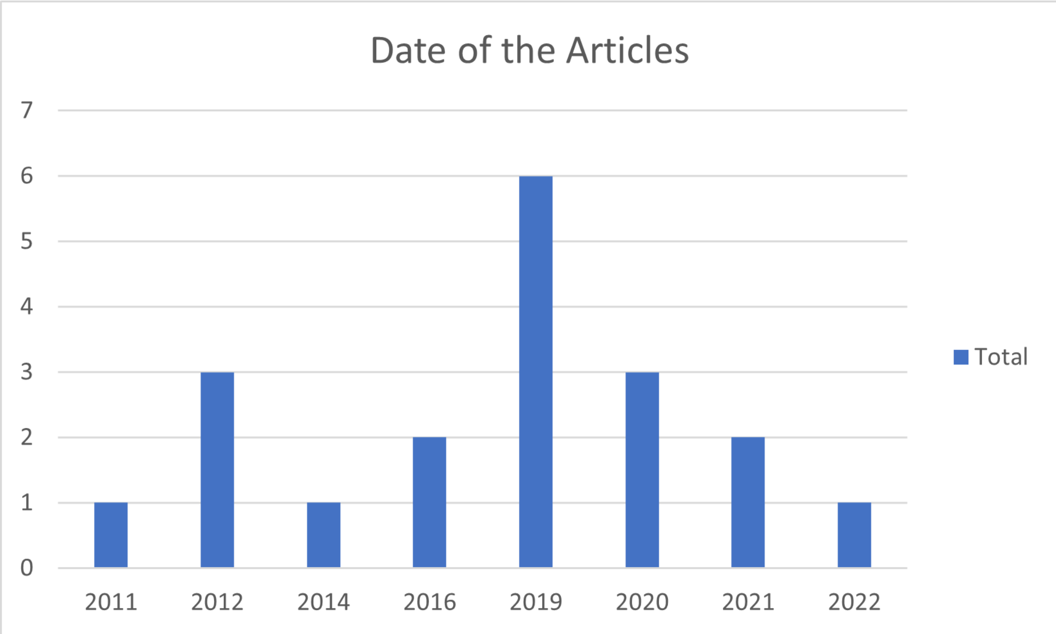


Figure 2.2: Year of publication of the reviewed articles

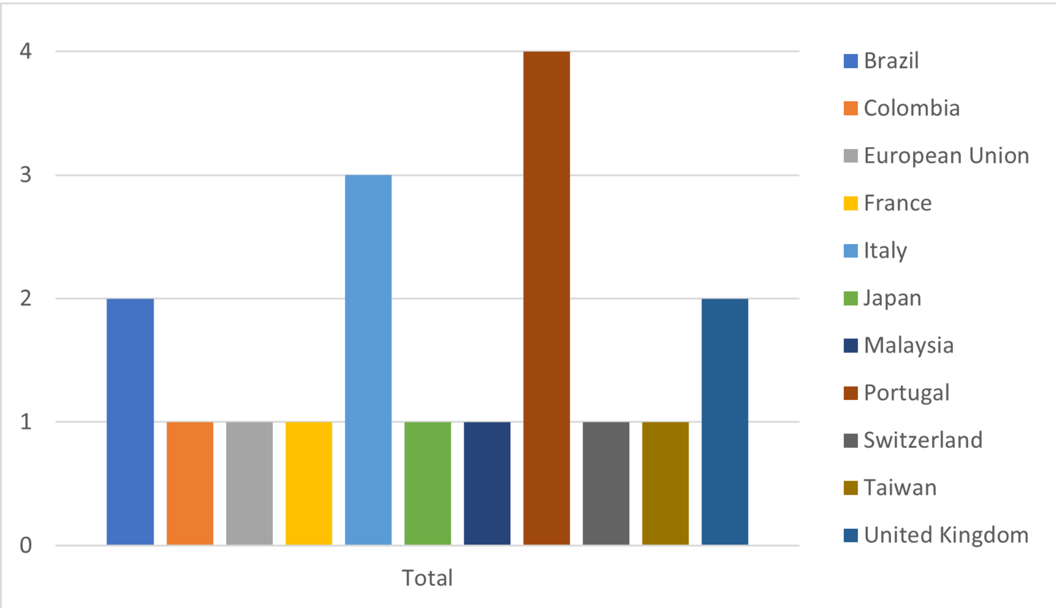


Figure 2.3: Geographical distribution of the reviewed articles

2.6 Category Identification

As a result of the careful analysis of each article's content, the A shows, for each article, the ID, author, country, publication year, objective, methodology, participants, type of game/modality, and assessment tool.

From the A, the three major dimensions, barriers, smart cities, and inclusion, were identified and explored, with some apparent links between categories such as inclusion and physical environments, barriers and crowdsourcing, smart cities, and accessibility.

Regarding barriers, the most common barriers found were the steps between as steep ramps, bouldering, and other uneven pathway covering are sometimes impassable for mobility-impaired or wheelchair users. Therefore, if removing the height difference by raising or lowering the floor level is not feasible, you may be able to install a wheelchair lift or a permanent ramp next to the stairs, providing a safe way for the wheelchair user to reach their destinations. The main solution for the steep ramps was installing gentler-sloped wheelchair ramps. This is accomplished by lengthening the ramp or adding bends to the ramp. Another solution can be installing an elevator or lift to offer access to multiple floors of a building, or in some cases, platform lifts, which are often self-leveling and may be used by individuals in wheelchairs or scooters. Bouldering and other impassable uneven pathways can be measured by improving the pavement, repairing and replacing the material with a smooth, leveling surface, creating alternative pathways with well-maintained surfaces, and providing a more accessible option. These solutions seek to make outdoor environments more accessible and inclusive for those with mobility disabilities, as well as to minimize mobility obstacles.

The process of getting services or ideas from a vast, undefined group of individuals, particularly over the Internet, is known as crowdsourcing [17]. By harnessing the pooled knowledge and experiences of many people, crowdsourcing can assist in identifying those physical barriers for persons with disabilities. Crowdsourcing Accessibility Applications can provide information that many people can check before visiting a location to learn about its accessibility [12]. Those can contribute by describing the accessibility of public places as a place entrance, indoor, outdoor, and additional information about services and facilities [12]. And also engage people with physical disabilities to actively participate in the process of identifying and addressing physical barriers, helping to ensure that solutions are more inclusive and fulfill the demands of the target population.

Accessibility is a key component of smart cities, affecting the quality of life of it's residents and reduce the the gap between those with unrestricted movement and those who have movement restrictions owing to disabilities [36]. Accessibility is a component of living quality that has global appeal, is a human right, determines how liveable a city is, and is crucial to contemporary civilization. In its sensible use, it offers safety, comfort, and autonomy to pedestrians and wheelchair users[33]. The lack of data is a good representation of the major problem with developing a digital service that can produce individualized and accessible urban mobility[36]. They also face new issues due to population growth, such as resource consumption, urban design and design of communication routes , these can be addressed by leveraging the full potential of technological solutions[33].

Also, resulting from the performed analysis, there were some social barriers found like the difficulty of people with a disability to make new friends and get involved in society, the negative feeling of people with a disability being a burden or nagging on their family.

2.7 Related Work

Jaccede [5] is a collaborative platform developed in 2006 to assist persons with limited mobility in finding accessible destinations and sharing accessibility information everywhere. Users may help by characterizing public place accessibility as a location entry, indoor, or outdoor, as well as other information regarding services and amenities. Jaccede also attempts to promote awareness about the social inclusion of people with disabilities. They organize activities and events on accessibility on a regular basis in order to increase awareness and recruit new members. It is a significant step toward increasing the popularity of such platforms and encouraging the community to contribute to them [12].

WheelMap[10] is a wheelchair-accessible online map that was launched in 2010. The platform use a traffic light system to assess a location's wheelchair accessibility. As a result, it colors the venues on the map based on their level of accessibility. Furthermore, they give descriptive information under each color to assist users in making more accurate accessibility assessments. Green indicates that the entry and all rooms are accessible without the use of stairs, whereas orange indicates that the entrance comprises one 3-inch-high step. This description can assist in avoiding subjective judgement. The platform, on the other hand, features a news page to engage the community. It invites volunteers to assist in improving the material to accommodate many languages [12].

WheelMate [11] was released in 2012. It enables wheelchair users to search, rate, review, and add accessible toilets and parking throughout the world. Users, however, are unable to amend or report inaccuracies in existing listings. As a result, if a location or institution upgraded its accessibility, or if someone provided incomplete or misleading information, users had no ability to modify it. [12]

Ability App [1] is an online platform that debuted in 2015. It is mostly based on community evaluations to assist persons with mobility, visual, hearing, and cognitive disabilities in finding and rating accessible venues worldwide. Users may browse accessible destinations by category, explore the map, or search by place name on the app.Based on the 5-score schema, a list of location names with accessibility rating scores displays. Each location has four basic impairment categories: mobility, vision, hearing, and cognition, each with its own set of attributes rated 36, 31, 19, and 31, respectively. Users can evaluate a location's accessibility characteristics by utilizing a smiley face system, which includes a happy, neutral, and sad face that represents a specific accommodation in place. Although the application is comprehensive for all sorts of disabilities, an assessment requires too much information, which might be a time-consuming chore, and individuals may be deterred from completing it [12].

Flooding Points is a crowdmapping technology that intends to generate a Web map displaying the flooding sites in So Paulo at the time of the flooding disaster. Web users offer this location information in near real time. The system has proven to be a useful tool for exchanging information on inundation and flooding problems in So Paulo in near real time[23].

Turismo Accesible by Equalitas [7] is a mobile application that provides information on hotels, rural residences, rural tourism, beaches, cultural routes, and museums, among other things, for those with limited mobility [35].

VisitAzores [2] is a smartphone application that serves as a tourist guide for the Azores Archipelago. Each island has its own map containing places of interest, directions to the desired area, hiking trails, tourist entertainment companies, hotels, restaurants, attractions, and curiosities, as well as their accessibility [35].

2.8 Concepts

Accessibility refers to the ability to make environments, products, services, and information accessible and usable by all individuals, regardless of their abilities or limitations [19]. It means that the physical environment and built environment should be planned and designed in a way that allows all people to function with as much independence as possible. Accessibility is the foundation for ensuring equal participation and opportunities for all individuals, including those with disabilities [19].

Social inclusion involves the full and equal participation of all individuals in society, regardless of their personal characteristics, backgrounds, or abilities[19]. It means creating a society that embraces and values diversity, ensuring that everyone has access to opportunities and resources, and the ability to contribute to the community. Social inclusion entails removing physical, attitudinal, and social barriers that may lead to discrimination or exclusion of any individual or group [19].

Therefore, accessibility is an essential component in promoting social inclusion [19]. Ensuring the accessibility of physical, technological, and social environments is crucial to enabling all individuals, including those with disabilities, to actively participate in society, have equal opportunities, and live with dignity and independence [19]. By adopting the concept of "universal design" and implementing policies and actions that promote accessibility, it is possible to achieve a more inclusive society, where everyone is valued and can contribute to the collective well-being.

A smart city is one that employs technology to improve the lives of its citizens [16]. This might involve things like intelligent traffic management systems, efficient public transportation, and improved public services. A critical aspect of creating a smart city is ensuring that it is inclusive for all residents, including those with mobility disabilities. This can be achieved through a variety of means, such as:

- Providing accessible transportation options, such as buses and trains with low floors and wheelchair ramps, and dedicated spaces for wheelchairs on buses and trains.

- Making sidewalks and streets more accessible, with features like curb cuts, tactile paving, and signalized crosswalks.
- Providing real-time information about the accessibility of public buildings and transportation options.
- Incorporating universal design principles in the planning and development of public spaces, buildings, and infrastructure to ensure they are accessible to people with disabilities.
- Encourage private sector and government to be more inclusive in their service delivery, hiring and procurement.

By taking these steps, a smart city can become more inclusive for people with mobility disabilities and improve their quality of life [16] . To achieve the goal of smart cities, it requires a collaboration of multiple stakeholders including government, private sector, citizens and researchers. Smart city initiatives often involve the use of sensors, Internet of Things (IoT) devices, and other technologies to collect and analyze data about the city. This data is then used to make decisions about how to improve the city's infrastructure, services, and overall livability [32].

Smart city also focuses on sustainability, resilience, and inclusivity, by providing equal opportunities and services to all citizens, regardless of their social background or abilities, involving the use of technology and data to create a more comfortable, efficient, and sustainable urban environment for all residents [32].

Gamification is the use of game design elements and principles in non-game contexts to engage and motivate people and enhance their learning, problem-solving, and participation [41]. This concept can be related to accessibility and social inclusion in various ways, by incorporating gamification principles into projects, initiatives, or applications aimed at promoting accessibility and social inclusion, enhancing the engagement, encouraging the participation, and creating a more inclusive environment for all individuals, including those with disabilities [22]. Using gamification techniques, such as points, badges, leaderboards, and rewards, can motivate individuals to actively participate in activities or programs that promote accessibility and social inclusion[37]. By making the process engaging and enjoyable, more people are likely to get involved, contributing to a broader and more diverse community. In addiction, the gamification can be used as an educational tool to raise awareness about accessibility issues and promote understanding of the challenges faced by individuals with disabilities. Interactive games or simulations can help people experience firsthand the difficulties others may encounter and foster empathy and compassion [37].

Chapter 3

Methodology

This chapter shows the methodology chosen as well as the phases included.

The methodology used in this dissertation is focused on the user named User-Centered Design. This methodology is an interactive design approach where users' needs, objectives, and global satisfaction are product design and development triggers. The User-Centered Design approach encourages cooperation among users, designers, and developers throughout the design process. It considers user feedback at each development step to guarantee that the final product is user-friendly and practical.

The methodology is divided in 5 different phases:

- Understand the context -> Using the Systematic Literature Review with PrismaFlowDiagram
- Understand the needs -> Using Interviews to collect the requirements
- Design -> Using collaborative design platform Adobe
- Development -> Using Android Studio to develop the application
- Validation -> Using Usability Tests, validating the prototype

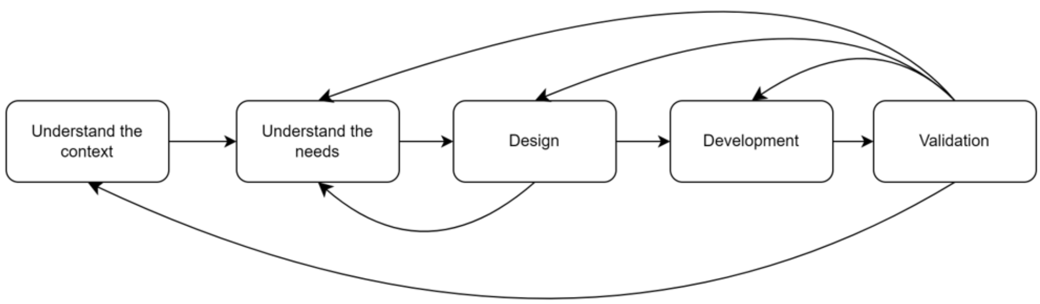


Figure 3.1: Methodology Diagram

3.1 Understand the context

In this first phase, Understanding the context will be done through the study of the state of the art of this dissertation subject, where we analyze and evaluate the current state of knowledge and development about the city's accessibility, social inclusion, and smart cities. Further, it's realized a literature review where are selected sources to gather information and then an analysis of the data collected. This way is provided a comprehensive understanding of the current state of the city's accessibility, social inclusion, and smart cities and helps to inform and guide future research and development. The concepts and information about the base topics of this dissertation, including accessibility, social inclusion, gamification and smart cities as well as their relationships can be found in 2.

3.2 Understand the needs

A crucial component of the design of this project is the identification and comprehension of parameters that affect mobility experiences when users are doing their routes. So we conducted a set of Interviews sessions with people with limited mobility to supplement all of the information gathered. These Interviews sessions are a technique of qualitative analysis where users share their opinions, perspectives, and experiences about a specific search topic. This way is gathered an in-depth knowledge of the domain of the study questions based on the users in a short time [9]. According to the guidelines, each interview was expected to have a duration of fifteen to twenty minutes. In total, five participants were interviewed.

For the purposes of this dissertation, the selection of participants as a research method was based on the convenience of collecting data in the field of study within a broad social context and within a short period of time temporal. To ensure a comprehensive exploration of the research topic, the group discussion sessions were supported by a script of the interview, which can be found in B of this document. The script was formulated based on the concepts identified in the thorough systematic literature review in 2.

After the recruitment stage, all participants were informed about the study's objectives, the rules and guidelines for participation, and the limits of confidentiality regarding their involvement. They were required to verbally consent, indicating their understanding and agreement to participate in the study.

In addition to the empirical data gathered from the sessions, a preliminary questionnaire was also administered to gather sociodemographic information about the study sample. This questionnaire served as a complementary tool to further characterize the participants.

3.3 Design

The iterative design of a prototype for the barrier identifier is part of this dissertation's third key goal. Using a User Centered Design, it is an iterative design process that characterized by establishing the needs, objectives, and general satisfaction of the users as the driving force behind product design and development. Even if multiple methodologies have foreseen that guide the development of products technological and that enable outstanding quality goals for the purposes specific to this project, the decision was taken to adopt a User Centered Design methodology in virtue of its iterative structure and usability attributes. The prosperity of the barrier identification system is subordinated by the ease with which its end users relate and interact with the platform. Therefore, during the development stage, the system's usability must be assumed as an imperative factor. A collaborative design platform with graphical interface prototyping capabilities called Adobe was employed.

3.4 Development

In this phase its was developed a high-fidelity prototype that is completely functional and interactive and closely resembles the actual expected accurate depiction of the mobile application's user interface was created during this prototyping stage. Following a usability assessment, the prototype was improved based on user input, and for the application development, it used Android Studio using Kotlin as the programming language.

3.5 Validation

Another crucial component of the design of this solution is the creation of usability tests. The interactive user experience that comes with a user interface, such as a website or software program, is measured by its usability. An intuitive interface is simple to understand, supports users' activities and objectives successfully, and makes use enjoyable and engaging [9]. This can be measured by inviting users of the system to participate in a usability test session, where a user will respond to a set of activities that must be accomplished without the researcher's help utilizing the application. This allows for the recording of the user's actions, feelings, and performance as he attempts to complete each activity [9].

The usability of a computer system refers to how easily an untrained user can interact with the user interfaces of the system [13]. According to [34], usability applies to all features of a system with which the user can interact, and it is traditionally associated with five quality components: learnability, efficiency, memorability, errors, and subjective satisfaction. With this understanding, usability transitions from an abstract concept to an engineering discipline that can be systematically addressed, improved, and evaluated.

With the aim of quantitatively and qualitatively measuring the usability and usefulness of the barrier identification platform, the testing session was divided into three sub phases:

- pre-test survey;
- testing phase;
- post-test survey

For an overall view of the subjective usability evaluation of the designed technological product, the first sub phase used a sociodemograph survey to get information about their users, using a set of questions including their names, literary qualification, age, if they have any disability, and their comfort level using mobile phones using a Likert scale [27]. With this scale it's possible to understand the impact of the comfortness of each user while using mobile devices with the tasks to be done in the second sub phase. The second sub phase involves a set of tasks that illustrates the functionalities of the application. The third sub phase of the system evaluation stages utilized an adaptation of the System Usability Scale (SUS) [14]. This evaluation scale assumes that participants indicate their level of agreement on a 5-point Likert scale [27] regarding a set of 10 statements related to the system's context. The SUS has proven to be a powerful, robust, and reliable instrument for assessing the usability of a product [14]. Each validation sub phase is presented in the C appendix.

Chapter 4

Requirements Definition

The formulation of this dissertation's development scenario was made possible by studying scientific data in the context of the project's fundamental ideas, as found in a thorough assessment of the prior literature. The theoretical framework made it feasible to comprehend the landscape for improving accessibility and social inclusion of the population in smart cities, specifically in identifying potential barriers for those with limited mobility.

In order to identify impediments, this dissertation is dedicated to developing a technical solution among the population with limited mobility, assuming that part of the planning strategy for its development would be the study of the experiences of the target audience. A thorough analysis was created to counter the theoretical basis's probable subjectivity of wheelchair users' perspective of the shortcomings in social inclusion and accessibility in cities, serving as the foundation for the first formulation of the technical artifact's needs, which is one of the goals of this dissertation.

4.1 Interviews

Regarding the population's requirements and preferences in relation to the obstacles that now exist for those who have limited mobility and the factors that would contribute positively to accessibility and social inclusion in smart cities, interviews were designed with people with mobility impairments. The interviews addressed are grouped in three main groups: (i) Legitimization of interview and motivation for the same; (ii) Explore dynamics of people with mobility reduced; (iii) Reflection and completion of the interview;

4.1.1 Sample characterization

The interviews were divided into sessions that gathered a total of 5 participants. An effort was made to choose a sample diversity of participants from various age groups in order to attain a varied range of thoughts and perspectives on mastering the study issues. The following Figure 4.1 presents a detailed view of the socio-demographic characteristics of the sample.

	Faixa etária	Género	Habilitação literária
0	12-17 anos	Masculino	Ensino Básico ou equivalente (9ª ano)
1	12-17 anos	Masculino	Ensino Básico ou equivalente (9ª ano)
2	55-64 anos	Masculino	Ensino Básico ou equivalente (9ª ano)
3	35-44 anos	Masculino	Ensino Superior - bacharelato ou licenciatura
4	45-54 anos	Masculino	Ensino Secundário ou equivalente (12º ano)

Figure 4.1: Socio-demographic information about the participants of the interviews

Based on the findings illustrated in Figure 4.2, it can be inferred that the participants from the interviews use mobile applications frequently. With a significant majority of 80%, it is evident that developing a mobile solution would greatly benefit these participants, considering their daily usage of mobile applications.

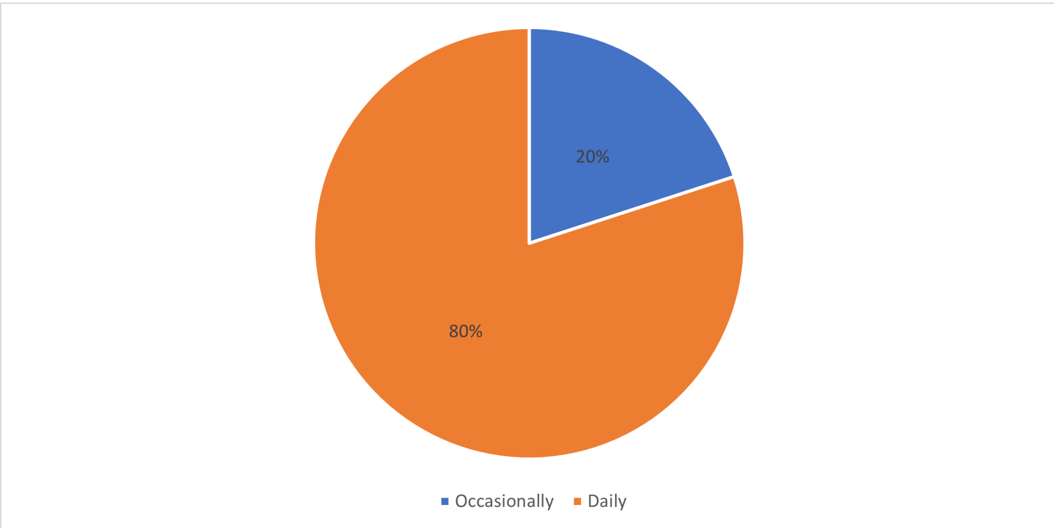


Figure 4.2: Usage of mobile applications in participants routine

Based on the findings presented in Figure 4.3, it can be concluded that participants in the interviews identified a total of six barriers that they encounter on a daily basis. These barriers include:

- Bouldering
- Steep Ramps
- Large Stairs
- Obstructed Access

- Improperly Occupied Parking Lot
- Lack/Missing Ramps

Among these barriers, the most frequently identified by the users was the "Improperly Occupied Parking Lot," which was mentioned by 28% of the participants. Following that, the barriers of "Lack/Missing Ramps," "Obstructed Access," and "Steep Ramps" were identified by 18% of the users each. The "Large Stairs" and "Bouldering" barriers were less commonly reported, with only 9% of users identifying them.

These findings provide valuable insights into the barriers that individuals with limited mobility face daily. Understanding these challenges makes it possible to develop targeted solutions to address and mitigate these barriers, thus promoting greater accessibility and inclusivity in smart cities.

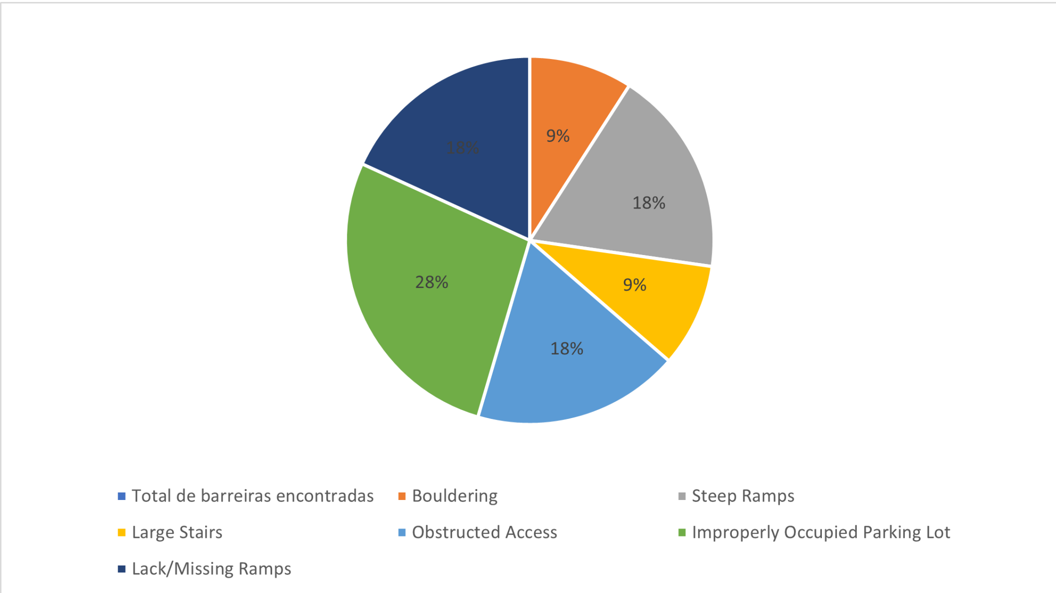


Figure 4.3: Types of Different Barriers Identified by participants in the Interviews

4.2 Discussion

The interviews followed a semi-structured guide, available in Appendix A.2, which encouraged participants to reflect on and discuss their experiences with the obstacles they encounter daily. Content analysis of the data generated during the group discussions revealed that all participants considered steep ramps, obstructed access, lack/missing ramps, and improperly occupied parking lots as fundamental factors influencing their perception of accessibility and social inclusion in cities. Large flights of stairs and holes or other objects on illuminated sidewalks were associated with negative experiences in terms of accessibility, leading to feelings of discomfort and sometimes requiring a change in their route. Taxis were commonly used in their daily lives to overcome these obstacles.

Regarding the questioning of data categories in the context of accessibility and social inclusion in smart cities, participants emphasized the crucial need for data to be made available regarding the main barriers they encounter daily: steep ramps, obstructed access, lack/missing ramps, and improperly occupied parking lots. These pieces of information should be provided in real-time, accurately identifying their location and status (whether they are true or false).

Adopting a User-Centered Design methodology involves studying the requirements and behaviors of potential users as the foundation for development decisions of the technological solution. Consequently, to achieve the second main objective set for this dissertation and as a supplement to the preceding theoretical foundations, a study was conducted on the challenges that people with limited mobility face. The key factors that were previously mentioned were:

- Bouldering
- Steep Ramps
- Large Stairs
- Obstructed Access
- Improperly Occupied Parking Lot
- Lack/Missing Ramps

Although the set of conducted interviews gathered a limited sample of opinions, they provided empirical evidence of data saturation, resulting in a clear understanding of the requirements. Through qualitative analysis of the generated data, it is feasible to confirm the significance of accessibility effects on the daily lives of individuals with mobility limitations.

Chapter 5

Application BarrierBeGone

This section provides a detailed discussion of the development process and the decisions that were made and implemented throughout this period.

5.1 Concept

Gaining from the widespread use of mobile and ubiquitous computing in people's daily lives, this dissertation proposes "BarrierBeGone", a tool that identifies possible barriers for persons with mobility difficulties that fulfills the requirements of users for personal protection, safety, and comfort, with the establishment of this as the main goal the promotion of accessibility, and social for all citizens. This tool is manifested as a mobile application, it provides user-centered services, with the system's features and resources defined in accordance with the theoretical underpinnings previously gathered from the literature review. As a result, it makes use of two key resources: barrier identification and classification.

The barrier identification system "BarrierBeGone" is based on location, GPS, and triangulation providers of the network that are incorporated in the mobile devices of its users, as well as mobile wireless communication technologies such as 3G, 4G, and Wi-Fi, giving its users real-time data on impediments they've identified.

5.2 Collaborative Model

The BarrierBeGone app embraces a collaborative model that empowers users to join forces in creating a more accessible world. Through the app, users become active contributors, advocates, and agents of change. They have the opportunity to report barriers they encounter in their daily lives, such as physical obstacles, inaccessible locations, or inadequate accommodations. This user-generated data forms a comprehensive database of accessibility challenges, providing valuable insights for individuals with disabilities, policymakers, and businesses. Users can also engage in discussions, share their personal experiences, and offer support and advice to fellow users. With an emphasis on collaboration, BarrierBeGone fosters a community-driven approach to breaking down barriers and promoting inclusivity. Together, users and the app work hand in hand, leveraging the power of collective knowledge, activism, and technology to create a more accessible and inclusive society for all.

5.3 Validation mechanism

The quality and accuracy of the information made accessible to BarrierBeGone's users is the primary criterion for its success. The decisions made by each user have a direct relationship with the database available to users, so information that is unreliable has negative effects on people with mobility disabilities.

Given that the data disseminated by BarrierBeGone are a result of user and system collaboration, it is essential to incorporate a validation mechanism that upholds the accuracy of the data in the system database. A confirmation approach, in which each user can either confirm or not confirm each barrier mark, is used to assure the correctness of the data supplied by the users, taking up the position of data validator. Currently, whenever a user adds a new entry to the system database, that entry is sent to other users with an analogous space-time reference, that is, users who are in the same geographic area as the person who contributed the data. When information is shared with the barrier identifier community, people can assess its accuracy using a rating system that allows for a negative or positive vote. The algorithm automatically qualifies information as untrustworthy and prevents its distribution to other users if it receives three or more negative votes from users.

In addition to the validation mechanism described above, BarrierBeGone incorporates several complementary features to enhance the organization and real-time transmission of data through user participation in spatio-temporal data validation. The app utilizes location-based services to ensure that users within the same geographic area receive relevant information regarding barrier reports. This localized approach facilitates a more efficient validation process by enabling users to assess the accuracy of data based on their familiarity with the surroundings.

To further enhance the validation process, BarrierBeGone implements a rating system that allows users to provide feedback through negative or positive votes. This rating system serves as an additional layer of validation, empowering the community to collectively evaluate the reliability of reported barriers. By considering the collective wisdom of the users, the algorithm can accurately identify and filter out untrustworthy information, preventing its dissemination to other users. This approach ensures that the data shared within the BarrierBeGone community remains reliable, credible, and valuable for individuals with mobility disabilities.

Real-time transmission of data is another crucial aspect of the collaborative model employed by BarrierBeGone. As users contribute new entries to the system database, the app promptly disseminates this information to other relevant users in the vicinity. This immediate transmission enables swift awareness and action, allowing users to navigate their surroundings with up-to-date information on barrier locations. By leveraging the power of collaboration and real-time data sharing, BarrierBeGone empowers users to make informed decisions, avoid obstacles, and ultimately improve their mobility and accessibility.

In summary, the collaborative model of BarrierBeGone prioritizes the quality and accuracy of information by incorporating a validation mechanism, a rating system, and real-time data transmission. Through user participation and collective evaluation, the app ensures that reported barriers are reliable and trustworthy. By embracing collaboration and technology, BarrierBeGone creates a community-driven platform where users actively contribute to breaking down barriers and improving accessibility for individuals with mobility disabilities.

5.4 Incentive mechanism

Due to the collaborative methodology used by the barrier detection technology BarrierBeGone is participatory, the main challenge with its execution is how to get consumers to want to provide the system information in the first place. A critical mass of participants is necessary for the collaborative approach to succeed, and while having access to more data and a sense of community can serve as incentives, these factors alone might not be sufficient to maintain high levels of community participation in the project. With the aim of boosting the active involvement of users in providing data about obstacles to people with mobility disability, the established collaborative model presupposes a incentive schema and retention to user involvement in the system's data entry process.

To address the challenge of user participation and ensure a sustained flow of data, BarrierBeGone incorporates an incentive schema and a retention strategy within its collaborative model. One of the key features of the app is the implementation of a leaderboard, which serves as a gamification element to encourage and reward active user engagement.

The leaderboard showcases the contributions and achievements of users based on their participation in the data entry process. Users earn points or badges for reporting barriers, verifying information, and actively participating in the validation process. By ranking users based on their involvement, the leaderboard creates a sense of competition and recognition within the BarrierBeGone community.

In addition to the leaderboard, the app employs various incentives to motivate users to contribute information about obstacles. These incentives can include virtual rewards, exclusive access to new features or content, or even tangible benefits such as discounts or vouchers for accessible services or products. These incentives not only provide immediate gratification but also foster a long-term commitment to the app, making users feel valued and appreciated for their contributions.

To ensure sustained user involvement, BarrierBeGone implements a retention strategy that focuses on community-building and fostering a sense of belonging. The app facilitates user interactions through discussion forums, chat features, and the ability to connect with other users facing similar accessibility challenges. By fostering a supportive and engaging community, BarrierBeGone encourages users to stay actively involved, collaborate, and share their experiences, thus strengthening the overall collaborative model.

By combining the elements of gamification, incentives, and community-building, BarrierBeGone strives to create an environment where users are not only motivated to provide data but also feel connected to a larger cause. The collaborative model, with its incentive schema and retention strategy, aims to overcome the initial challenge of user participation and maintain a critical mass of engaged users, ultimately enabling the app to fulfill its mission of enhancing accessibility and breaking down barriers for people with mobility disabilities.

5.5 Solution Architecture

The application BarrierBeGone's overall result of users' mobile device's wide variety of built-in features and sensors based on 3G, 4G, or Wi-Fi wireless connection technologies and location services like GPS and network triangulation. The Application Architecture has two main components, the server, and the client. The client represents the frontend of the application, which is the user-facing side, interacting with the server to perform the tasks, such as user login, data retrieval, and data storage. The server component can be subdivided into two sub-components, a database, and a web server. The database component stores and organizes the application's data, provided from the user's inputs through the sensors built into the mobile devices, interacting with the Firebase SDK(Software Development Kit) for Android.

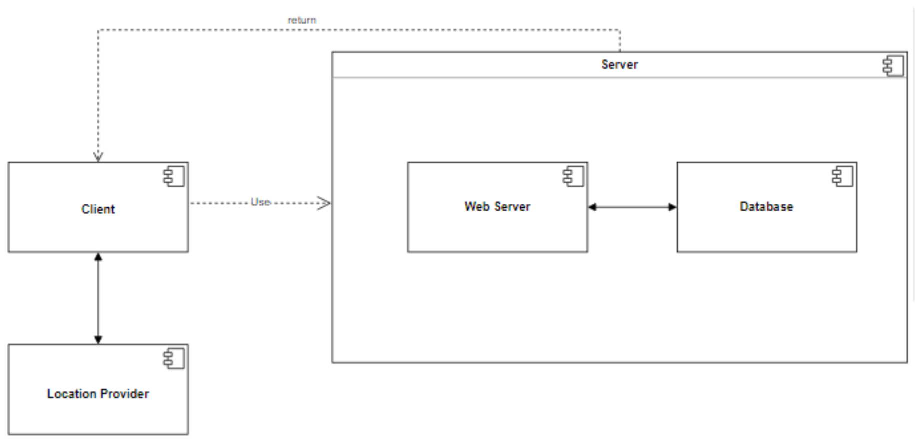


Figure 5.1: Solution Architecture UML Representation

The data is stored in Firebase, and it's divided into two principal segments: users and places. The user's class stores and list each user by UUID (Universally Unique Identifier), where every user has one unique ID protected in the Firebase. Each UUID stores the credentials of each user:

name, email, password, and score. The Places class stores the location of each barrier identified and addresses them with an identifier named placeID. Inside each placeID, it is stored the total number of confirmations that place have negative and positive confirmations, the longitude and latitude coordinates, and the barriers type.

5.6 Functionalities and Interface elements

5.6.1 Branding

In order to restore public faith in accessibility and social inclusion, the presented barrier identification system intends to address the needs of its users, primarily persons with mobility disabilities, regarding the criteria of personal protection, security, and comfort. In light of this goal, the name "BarrierBeGone" was chosen for the application, making reference to the promotion of social inclusion and accessibility in smart cities.

The barrier detection system's interfaces were created with an emphasis on a straightforward, neutral, and user-friendly look, with a focal point in the content that exceeds the system's high usability standards. Its iconic representation not only captures the essence of inclusivity but also symbolizes the very purpose and mission of the application [34]. By include the wheelchair emblem, we hope to empower people with mobility issues and advance a society in which obstacles do not restrict people with mobility disabilities from accessing opportunities. The wheelchair symbol acts as a worldwide language that is quickly understood by people of all cultures and all classes, bridging the gap between various communities. It acts as an effective reminder that everyone is entitled to the same rights and access to public areas, amenities, and services. At BarrierBeGone, we are dedicated to removing any obstacles that prevent people with disabilities from fully participating in society.

A portion of the visual resources in BarrierBeGone adhere to the iconographic paradigm, presenting relevant information as icons. The iconography used throughout the graphic interface follows a straightforward and clear pattern, making it simple for future system users to understand what each icon represents. The symbols used in BarrierBeGone were either created specifically for this project or sourced from the Pinterest database, a website that offers free graphic resources for programmers and artists.

5.6.1.1 Register and Login

In any mobile application, creating an identity for users increases conversion opportunities in the future and improves their engagement with the system later on[26]. However, the development of an authentication process in a mobile application represents a significant interaction cost for the user, which, when applied in the early stages, when your level of commitment to the system is still limited, can cause early abandonment phenomena and a subsequent withdrawal of use [34].

The Register Activity within the application plays a crucial role in allowing users to create new accounts and access the full range of features and services offered. To facilitate a seamless and secure registration process, it employed the powerful FirebaseAuthentication and FirebaseDatabase frameworks. FirebaseAuthentication, a comprehensive authentication service provided by Firebase, empowers us to handle user registration efficiently and reliably. By leveraging FirebaseAuthentication, we can securely store user credentials, such as email addresses and passwords, and employ industry-standard encryption techniques to protect sensitive information. This ensures that each user's data remains safeguarded [25].

When a user registers through the application, FirebaseAuthentication generates a unique private key for their account. This private key acts as a digital identifier, granting users exclusive access to their accounts and associated data. It serves as an additional layer of security, preventing unauthorized access and enhancing the overall integrity of the registration process. It's used FirebaseDatabase to manage and store user data along with FirebaseAuthentication. A real-time database solution called FirebaseDatabase enables effective user-related data archiving, retrieval, and synchronization. With this, the user profiles and preferences and any other pertinent data are securely stored for account management and individualized experiences within the application [25].

The Register Activity integrates the registration functionality, user account creation, and maintenance operations using Firebase's extensive services. As a result, the danger of data breaches is reduced, and the overall user experience is improved. It makes sure that each user's data is managed securely and effectively. We can offer a strong and dependable registration system that lays the groundwork for a safe and customized user experience within our application by utilizing FirebaseAuthentication and FirebaseDatabase.

The user's perception of the cost of engagement is one of the primary issues implied in the authentication process. When you are given lengthy forms, the system's incentive to register them is significantly reduced. Given the glaring limitations on screen width and the constrained data entry possibilities on mobile devices, this issue is much more apparent. The guidelines set out for the design of registration and authentication interfaces in mobile apps offered by Budiu aim to lower the user's perceived interaction effort in BarrierBeGone's system authentication procedure [15]. The barrier detection registration form fields have been condensed to the following information: name, email address, password, and confirmation of password as can be show in Figure 5.2.

The Login within BarrierBeGone serves as the gateway for users to access the app's features and services. This functionality is crucial for authenticating users and granting them appropriate access based on their credentials. User credentials, which are a username, an email address, and a password, are gathered from the user interface during the login process. After that, the application checks these credentials to confirm the user's identity. Only authorised users will be able to access the app's resources and features thanks to this verification. In addition to ensuring a safe and customised experience, the login capability is essential for enabling user-specific features and data retrieval. The user's perception of the cost of engagement is one of the primary issues implied in the authentication process. When you are given lengthy forms, the system's incentive to register them is significantly reduced. Given the glaring limitations on screen width and the constrained data entry possibilities on mobile devices, this issue is much more apparent.

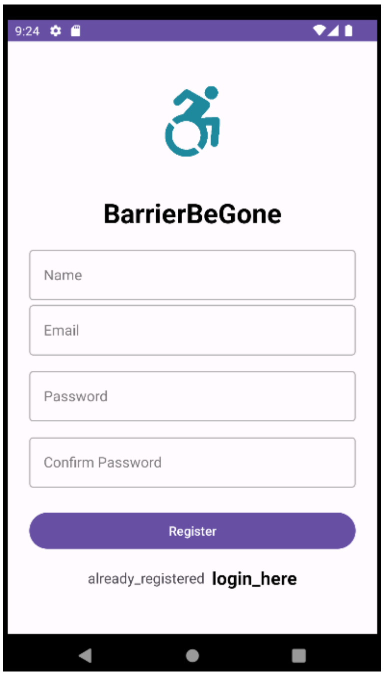


Figure 5.2: Registration Screen

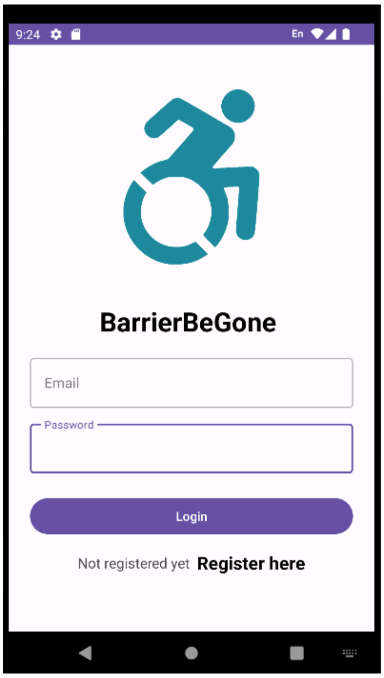


Figure 5.3: Login Screen

5.6.2 OnBoarding

The initial user engagement with any technical artefact is recognised as a critical phase in the development of the consumer's perspective on the system, appearing to be crucial in determining whether the technological product will be adopted long-term or will be abandoned and subsequently withdrawn from usage. This makes it necessary for the design of the system BarrierBeGone to ensure a clear knowledge of the operation of the suggested barrier detection system and a clear understanding of its usefulness from the user's perspective. In order to increase user retention in mobile applications, onboarding is described as a guided process of introducing a mobile application to its new users by reinforcing a transparent understanding of the system context, directing users towards resources, and functionalities that ensure higher probabilities of problem resolution and that clearly communicate their value as a product[ref para onboarding impact]. The major principles considered when developing the onboarding process were ease of use and simplicity. To provide a clear grasp of the features and functionalities that guarantee better value as a product for the consumer, the instructions provided are succinct and to the point.

The initial user interaction with BarrierBeGone incorporates integrated onboarding elements, strategically placed instructional prompts within the system's critical points, accompanied by concise descriptions of their value. The primary objective of this approach is to enable users to effortlessly acquire the essential skills required to accomplish tasks effectively. The Figure 5.9 presents the screens included in the barrier detection system BarrierBeGone.

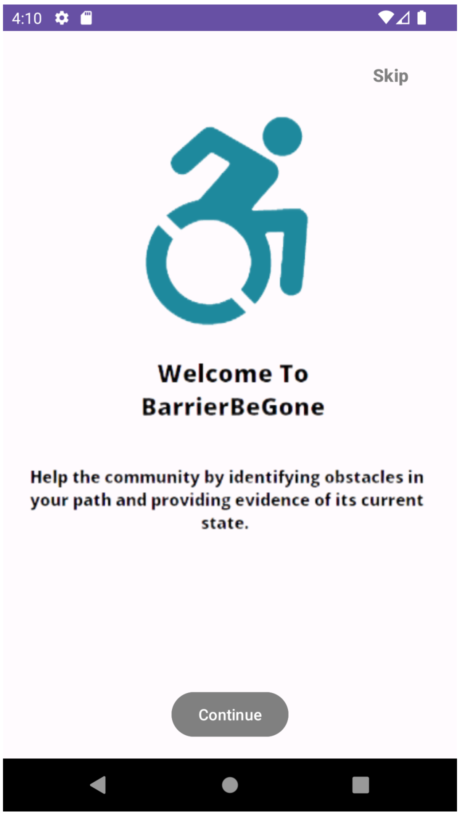


Figure 5.4: Welcome Screen

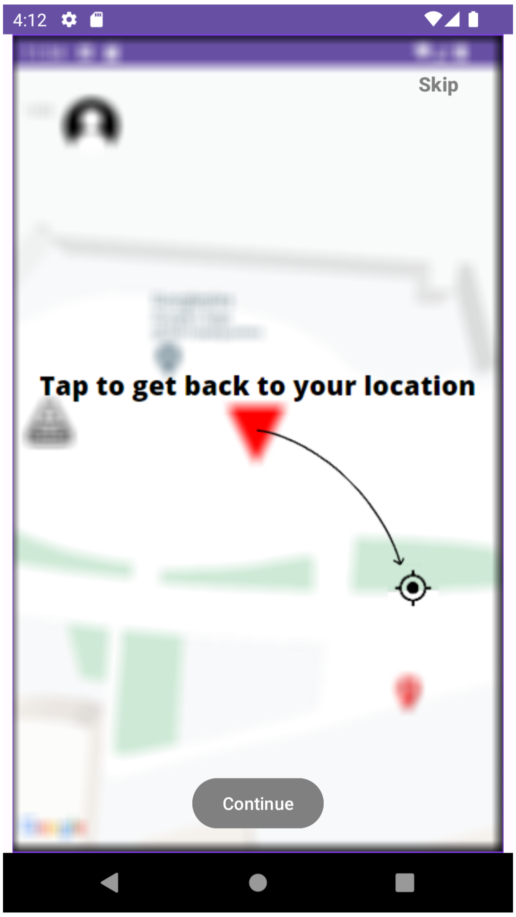


Figure 5.5: Onboarding Center User Information

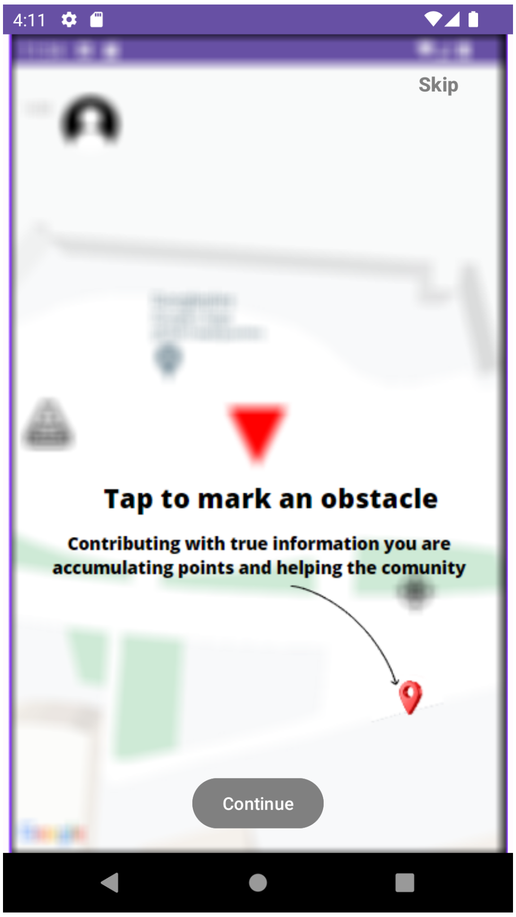
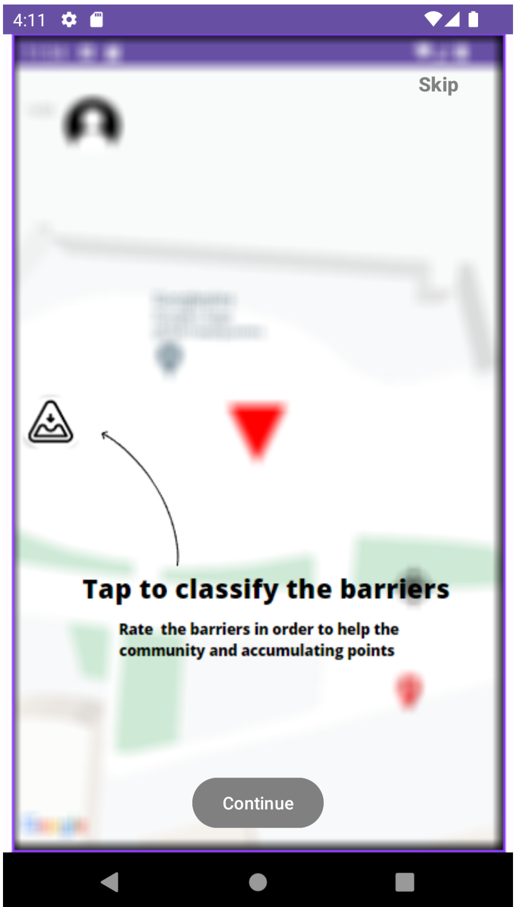
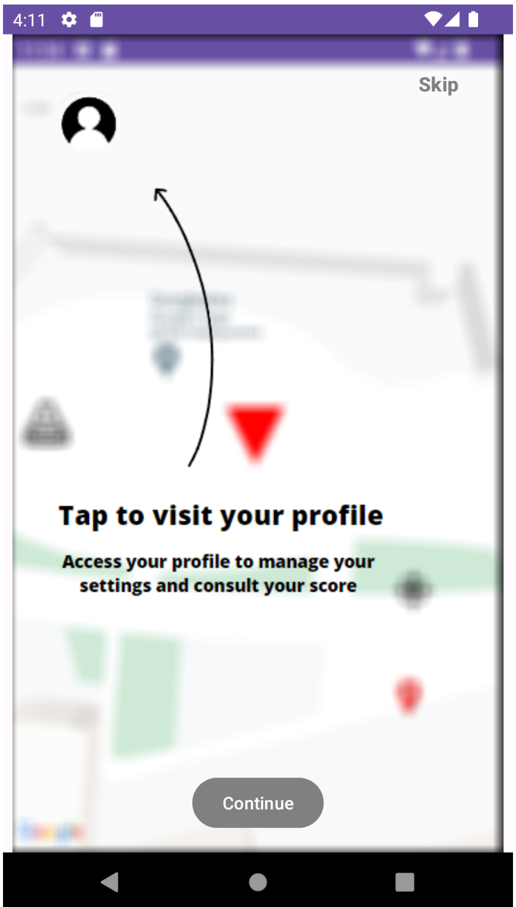


Figure 5.6: Onboarding Mark a Barrier Information





5.6.3 User Profile

The User Profile within our Android application is a dedicated space for users to manage and view their profile information, track their progress, and make necessary updates. This activity focuses on providing essential profile functionality without delving into specific implementation details. User data, including the user's name and any other pertinent information, is displayed through the Profile Activity, letting the users get a unified view of their account information.

Additionally, based on predetermined criteria or user engagements within the app, the Profile Activity computes and displays the user's level and score. Using this data can make the user experience more fun, and users can follow their progress and feel successful.

Another feature of the Profile Activity is the option for users to change their password. This functionality enables users to update their login credentials, ensuring the security and integrity of their accounts. The password change process typically involves the following:

- Collecting the user's current password.
- Verifying its correctness.
- Providing a means for the user to set a new password securely.

By providing these essential profile functionalities within the Profile Activity, we aim to enhance the user experience, foster a sense of personalization, and empower users to manage their account details conveniently. It serves as a central hub for users to access and modify their profile information, track their progress, and ensure the security of their accounts.

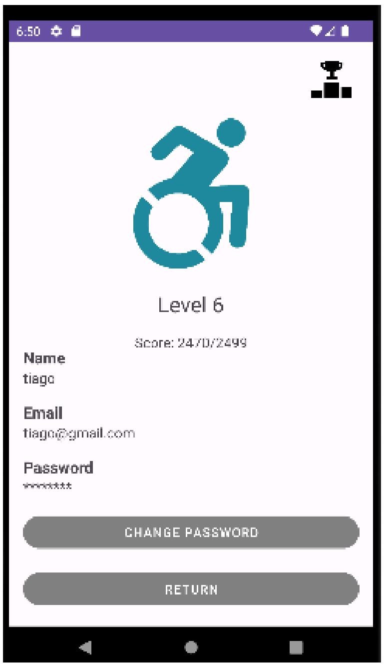


Figure 5.10: User Profile Screen

5.6.4 Barrier Identification and Confirmation

The barrier detection system, BarrierBeGone, incorporates a marking button feature that presents six types of possible barriers collected based on user interviews. The user visually locates the corresponding icon button within the application's user interface to identify a specific barrier. The user initiates the identification process by clicking on the image button corresponding to the identified barrier. The application captures the user's selection and stores it within its memory or passes it to other components for further processing. This process ensures that the identified barrier is retained and available for analysis and action. After successfully identification of the barrier, the application provides feedback or confirmation to the user, indicating that the identification process was successful. This feedback is through messages. BarrierBeGone uses this procedure to allow users to quickly and accurately identify barriers by visually picking the correct barrier icon, starting the identification process, and receiving a notification when their identification is successful.

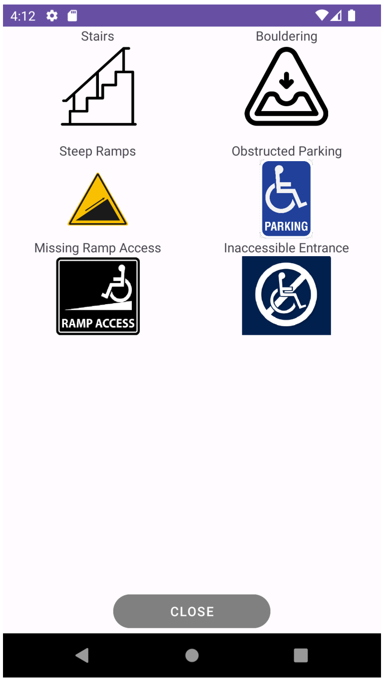


Figure 5.11: Barrier Selection Screen

BarrierBeGone incorporates a robust barrier confirmation feature to ensure the accuracy and reliability of identified barriers. Once a user selects a barrier using the marking button, the application initiates the validation process to verify its authenticity. The user engages with the BarrierBeGone application's user interface by clicking on either the "Not Confirm" or "Confirm" button, depending on their assessment of the identified barrier:

- If the user confirms the barrier as valid, their active involvement is recognized and rewarded. The application increments the user's score by 10 points, acknowledging their contribution to the barrier validation process.
- If the user confirms the barrier as valid, their active involvement is recognized and rewarded. The application increments the user's score by 10 points, acknowledging their contribution to the barrier validation process.

When a marked barrier accumulates three negative confirmations, the obstacle is deemed invalid and subsequently removed from the database. This ensures that barriers that consistently receive negative validations are no longer displayed to the user, avoiding misleading or inaccurate information. Additionally, a further increment of 10 score points is awarded to the user who provided the negative confirmation, acknowledging their role in maintaining the integrity of the barrier database.

BarrierBeGone improves the accuracy and dependability of obstacles that have been detected by incorporating this barrier validation method. Users take an active role in validating obstacles, and the results of their work are rewarded with score increases. Users are only shown confirmed and trustworthy barrier information thanks to this method, which increases the application's overall effectiveness.

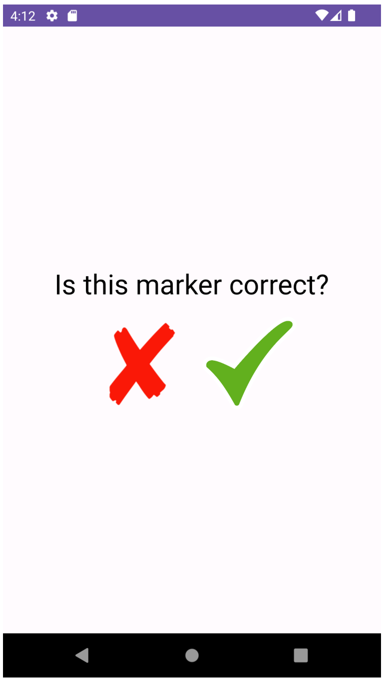


Figure 5.12: Barrier Confirmation Screen

5.6.5 Mapping

The Map is a crucial component of the BarrierBeGone application, responsible for managing various functionalities related to displaying a map, marking places on the map, and interacting with the Firebase Realtime Database. It serves as the main activity that users interact with to access important features. It leverages the capabilities provided by the Google Maps API to integrate maps seamlessly into the BarrierBeGone [24].

It include some features such as:

- **centerUserPosition** - displays and centers the view to the user's location on the map.
- **markPlace** - Provides mechanisms for users to mark places on the map.
- **zooming** - The initial zoom is defined as well as the maximum and minimum

5.6.6 LeaderBoard

The leaderboard is an engaging and competitive component of the barrier identification system BarrierBeGone, showcasing the achievements and rankings of users based on their scores. It serves as a visual representation of the top performers in a specific activity or game, fostering a spirit of healthy competition and recognition among users. The leaderboard presents a comprehensive list of users, their respective ranks, and their scores, allowing individuals to gauge their performance against others. It not only encourages users to strive for excellence but also motivates them to continuously improve their skills and scores in order to ascend in the rankings. By providing a clear picture of where users stand in relation to their peers, the leaderboard adds an element of excitement and drive, making the app experience even more rewarding and enjoyable.

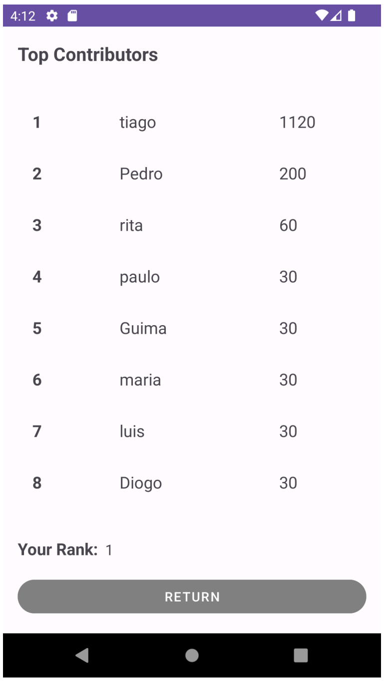


Figure 5.13: Leaderboard Screen

Chapter 6

Usability testing

Any technical artifact's usability can be maximised by using iterative design models, where the system diverges as a result of the usability evaluation processes. Potential users are taken into consideration throughout the development process, which results in a finished product with higher levels of usability and, as a result, better user experiences for your customers [4]. Barrier detection system BarrierBeGone's usability was validated by an evaluation, incorporating the testing method of usability studies with representative users. This validation

The usability test session was broken up into three sub-phases in order to measure the BarrierBeGone application's usability and usefulness both numerically and qualitatively:

- **Pre-test survey** - designed to assess participants' levels of digital literacy, determine their mobility limitations, and characterise the sample's sociodemographic features.

- **Testing phase** - Participants were required to execute a predetermined set of tasks that matched steps needed to be taken in the application mobile prototype. The participants were urged to explain your thinking while carrying out the tasks during its performance[21]. Additionally, in Participants were asked to rate the perceived difficulty of each activity after completing it. In Addiction, participants should rate the perceived difficulty of each task after completing it.

- **Post-test survey** - using a small adaptation of the System Usability Scale(SUS), the participants were urged to rate how much they agreed with the statement in on a five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" as a set of nine statements about the system:

  - Acho que a aplicação é fácil de usar (I think the application is easy to use)
  - Acho que a aplicação requer conhecimento adicional ou suporte para utilização adequada (I think the application requires additional knowledge or support for proper use)
  - Acho que a aplicação é fácil de entender (I think the application is easy to understand)

– Acho que a aplicação possui uma interface intuitiva e fácil de navegar (I think the application has an intuitive and easy to navigate interface)
– Acho que a aplicação está bem organizada (I think the application is well organized)
– Acho que a aplicação móvel é útil (I think the application it's useful)
– Acho que poderia facilmente obter informações através desta aplicação (I think I could easily get information through this application)
– Acho que a aplicação é intuitiva e de rápida adaptação (I think the application is intuitive and quick to adapt)
– Acho que utilizaria esta aplicação frequentemente (I think I would use this app often)

The second statement is considered a negative statement, step that is accepted as a positive statement. Along with the expected statistics on the many dimensions of the user's perceived experience of interaction with the high-fidelity prototype of the barrier identifier, the assessment stage participants were also asked to respond to a set of exploratory questions:

– Considera que a aplicação pode vir a ser útil no seu dia a dia? (Do you consider that the application could be useful in your daily life?)
– O que mais gostou na aplicação. (What did you like most about the application?)
– O que menos gostou na aplicação. (What did you like least about the application?)
– O que achou mais confuso na aplicação. (What did you find most confusing about the application.)
– Que tipo de funcionalidades acrescentava à aplicação.(What kind of features added to the application.)
– Que tipo de funcionalidades retirava da aplicação. (What kind of features would you remove from the application)

6.1 Pre-test survey

The participants of the usability test sessions were chosen for the first stage of the barrier identification system's usability evaluation based on convenience, with the minimum recruitment goal of five participants set in order to [40] recommendations. According to this, conducting usability tests with at least four to five participants is usually adequate to find 80% of an interface's usability issues. If the sample is increased to nine participants, on average, the proportion of problems found increases to over 95%. As a follow-up, nine potential users were included in the system usability testing sessions. We aimed to find a diverse set of participants with equal gender distribution, various mobility patterns, and a variety of tracks age groups in order to gather a widely of range of contexts and views of use. A full breakdown of the sample's sociodemographic makeup is shown in Figure 6.1 .

	Age Group	Gender	Literacy Level	Profession	Comfort level with mobile devices
0	12-17 years	M	9th Grade	Student	5
1	12-17 years	M	9th Grade	Student	5
2	12-17 years	F	9th Grade	Student	4
3	45-54 years	F	Bachelor's Degree	Nurse	2
4	18-25 years	M	Bachelor's Degree	Lab Technician	5
5	25-34 years	M	High School	Contact Center	5
6	25-34 years	F	High School	Technician	4
7	25-34 years	M	High School	Unemployed	3
8	45-54 years	F	Bachelor's Degree	Engineer	5

Figure 6.1: Socio-demographic information about the participants of the usability tests

Nine potential users that participated in the assessment of the barrier identification system ranged in age from fifteen to fifty-two, with a preponderance of male participation. Of the nine participants, four had previously joined the sample of discussion groups conducted within the scope of this project.

In the surveyed sample of socio-demographic data, several key findings emerged. Firstly, it was observed that 44% of the participants reported having a disability or mobility limitation. This indicates a significant portion of the sample facing challenges related to mobility as can be shown in Figure 6.2. In this sample was included people without any disability in order prove the usability of the application, which can be an irrefutable proof of its usability both with people with reduced mobility and without.

Furthermore, within this subgroup, it was found that 33% of individuals relied on wheelchairs for mobility assistance, 6.3 . This statistic highlights the prevalence of wheelchair users within the sample, further underscoring the importance of considering accessibility and mobility-related factors in the context of the study.

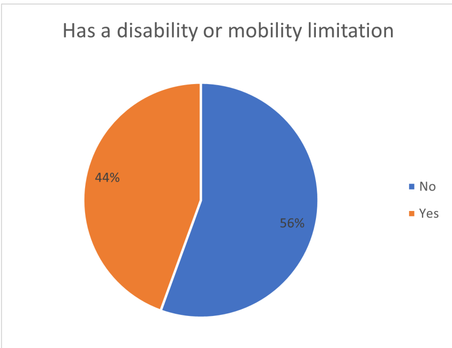


Figure 6.2: Participants with mobility Disabilities

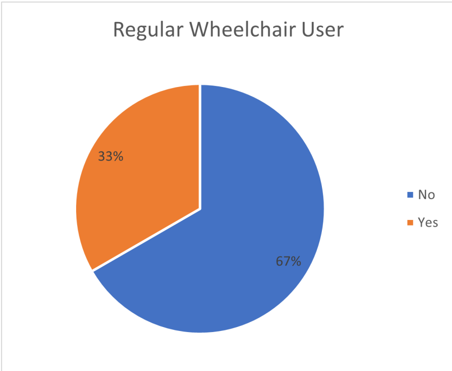


Figure 6.3: Regular WheelChair Participants

Additionally, when examining the participants' comfort level with mobile devices, the average rating was found to be 4.22 out of 5(Figure 6.4). This indicates a relatively high level of comfort and familiarity with mobile devices among the surveyed population. Such positive attitudes towards mobile technology suggest that the participants are receptive to utilizing mobile applications and platforms in their daily lives.

These results provide insight into the sample's sociodemographic features, highlighting the high incidence of disabilities or mobility restrictions as well as the significant number of people who rely on wheelchairs for transportation. A solid basis for incorporating mobile technology into future interventions or solutions aimed at promoting accessibility and addressing the requirements of people with disabilities or mobility constraints is also suggested by the high average level of comfort with mobile devices.

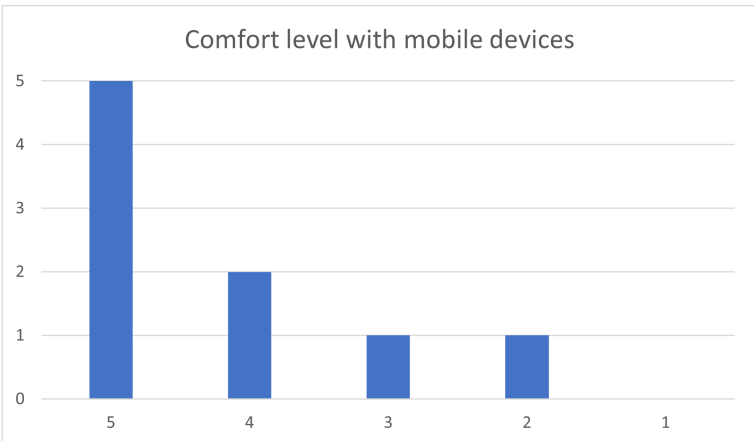


Figure 6.4: Comfort With Mobile Devices

#	Tarefa	Cassificação média
T1	Descarregue a aplicação BarrierBeGone.	5
T2	Registe e crie uma conta na aplicação.	5
T3	Efetue o Login.	5
T4	Abra a página do utilizador e mude a sua password e volte outra vez para o mapa principal.	4.2
T5	Identifique num raio até 50m uma possível barreira e depois centre a sua posição usando o botão center.	3.8
T6	Classifique a barreira e verifique a sua pontuação	4.2
T7	Verifique a sua posição no Leaderboard	4.8

Figure 6.5: Average quantitative assessment per task performed on the prototype

6.2 Testing phase

Potential users had their first interaction with the prototype of the barrier identification mobile application during the test phase, which followed the initial evaluation step. Seven ordered interaction tasks were developed to be completed by participants in the prototype of the mobile application(Figure 6.5), taking into account all of BarrierBeGone's main functionalities, in order to gauge their comprehension of the system's concept and degree of usability. The participants completed all seven written assignments in full throughout the testing phase, highlighting the task's flawless implementation.

The categorization index of the perceived ease of running each task on the BarrierBeGone system prototype was analyzed and summarized in Figure 6.5. The table utilizes a color-coding system to enhance the interpretation of the results. In this system, the color red indicates a low level of execution ease, with an average rating of two points or less. The color yellow highlights an average result, with average ratings ranging from three to four points. Finally, the color green represents a high level of execution ease, with scores above four points.

The findings from the analysis reveal that all tasks in the BarrierBeGone prototype were completed by potential users with high levels of execution efficiency. The average categorization index across the seven tasks was 4.57 out of 5 points in Likert scale[30]. This outstanding average score demonstrates the system's effectiveness in facilitating task completion and indicates the users' perception of the system as user-friendly and easy to use.

The color-coded table provides a quick and intuitive overview of the results, allowing for easy identification of tasks with high execution ease (green) and areas that may require further improvement (red). The positive outcomes validate the successful design and development of the BarrierBeGone system prototype, affirming its usability and user satisfaction.

The task "Identify a possible barrier within a radius of up to 50m and then center your position using the center button" received a lower score compared to the other tasks, indicating that it was perceived as more difficult by the users. There are several possible reasons for this:

- **Task complexity:** Identifying a possible barrier within a 50m radius and then centering the position may require a higher level of attention, observation skills, and understanding of the system's functionality. This complexity could have contributed to a higher perceived difficulty by the users.

- **Technical requirements:** Executing this task may depend on specific technical resources, such as the accuracy of the location system and the availability of information about possible barriers. If users encountered technical difficulties during this task, such as inaccurate location or lack of clear information about the barriers, it could have impacted their perception of difficulty.

- **User experience:** Some users may have less experience or familiarity with mobile applications and using features like the "center" button to position themselves. This may have led to a higher sense of challenge and difficulty when performing this task.

It is important to note that a lower score does not necessarily mean that the task could be better designed. On the contrary, this score can provide valuable insights into areas that can be improved to enhance usability and user experience. Based on this feedback, adjustments can be made to the system, clearer instructions can be provided, or additional support can be offered to users, making the task more accessible and easier to complete.

Analyzing the scores and the justifications provided by users can help identify areas for improvement and optimization of the system, with the goal of enhancing the ease of executing this specific task and, consequently, the overall user experience.

The authentication, however, was deemed a task with a high level of execution ease by every participant in the usability test sessions, earning a quantitative assessment average of 5 points.

During the prototype testing phase, some issues were identified with the Onboarding mechanism. It was found that the size of the displayed information needed to be bigger, making it difficult for users to read. This affected the overall user experience and comprehension of the onboarding process.

Furthermore, feedback from the testers indicated that once a user had completed all the steps of the Onboarding process and subsequently logged in again, the Onboarding steps should no longer appear. Instead, users suggested that these steps could be accessed and revisited through their user profiles.

These findings highlight the need for improvements in the Onboarding process. Enhancements should focus on optimizing the readability of the information provided during the initial setup and ensuring that the steps are clearly visible and easily comprehended. Additionally, implementing a feature where users can access and revisit the Onboarding steps through their profiles would streamline the user experience and eliminate unnecessary repetition.

By addressing these issues and incorporating the suggested changes, the overall usability and effectiveness of the Onboarding process can be improved, leading to a more seamless and user-friendly experience for individuals engaging with the BarrierBeGone application.

6.3 Post-test survey

During the post-test survey phase, potential users highlighted the favorable impact of real-time data dissemination on personal protection, security, and comfort in the context of accessibility in cities offered by the proposed barrier identification system. They expressed that such data provision provides additional information for planning mobility schemes tailored to their individual preferences and needs.

The users emphasized that having access to up-to-date and interconnected data enhances their ability to make informed decisions regarding their mobility. They appreciate the system's ability to provide valuable insights into potential barriers in their surroundings, allowing them to plan their routes more effectively and avoid obstacles that may hinder their accessibility. This real-time information empowers them to navigate the urban environment more confidently and conveniently.

By incorporating real-time data into the system, users believe the proposed barrier identification system can significantly improve their overall mobility experience. They appreciate the system's ability to adapt to their specific requirements and preferences, enabling them to navigate the city with greater ease and independence.

The participants in the third evaluation stage highly appreciate the diverse range of information the BarrierBeGone barrier identifier provides. They compare it to other leading obstacle identification tools and consider it a reference element for their future usage intentions. They emphasize the importance of this tool for the community, as it can enhance accessibility and promote social inclusion in cities. The application's simplicity, speed, and user-friendly nature have significantly contributed to a more enjoyable user experience. Additionally, the participants believe that BarrierBeGone has the potential to make a positive impact by facilitating access to information and promoting inclusivity for all individuals.

At the end of the post-test questionnaire phase, representative users expressed their level of agreement regarding a set of nine statements adapted from the System Usability Scale. Figure 6.6 illustrates the quantitative distribution of opinions among participants in the third stage of system evaluation.

The fruitful results validate the perceived ease of interaction with the high-fidelity prototype and reaffirm the usefulness and convenience of the proposed barrier identification system in the context of promoting accessibility and social inclusion in smart cities. According to the participants in the usability testing sessions, the BarrierBeGone barrier identification system demonstrates significant positive outcomes across multiple dimensions of the user experience. Furthermore, the vast majority of representative users express a solid intention to use BarrierBeGone frequently in their daily lives.

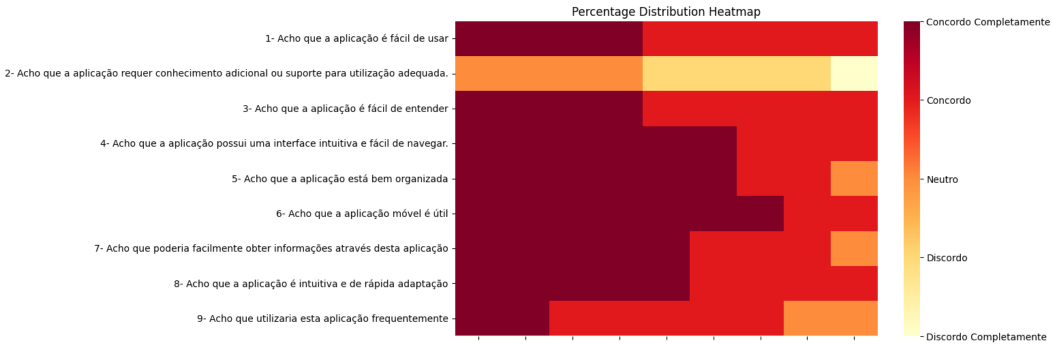


Figure 6.6: Results of the post-test survey phase

6.4 Discussion

In a global perspective, the usability evaluation results of the BarrierBeGone barrier identification system are undeniably positive, reinforcing its simplicity, speed, and consistency in promoting accessibility and social inclusion in smart cities, as proposed in this dissertation. The quantitative analysis revealed high levels of ease of execution in the majority of interaction tasks performed by potential users in the mobile application prototype, with average scores exceeding four points on a five-point Likert scale (4.57), as shown in the usability evaluation stage of BarrierBeGone (see Figure 6.7). The average execution time was approximately 146 seconds, 2 minutes and 26 seconds.

These auspicious results reaffirm the perceived ease of interaction and validate the underlying concept of the barrier identification system.

	Tempo médio para concretização	Média das Tarefas
0	2:26 min	4.57

Figure 6.7: Post-test Average Time and Classification

Chapter 7

Conclusions and Future Work

7.1 Conclusions

The present dissertation focuses on promoting the overall population, specific individuals with reduced mobility, with its purpose segmented into objectives previously described.

The first objective aims to locate and analyze empirical evidence in the domain of the project's foundational concepts, accomplished through a detailed, systematic literature review. The review examined the perception of accessibility and social inclusion in smart cities. The first objective was fully achieved by studying the project's conceptual foundations. Notably, the predominant conclusions highlight the lack of information on the current accessibility of cities and their establishments.

The second objective of the dissertation focuses on identifying and comprehending the challenges that people with limited mobility face. In addition to the theoretical foundation from the literature review, discussion groups were conducted with individuals with mobility limitations, gathering a broad spectrum of perspectives on the barriers that affect accessibility in cities, which are Bouldering, Steep Ramps Large Stairs, Obstructed Access, Improperly Occupied Parking Lot, and Lack/Missing Ramps .

The third objective centered around the design and development of a prototype of a barrier identification system that addresses the requirements of accessibility and social inclusion based on the primary purposes of the dissertation. Leveraging the proliferation of mobile and ubiquitous computing in people's daily lives, BarrierBeGone was designed as a platform for identifying obstacles. Materialized in the form of a mobile application, the system allows users to identify and validate any potential physical barriers in real time that a wheelchair user may encounter. To enhance the relevance of the information provided to the user and offer a user-centric service delivery, the information sources of BarrierBeGone extend to the active participation of its users in a collaborative model, providing contextual data of interest to the users.

The evaluation of the BarrierBeGone barrier identification system's usability fulfilled this dissertation's final objective. With the aim of quantitatively and qualitatively measuring the usability and usefulness of the designed obstacle identification platform, the usability evaluation took the form of usability tests with representative users, enabling the final product refinement.

Overall, the evaluation results are clearly positive. The system's usefulness and the intention to frequently use the BarrierBeGone application were consensuses among a significant portion of participants, although less consensual among users without mobility impairments. Its simplicity and user-friendliness were highlighted as disruptive elements of the platform and the primary motivation for future usage intentions, surpassing other accessible solutions in the market.

Considering the success of the four primary objectives of this dissertation, the final objective of enhancing user experiences when faced with various obstacles and increasing accessibility and social inclusion in smart cities is deemed feasible.

7.2 Limitations and Future work

The scope of this dissertation was segmented into four main objectives, focusing on the requirement of promoting accessibility and social inclusion in smart cities, as successfully concluded in the aforementioned findings. One of the primary objectives of this dissertation is the development of a technological solution to promote accessibility and social inclusion among the population, particularly individuals with mobility limitations. This solution aims to identify and potentially remove barriers that users encounter, with the consideration of user experiences being an integral part of its design and development planning strategy. To establish a solid foundation for the initial definition of the technological artifact's requirements, an in-depth study of accessibility deficiencies in cities was conducted, specifically from the perspective of individuals with reduced mobility, through the use of discussion groups.

The sample of respondents showed a mismatch of schedules which constituted an obstacle, both recruitment with a higher degree of diversity in the survey sample and delayed completion.

For future work in this dissertation, there is a need to conduct a comprehensive study on the same research topics, allowing for a larger-scale and more in-depth assessment of the main physical and non-physical barriers affecting accessibility and social inclusion for individuals with reduced mobility. Furthermore, it is expected that in the continuation of this work, the user study should be expanded geographically.

To enhance the value of the barrier identification system and provide better experiences for its users, another future work is the creation of a route planner that allows users to proactively identify the types of issues they may encounter during their journeys. Although the usability evaluation of the barrier identification system, conducted with representative users, yielded undeniably positive results, there were areas for improvement identified that could enhance the quality and subsequent value of the barrier identification system within the community. These improvements should be considered in a subsequent iteration of BarrierBeGone. Additionally, it is recommended that BarrierBeGone be evaluated in a real mobility environment in urban areas.

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Appendix A

Categorização

In this Appendix is shown the Categorization phase.

Lista de Artigos

Realçar itens ? Sim

ID de Artigo	Autores	Pais	Ano	Exclusão Motivo	Artigo Disponivel (Sim/Não)	sobre Barreiras? Sim/ não	Objetivo	Método/ tipo de Estudo	Participantes	Tipo de jogo /Tempo/modalidade	Instrumentos avaliação	Beneficios	Limitações	Observações
888231207	Michela Dalprà,	Italy	2022	Não excluído	Sim	Sim	investigate the inclusiveness of outdoor playgrounds	survey, assessment tool	on-site visits and from end users.	case study research	survey, assesment tool, checklist	inclusive cities, we need to find adequate resources and effective operational tools to implement inclusive restyling in existing playgrounds and ensure the requirement of inclusion in all new play areas; Related to smart cities	restricted to playgrounds,	
888231209	Mason, L.; Gerling, K.; Dickinson, P.; Holopainen, J.; Jacobs, L.; Hicks, K.;	USA	2022	Não excluído	Sim	Não	bridge the gap between these recommendations and the examples, to provide supplementary considerations which can be used to guide the design of movement-based games which are accessible to disabled players and emphasise engaging, positive play experiences over therapeutic outcomes.	Interpretative Phenomenological Analysis; online survey (N=21)	eight game concepts for semi-structured interviews (N=6) with wheelchair users; online survey (N=21)	Nintendo Wii ; Virtual Reality games with Kinect	survey and interviews	Movement-based games offer an opportunity for physical activity, ensuring accessibility of such systems for disabled players. With an online survey, they highlight how existing recommendations for the design of movement-based games for non-disabled players need to be adjusted to also consider the needs and preferences of physically disabled players; Related to smart cities	Not relactive to barriers, their games are limited in terms of movement integration, and there are other approaches (e.g., location-based games) that were not explored.	
888231233	Ponciano, V.; Pires, I.M.; Ribeiro, F.R.; Garcia, N.M.;	Portugal	2021	Não excluído	Sim	Sim	a mobile application developed that allows the practice of inclusive tourism, using google maps and using an algorithm that helps classify the level of accessibility of each point of tourist interest, allowing the person with disabilities to know at the outset whether that point is inaccessible to its characteristics.	A survey based on a questionnaire related to tour operators to characterize their touristic points.	People that logged and profiling information is available in applicationthrough the georeferencing of a point of interest	Mobile Application	survey	Users can adapt his visit to their own needs to promote inclusion, classifying the adequacy of each point of interest about the individual, text-to-speech so that people with vision problems can hear a description of the topics, and the points of interest framework from google; Related to smart cities	Lack of points and various locations differentiation	
888231248	Paiva, S.; Castro, P.; Mateus, B.; Pinheiro, C.; Ferreira, R.; Rodrigues, S.; Silva, J.; Curralo, A.;	Portugal	2021	Não excluído	Sim	Sim	inform app users about taxi points, parking spaces and landmarks in the city, with additional information on the best navigation route to the desired location, optimized for the type of user segment	Research study	Not tested with users	Mobile Application	not evaluated, presenting a mobile application with accessibility information	Quick access to information regarding parking locations, taxi pick-up locations, route visualizations that are segment-optimized, and location/navigation to important landmarks in the city.	Lack of points and various locations differentiation; not tested	
888231259	Jimeno, M.; Wightman, P.; Salazar, A.; Garcia, L.; Capacho, J.;	Colombia	2020	Not focused on smartcities	Sim	Sim	give high school students an understanding of the importance of an inclusive society and the engineering tools to produce a mobile game that spreads the message to a much broader audience.	training undergraduate students to develop serious mobile games, creating training material for high school students, and delivering the material to IT professors at those schools.	students from university	study research				
888231272	Alqadi, R.; Alhowaiti, M.; Almohaimeed, F.; Alsabban, M.; Raviselvam, S.;	Switzerland	2020	Não excluido	Sim	Sim	Show how accessibility crowdsourcing platforms and mobile applications offer intriguing new opportunities for accomplishing different kinds of tasks or achieving broader participation from the PwD communities than previously possible	Research study	not tested with users	case study research	none	This research shows us some crowdsource applications with detailed information about ech one and some use cases	The limitations of the crowdsource applications are not detailed, and some of the applications are not focused on smart cities	
888231290	Ohashi, S.; Aochi, M.; Shionoya, A.;	Japan	2019	Not focused on smartcities	Sim	ty	was measuring the acceleration rate and angular rate of the wheelchair during outdoor and indoor driving and discerning changes in the road surface conditions.	none	Not tested with users	Measurement experimentation	to evaluate measurement results they used an acceleration sensor and angular rate sensor as the wheelchair moves on asphalt roads and an interlocking concrete block pavement surface. Therefore, they produced a prototype sensor board that we used to find relations between road surface conditions and sensor-acquired information.			
888231296	Rasam, A.R.A.; Azlin, A.H.; Saraf, N.M.;	Malaysia	2019	Não excluido	Sim	Sim	the development of a web GIS-based system consisted of two main applications, which are PWDSupport2U (Mobile apps) and PWDs monitoring system (GIS-web system).	Need Assessment Phase Planning Phase Data Collection Phase Design Phase Web Map Application Phase Testing and Implementation Phase	50 respondents , 76% of the respondent was PWDs or close person to those PWDs.	Mobile Application	Interviews	This web mapping application allows medical support team to manage the entire request submitted by PWDs and delivering needs and allows the PWDs to request for doctor home visit, ambulance and medication delivery service in Ampang.	Is a prototype; Does not relate with many physical barrirer for PWDs	
888231302	Abdallah, S.B.; Ajmi, F.; Othman, S.B.; Vermandel, S.; Hammadi, S.;	France	2019	Não excluido	Sim	Sim	help many wheelchair users providing accessibility information and allowing them to navigate freely and surely from a source to a destination in real-time.	interviews	students using wheelchair	Mobile Application		wheelchair users balk to visit a foreign place, as they have no information about the new environment and its accessibility conditions; covers a large number of barriers	Is a prototype;	
888231306	Silva Alves, L.A.; Reis e Silva, A.N.; de Jesus Viana Sá, E.; da Silva, T.R.;	Portugal	2019	Não excluido	Sim	Sim	assist and integrate the physically disabled in the digital environment.	interviews	tested with users	Videogame	bibliographical research	players can notice the barriers along the game.	a simple game not too developed;	
888231307	da Silva Lima, N.; Leite, J.P.C.; de Paiva, A.C.; Maia, I.M.O.; Silva, A.C.; Junior, G.B.; de Souza Baptista, C.;	Brazil	2019	Não excluido	Sim	Sim	to provide essential means to communities of users with disability or low mobility problems to contribute on building a map of accessibility traps, showing problems that these people may find in their daily-based activities.	none	Not tested with users	Mobile Application		indicates, classifies and rates accessibility traps, and suggests the most accessible routes in urban centers.	Lack of points and various locations differentiation; not tested	
888231361	Gerling, K.M.; Linehan, C.; Kirman, B.; Kalyn, M.R.; Evans, A.B.; Hicks, K.C.;	United Kingdom	2016	Not focused on smartcities	Sim	Sim	participatory design for and with people using wheelchairs, and reflects upon challenges and opportunities that were identified when working with game design experts who do not use wheelchairs, and young people who use wheelchairs on a daily basis.develop wheelchair-based movement-based games building on the KINECTWheels toolkit that allows the integration of basic wheelchair movement (back and forth, turning to the sides) as part of a game control interface.	facilitating participation and design through interaction	Nine young people aged 13-22 years; 22 students enroled in a game development;	KINECTWheels Game	research questions; Data collection and analysis; Design process	Some barriers are identified as:" People with a disability find it harder than others to make new friends; People with a disability have problems getting involved in society; People with a disability are a burden on society; People with a disability are a burden on their family	Not focused on smart cities and enviromental barriers;	
888231369	Palazzi, C.E.; Bujari, A.;	Italy	2016	Não excluido	Sim	Sim	create unprecedented services able to improve the interaction with the environment, the social inclusion and the quality of life.	Research study	tested with users	Mobile Application		Any user (both with and without impairments) may actively provide the centralized server with a detailed report on some encountered obstacle or its own evaluation of its most frequently utilized road segments, identifying the best path.	Few number of possible barriers that can be found, lack of information about the results of the paper	
888231399	T. Heitor, V. Medeiros, R. Nascimento and A. Tomé	Portugal	2014	Não excluido	Sim	Sim	get information about the excessive physical effort and time consumption demanded of disabled people when overcoming such barriers as: stairs, ramps, pathways and sidewalks		tested with users	Mobile Application	This study was developed by means of a mapping profile using both high- and lowtech spatial description techniques, namely space syntax synchronised with a conventional measured survey involving direct data capture and map interviews, i.e. an inquiry procedure combining walkthroughs with semistructured interviews, documentary analysis and space-use observations.	Indicates, classifies and rates accessibility traps, and suggests the most accessible routes in Lisbon University.	Lack of points and various locations differentiation;	
888231417	Fradj, S.B.;	United Kingdom	2012	Excluido Artigo não disponível	Não	Sim	make minorities' life, especially persons with disabilities, better: not only be by destroying physical barriers but also by trying to include them socially.			study research				
888231419	Popescu, C.; Brown, O.; Shopland, N.;	European Union	2012	Não excluido	Sim	Sim	allow users to plan and practice their routes to different community opportuni-ties.	Research study	tested with users	Mobile Application		Indicates, classifies and rates accessibility traps, and suggests the most accessible routes in many regions.		
888231172	Wu, Yenchun Jim; Liu, Wan-Ju; Yuan, Chih-	Taiwan	2020	Não excluido	não	Sim								
	Mora HGilart-Iglesias VPérez-del Hoyo R et al.	Spain	2017	Não excluido	Sim	Sim	design a model for evaluating the effectiveness of urban accessibility, improving the habitability of cities and citizens' quality of life, and achieving equal opportunities for people with disabilities.	Research study	tested with users	Mobile Application	self reporting system; interviews; analysing the daily paths of the students and lecturers	Provide information about Accessibility and Smart Cities, showing the effectiveness of urban accessibility over the time as a user-centric tool supperted by technology.	Not focused on people with physical impairments.	

Appendix B

Interviews

In this Appendix is shown the Interview survey.

Guião da Entrevista

Tema: *"Promoção de acessibilidade e inclusão social em cidades inteligentes"*

Objectivos gerais:

- Legitimar a entrevista e motivar o entrevistado a participar (bloco I)
- Explorar dinâmica diária das pessoas com mobilidade reduzida (bloco II)
- Explorar a avaliação da aplicação(bloco III)
- Concluir, legitimando as ideias principais do entrevistado (bloco IV)

Nome: ____

1 - Idade: ________ anos
2 - Género: ❒ Feminino ❒ Masculino
3 - Estado Civil: ________________________________
4 - Habilitações literárias: _________________________
5 - Profissão: __________________________________
6 - Utilizador regular de cadeira de rodas: ❒ Sim ❒ Não

Bloco II

- Como se veem a si mesmos as pessoas utilizadoras de cadeiras de rodas, e como a comunidade os descrevem?

- Que tipo de dificuldades encontra no dia a dia? Como supera essas dificuldades?

- Com que frequência utiliza dispositivos eletrónicos como por exemplo telemóvel ou tablet?

- Conhece/utiliza alguma aplicação que o ajude diariamente? Sim, Qual?

- Costuma fazer deslocações diariamente?

Bloco III

- Considera que seria pertinente existir uma aplicação onde fossem identificassem possíveis barreiras para pessoas com mobilidade reduzida?

- Quais os temas que seriam mais adequados abordar na aplicação?

- Considera que a aplicação terá algum impacto em si? A que nível?

- Considera que esta metodologia adequada para cada cidadão?

- Recomendaria a alguém a utilização desta aplicação?

Blocos temáticos	Objectivos	Questões	Obs.
Bloco I Legitimação da entrevista e motivação para a mesma	• Dar a conhecer o estudo e objectivos da entrevista • Solicitar colaboração do entrevistado • Consciencializar a pessoa da importância do seu contributo para o estudo • Assegurar o anonimato e confidencialidade dos dados • Incentivar a colocação de questões	• Questões demográficas entre outras de modo a minimizar constrangimentos • Deseja colocar alguma questão?	
Bloco II Explorar dinâmica das pessoas com mobilidade reduzida	• Explorar dinâmica das pessoas com mobilidade reduzida • Realizar breve avaliação • Explorar opiniões emitidas	Costuma fazer deslocações diariamente? Como se veem a si mesmos as pessoas utilizadoras de cadeiras de rodas, e como a comunidade os descrevem? Que tipo de dificuldades encontra no dia a dia? Como supera essas dificuldades? Com que frequência utiliza dispositivos eletrónicos como por exemplo telemóvel ou tablet? Conhece/utiliza alguma aplicação que o ajude diariamente? Sim, Qual?	

Bloco III Explorar a avaliação da aplicação	• Conhecer opinião sobre a aplicação • Compreender a utilidade da estratégia • Explorar opiniões emitidas	Depois de dar a conhecer a ideia da aplicação: a) Considera que seria pertinente existir uma aplicação onde fossem identificassem possíveis barreiras para pessoas com mobilidade reduzida? b) Quais os temas que seriam mais adequados abordar na aplicação? c) Considera que a aplicação terá algum impacto em si? A que nível? d) Considera esta metodologia adequada para qualquer cidadão? e) Considera que o jogo terá algum impacto em si? A que nível? f) Recomendaria a alguém a utilização desta aplicação?	
Bloco VI Reflexão e conclusão da entrevista	• Reflectir sobre as principais opiniões emitidas • Concluir a entrevista	• Devolver algumas questões menos esclarecedoras • Rever a entrevista a) Ver se o registo reflecte as ideias do entrevistado b) Ver se o entrevistado quer alterar alguma coisa do que disse • Concluir a entrevista a) Reforçando a importância do entrevistado para o estudo b) Reforçando a disponibilidade dos dados ou conclusões	

Appendix C

Validation

In this Appendix is shown the Validation survey.

Guião da Entrevista

Tema: *"Promoção de acessibilidade e inclusão social em cidades inteligentes"*

Objectivos gerais:

- Legitimar a entrevista e motivar o entrevistado a participar (bloco I)
- Explorar dinâmica diária das pessoas com mobilidade reduzida (bloco II)
- Explorar a avaliação da aplicação(bloco III)
- Concluir, legitimando as ideias principais do entrevistado (bloco IV)

Nome: ____

1 - Idade: ________ anos
2 - Género: ❐ Feminino ❐ Masculino
3 - Habilitações literárias: ___________________________
4 - Profissão: _____________________________________
5 - Você possui alguma deficiência ou limitação motora?: ❐ Sim ❐ Não
6 - Você é um utilizador regular de cadeira de rodas?: ❐ Sim ❐ Não
7 - Em uma escala de 1 a 5, qual é o seu nível de conforto ao usar dispositivos móveis? ________

Bloco II

1- Descarregue a aplicação BarrierBeGone.

2- Registe e crie uma conta na aplicação.

3- Efetue o Login.

4- Abra a página do utilizador e mude a sua password e volte outra vez para o mapa principal.

5- Identifique num raio até 50m uma possível barreira e depois centre a sua posição usando o botão center.

6- Classifique a barreira e verifique a sua pontuação.

7- Verifique a sua posição no Leaderboard

Bloco III

Responder entre 1-5 (5-Concordo Completamente, 4-Concordo, 3-Neutro, 2-Discordo, 1-Discordo Completamente)

1- Acho que a aplicação é fácil de usar

2- Acho que a aplicação requer conhecimento adicional ou suporte para utilização adequada.

3- Acho que a aplicação é fácil de entender

4- Acho que a aplicação possui uma interface intuitiva e fácil de navegar.

5- Acho que a aplicação está bem organizada

6- Acho que a aplicação móvel é útil;

7- Acho que poderia facilmente obter informações através desta aplicação

8-Acho que a aplicação é intuitiva e de rápida adaptação

9- Acho que utilizaria esta aplicação frequentemente

Bloco IV

Resposta Aberta

1- **Considera que a aplicação pode vir a ser útil no seu dia a dia?**

2- **O que mais gostou na aplicação**

3- **O que menos gostou na aplicação**

4- **O que achou mais confuso na aplicação**

5- **Que tipo de funcionalidades acrescentava à aplicação**

6- **Que tipo de funcionalidades retirava da aplicação.**