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LONG PAPER

Accessibility of mobile applications for tourism—is equal access a reality?

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Abstract
With the increasing use of smartphones in people's daily lives, mobile accessibility has become a key factor for them. Tourism is one of the sectors that has benefited the most from this growth but has not yet reached its full potential as accessibility has not yet been fully exploited. The main goal of this study is to assess accessibility in mobile applications for the tourism sector. Thus, 14 mobile applications were analyzed, using a manual and automatic methodology through the proposal of an evaluation model divided by quantitative and qualitative requirements, as well as the use of features such as VoiceOver and TalkBack. The results show a high overall number of errors in most quantitative requirements as well as non-compliance with most qualitative requirements. On iPhone 4, "Viseu – Guia da Cidade" was the application with the highest rating, while on Wiko GOA, it was the "JiTT.Travel Funchal" application. In turn, on iPhone 6 Plus, iPhone XR, Nokia 5.1 and OnePlus 6 devices, the best results were achieved by the "Viseu – Guia da Cidade," "JiTT.Travel Funchal" and "TUR4all" applications. Regarding the accessibility of mobile applications on different versions of the same mobile operating system, it was concluded that there are no differences in their accessibility on both operating systems (iOS and Android). Finally, regarding the accessibility of applications on smartphones with different screen sizes, there are also no differences in their accessibility.

Keywords Accessibility · Mobile applications · Accessibility of mobile applications · WCAG 2.1 · Tourism

1 Introduction

There is a lack of the literature on accessibility in mobile applications for the tourism sector. The fact that there is a very limited number of studies and the inexistence of enough knowledge on the subject, were some of the main factors that motivated this article. On the other hand, the global number of users with some type of disability, the growing use of mobile devices and, consequently, the increasing use of mobile applications in daily activities were also important factors.

With globalization and changing scenarios taking place rapidly, society is increasingly demanding to optimize time in the best way. Thus, companies are increasingly adopting mobile applications, which offer more convenience, as customers can ask their questions, learn more about the

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services offered and even make purchases directly through their smartphone [1]. In addition, mobile applications also have the power to promote the company, arousing user interest in the brand [1].

However, these applications not only affect the daily lives of users, but also industries, including tourism. Creating mobile tourist applications facilitates tourist integration and thus enhances the experience and attractiveness of the destination [2].

There is a percentage of users who have not been properly valued: people with disabilities. These can constitute a significant market segment for the tourism industry [3]. That said, it is crucial that both developers and designers of mobile applications consider their accessibility for these users, as even for those tasks that are considered simple by others, they encounter difficulties that they have to deal with [4]. Accessibility in mobile applications means that the application, services and content provided by it are accessible to the user in real time.

In order to achieve better accessibility for mobile applications, designers and developers need to develop them according to accessibility standards, such as the Web Content Accessibility Guidelines (WCAG). WCAG are developed through the World Wide Web Consortium (W3C) in cooperation with individuals and organizations from around the world to provide a standard for mobile application accessibility that meets the needs of individuals, organizations and international governments [5].

Therefore, the main objective of this work is to assess accessibility in mobile applications in the tourism sector. In addition, three specific objectives were also defined:

(1) Check if there are differences in the accessibility of mobile applications on different mobile operating systems;
(2) Check if there are differences in the accessibility of mobile applications on smartphones with different screen sizes;
(3) Check if there are differences in the accessibility of mobile applications on smartphones in different versions on the same mobile operating system.

2 Mobile accessibility

2.1 Conceptualizing accessibility

Accessibility is not a new concept. In 1959, Hansen defined accessibility as the ease of reaching goods, services, activities and destinations, which together are called opportunities [6]. Over the years, other definitions on this topic have emerged to the point of accessibility be considered as the existence of features that allow for ease of access and use of environments, products and services by anyone despite their possible incapacities or disabilities. The overall accessibility concept involves the Inclusive Design area, thus offering a wide range of products and services that cover the needs of different populations, the adaptation of artifacts and the implementation of alternative means of information, communication and mobility [7].

Although there is no universal definition of accessibility, its goal is seen as unanimous in the literature, that is, allowing all citizens to participate actively in society.

This term is not just a social problem, nor is it just about the built environment and physical barriers. Darcy [8] draws particular attention to the sensory requirements, especially important for those with hearing and/or visual disabilities, and the requirements associated with communication, which include those with speech, writing and/or language.

2.2 World accessibility

There are several Decree-Laws on accessibility around the world that have helped integrate disabled citizens into society.

In Portugal, the government showed for the first time an interest in accessibility with the creation of Decree-Law No. 43/82. This Decree consisted of a series of measures to combat movement limitations especially of architectural order to citizens with movement limitations [9]. Since then, other accessibility decrees have emerged (Decree-Law No. 172-H/86, Decree-Law No. 123/97, Decree-Law No. 163/2006, Decree-Law No. 136/2014), having as a common objective the improvement of accessibility rules in public buildings, public roads and residential buildings [10–13]. This has substantially improved the quality of life of citizens, especially individuals with motor disabilities. However, the implementation of these measures did not have significant benefits for subjects with other types of disabilities (e.g., intellectual, hearing and visual). Finally, in 2018, Decree-Law No. 83/2018 emerged, which defines the accessibility requirements of websites and mobile applications of public organizations [14].

In 1948, the United Nations proclaimed a core of rights inherent to all human beings, regardless of their nationality, gender, age, race, belief or personal and social condition [15]. With the universal acclaim of human dignity as a value, criticism began regarding the isolation of persons with disabilities. Human rights defenders and researchers have become concerned about the integration of people with disabilities into their communities and the need to assert their rights [15]. In 1975, the UN published the Declaration of the Rights of the Disabled Persons, claiming that the document would guarantee the protection of these rights. They defined disabled person as those who are unable to

secure on their own the needs of a normal, individual and social life on account of a disability [16].

In the USA, with the creation of Section 504 of the Rehabilitation Act in 1973, adaptations in higher education were made so as not to exclude any citizen [17]. In 1980, the USA also created the Americans with Disabilities (ADA) Act, legislation that aimed to reduce (prohibit) discrimination and promote accessibility at work [18]. Finally, in 2017, the USA created the Information and Communication Technology Standards and Guidelines, thereby ensuring that the information and communication technologies covered by its statutes were accessible and usable by individuals with disabilities [19].

In Brazil, in 1989, Law No. 7.853/89 was approved, and the responsibility for the adoption of norms that eliminated barriers to access for disabled people to public buildings, urban spaces and means of transport was transferred to states and municipalities [20]. In 1999, the creation of Decree No. 3,298/99 was highlighted, which ensured access to health, training and rehabilitation, education, work, culture, sport, tourism and leisure [20]. In 2000, Law No. 10.098/2000 was issued, which promotes the accessibility of people with disabilities or reduced mobility [20]. In 2015, with the creation of Law No. 13.146, the "Lei Brasileira de Inclusão da Pessoa com Deficiência" was instituted. This law aimed to ensure and promote, under equal conditions, the exercise of fundamental rights and freedoms by persons with disabilities, aiming at their social inclusion and citizenship [21].

In the UK, in 1995, the Disability Discrimination Act was created, which represents a legislative attempt to combat discrimination against persons with disabilities in various areas, such as employment, access to goods, facilities and services, the sale and lease of land and property, access to public transportation and education [22]. In 2018, the Public Sector Bodies (Websites and Mobile Applications) were created, which impose an obligation on public sector bodies to make their websites and mobile applications more accessible, unless that doing so would impose a disproportionate burden on the public sector body [23]. In addition, it also contains an additional obligation for public sector bodies to publish an accessibility statement about compliance with the accessibility requirement and to keep that statement under regular review [23].

2.3 Smartphone and mobile applications

The smartphone is considered a cell phone with advanced capabilities, which executes an identifiable operating system allowing users to extend its functionality with third-party applications that are available from an application repository [24]. Thus, smartphones must include sophisticated hardware with advanced processing capabilities and multiple connectivity features (e.g., Wi-Fi). In addition, the operating system must be clearly identifiable, e.g., Android, Apple's iOS [24]. Finally, the operating system must allow third-party applications to be installed from application repositories such as the Google Play Store, the Microsoft Store and the Apple Store [24]. According to Purcell, Entner and Henderson [25], a mobile application can be defined as a software application designed for a mobile device operating system that extends device capabilities, allowing users to perform specific tasks.

With globalization and changing scenarios taking place rapidly, society is increasingly demanding and is seeking to optimize time in the best way possible. Thus, companies are increasingly adopting mobile applications, which offer more convenience, as customers can ask their questions, learn more about the services offered and even make purchases directly through their smartphone [1]. In addition, mobile applications also have the power to promote the company, arousing user interest in the brand [1].

However, it is also crucial that we address accessibility in mobile applications. According to the Apple definition [26], "a mobile application is accessible when all user interface elements with which they can interact are accessible. A user interface element is accessible when it correctly indicates that it is an accessibility element." According to González [27], this definition refers to the fact that the elements that make up the user interface must provide certain information so that accessibility services operating in the operating system or support products (software or hardware) can interact with each other properly and allow user access to the device. Thus, it can be said that a mobile application is accessible when any user, regardless of their functional diversity, can use it on their mobile device to their satisfaction.

Due to the rise of smartphones, there are many social groups that make use of these, among them people with disabilities. This social group makes intensive use of this type of device as it helps to overcome many of the barriers established in society [28]. In order for a disabled person to access content available on mobile applications, it must be accessible. In addition, when talking about accessibility on mobile devices we are also referring to the design of the device for its applications, as both will allow users to perceive, navigate and interact with the device without any barriers [28].

2.4 Accessibility standards

2.4.1 WCAG standards–W3C

Web Content Accessibility Guidelines (WCAG) are developed by the World Wide Web Consortium (W3C) in cooperation with individuals and organizations from around the world to provide a web accessibility standard that meets the needs of individuals, organizations and international

governments [5]. WCAG documents explain how to make Web content more accessible to people with disabilities, including blindness and low vision, deafness and hearing loss, movement limitations, speech difficulties, photosensitivity and cognitive limitations. However, they do not address all the needs of users with these disabilities. These guidelines address the accessibility of web content on personal computers, tablets and mobile devices. Following these guidelines will also make web content more usable for general users [29].

Currently, WCAG 2.1 is the latest version of the standard, containing 13 guidelines organized into four principles [29]:

(a) Perceptible: Information and user interface components must be presented to users in order for them to understand the information presented. In addition, it must be visible to all users' senses;
(b) Operable: Users must be able to work with interface components (interface cannot require interaction that a user cannot perform);
(c) Understandable: Users must be able to understand the information and how the user interface works (the contents or operation cannot be beyond their comprehension);
(d) Robust: Users must be able to access content as technologies advance (when technologies and user agents evolve content must still remain accessible).

2.4.2 Best practices provided by Google and Apple

Apart from the guidelines for mobile accessibility provided by the W3C, Google and Apple also offer their own guidelines.

Google has created guidelines for mobile accessibility to make it easier for developers to create applications while allowing applications available for this mobile operating system to be accessible to as many users as possible. Thus, seven main guidelines were created [30]: Assistive Technologies, Hierarchy, Color and Contrast, Layout and Typography, Writing, Imagery, Sound and Motion and finally Implementing Accessibility.

Apple has also created mobile accessibility guidelines to make applications more accessible. Thus, seven main guidelines were created [31]: Inclusive Design, User Interaction, Navigation, Text Size and Styles, Color and Contrast, Appearance Effects and Motion and finally Content.

2.5 Accessible tourism and the smartphone

Smartphone use, especially mobile applications, has affected not only daily life, but also the tourism industry and people's travel behavior [32]. The smartphone's ubiquitous ability to enable location-based data exchange and social information has quickly made it a powerful tool for tourists. Smartphones are therefore an inevitable partner for tourism, and the tourism context has become a fertile ground for mobile computing [33]. Similarly, Muñoz and Sánchez [2] argue that the creation of mobile tourist applications facilitates the integration of the tourist and, therefore, improves the experience and attractiveness of the destination. Within the mobile applications market, travel applications in 2011 were already the seventh most popular category of applications being downloaded [34].

In recent years, a multitude of new approaches and mobile applications have emerged, including tourist-specific applications, travel planning applications (such as TripAdvisor), transportation (Skyscanner, Uber), accommodation (Booking.com, Airbnb), tourist guide (NY Travel Guides), navigation services (Google Maps) and finally social networking applications [32, 35]. With a growing number of users, mobile applications are increasingly influential in tourist travel decisions and behavior [36] at all stages of tourism consumption [37, 38].

According to the UNWTO [39], one of the keys to the successful establishment of tourist communication is to ensure that information is accessible to all; this is, both destination and information must be accessible to tourists with disabilities. These individuals are sensitive to market trends and want to access, like everyone else, the products that stand out [27]. In 2016, travel and tourism generated 8.4% of GDP [40] and by 2020, according to some estimates, 25% of travel and leisure spending will come from people with disabilities [41]. For these tourists, it is crucial to know in advance how their needs can be met at the place they intend to visit, especially because some studies point to the fact that they avoid traveling because they are unaware of vital information to do so safely [41]. For this, mobile applications, in particular, can play a decisive role [42]. Therefore, destinations must apply technology to serve this audience; otherwise, they may risk not benefiting from the economic impact of this market.

Currently, most mobile applications developed to support people with disabilities in their travel and tourism activities provide recommendations for places to visit or information about accessible facilities in public places and transportation [42]. In addition, they also provide information about their accessibility features, considering the user's location or the characteristics of the disability group to which they belong. However, for tourists with disabilities, these mobile applications, or even common tourist resources (such as online guides), are not enough. It is important to consider that each person with disabilities has their own limitations and even within the same group (e.g., people with reduced mobility), each person has their specific needs. These may differ in physical, functional characteristics or transport needs, and many mobile applications deal with this as a homogeneous

group, which is not true [42]. To be useful, mobile applications should provide each disabled tourist with information about the most appropriate point of interest and recommend the most suitable places to visit, which should be contextualized according to their specific needs and interests [42].

At an early stage, it was necessary to develop an evaluation model which contains the requirements that were evaluated in the different mobile applications of both operating systems. These requirements have been adapted from the WCAG 2.1 Guidelines [29], as well as some best practices of both operating systems Google [30] and Apple [31] for mobile application development and still some requirements used in the study by White [43]. Finally, two requirements were proposed by the researchers of the present study. Table 1 presents the evaluation model.

Table 1 Adaptation of WCAG 2.1 Guidelines, iOS and Google good practices and White's study

Requirements	Context	Reference
Guidelines/quantitative requirements		
REQ 01	Contrast ratio of at least 3:1	WCAG 2.1
REQ 02	Contrast ratio of at least 7:1	WCAG 2.1, iOS and Google
REQ 03	Legible and functional content at 200% zoom	WCAG 2.1
REQ 04	Target size 48 × 48dp	WCAG 2.1, iOS and Google
REQ 05	All content usable from VoiceOver/TalkBack	iOS, Google and White
REQ 06	Space between elements at least 2 mm	iOS and Google
Guidelines/qualitative requirements		
REQ 07	Subtitles for content audio or video with audio	WCAG 2.1
REQ 08	Sign language for all audio content	WCAG 2.1
REQ 09	Alternative media for all pre-recorded media	WCAG 2.1
REQ 10	Alternative for all live audio content	WCAG 2.1
REQ 11	Supports both orientations	WCAG 2.1
REQ 12	All audio that plays automatically for more than 3 s can be stopped	WCAG 2.1
REQ 13	Background audio (absence, muted or decrease)	WCAG 2.1
REQ 14	Additional content is not triggered just with focus	WCAG 2.1
REQ 15	Color is not the only visual way of transmitting information	WCAG 2.1
REQ 16	Content with automatic movement for more than 5 s can be stopped	WCAG 2.1
REQ 17	No functionality has a time limit to be actionable	WCAG 2.1
REQ 18	When an authenticated session expires, the user can continue the activity without loss of data after re-authenticating.	WCAG 2.1
REQ 19	No content should blink for more than 3 times per second	WCAG 2.1
REQ 20	All non-essential motion animation can be disabled	WCAG 2.1
REQ 21	The purpose of the link can be determined from the text alone	WCAG 2.1
REQ 22	Functionality that can be operated by device motion or user motion can also be operated by user interface components	WCAG 2.1
REQ 23	No functionality can only be used by complex gestures	WCAG 2.1
REQ 24	Technical words and jargon should be included in a glossary	WCAG 2.1
REQ 25	Abbreviations should be identified the expanded form or meaning	WCAG 2.1
REQ 26	Text requires reading ability not more advanced than the lower secondary education level	WCAG 2.1
REQ 27	Input error automatically detected should have suggestions for correction	WCAG 2.1
REQ 28	If a label is not enough to explain the fill of a field, a contextual help should be provided.	WCAG 2.1
REQ 29	Forms can be reversible, checked or confirmed	WCAG 2.1
REQ 30	Color to grayscale without the use of assistive technology	White
REQ 31	Invert colors without the use of assistive technology	White
REQ 32	Zoom without the use of assistive technology	Researchers
REQ 33	CAPTCHA can be solved by every user	Researchers

3 Evaluation procedure

Currently, the number of devices running the iOS operating system is limited, with Apple being the sole manufacturer of these devices. In contrast, for devices running the Android operating system, there are many different hardware manufacturers [44].

For the evaluation of the accessibility of mobile applications to be as accurate and reliable as possible, it is necessary that the mobile device and the test environment meet certain criteria. Therefore, tests on six mobile devices will be performed according to the following criteria:

(1) Same level of environmental light intensity;
(2) Equal light intensity level on mobile devices;
(3) The mobile device must contain the latest available operating system update for that device;
(4) The screen size of the Android mobile device should be similar to the mobile device with the iOS operating system;
(5) The screen resolution of the Android mobile device should be similar to the iOS mobile device.

Regarding the first criterion, it is important to note that different conditions of ambient light intensity can interfere with the results and, consequently, lead to wrong conclusions. Due to this factor, it became necessary to subject both mobile devices to a similar level of ambient light intensity. In turn, different levels of light intensity on mobile devices can have the same consequences as the criterion previously mentioned and, for this reason, the same level of light intensity was defined. Regarding the third criterion, it was established that each of the mobile devices must contain the latest update of the operating system available. In this way, it is possible to obtain a version of the mobile applications as close as possible between the devices. At the same time, it is also possible to ensure that mobile devices contain the latest update available in the Accessibility support tools (for example, the TalkBack and VoiceOver tools). On the other hand, it was defined that the screen size and resolution of the Android mobile device should be like those of the iOS mobile device. In this way, the likelihood of influencing the results and conclusions will be reduced.

Therefore, six mobile devices will be used to evaluate the accessibility of the applications: three with the Android operating system (screen sizes ranging between 3.5 and 28.6 inches) and three with the iOS operating system (screen sizes ranging between 3.5 and 6.1 inches). The different characteristics of the six devices used are shown in Table 2.

These mobile devices were chosen for two reasons. One of them is related to the fact that the six smartphones contain different screen sizes, in the same mobile operating system. The other reason concerns the fact that the researcher took into account that not all users have a recent smartphone.

Regarding the evaluation method used in the present study, manual evaluation was performed with the aid of two functionalities present in each of the mobile operating systems ("TalkBack" and "VoiceOver" in Android and iOS systems, respectively). In turn, the automatic evaluation was performed with the help of two tools—the Accessibility Scanner and the Pixel Picker.

Since an accessibility level that mobile applications must comply with will not be used, it will be necessary to adopt another strategy or evaluation model. Therefore, the quantitative assessment was performed using a Likert scale from 1 to 7 points, where 1 (minimum level) corresponds to an insufficient degree and 7 (maximum level) to an excellent degree [45]. However, despite the objectivity of the quantitative method, it does not allow for a thorough understanding of a given phenomenon. Therefore, it was necessary to adopt another valuation method for non-accounting requirements, such as valuation using qualitative methods. This is also due to the fact that there are new requirements proposed by the researchers of the present study and questions to verify the existence of certain functionalities that can only be answered through a dichotomous scale, and the assignment of classifications is not feasible.

Table 2 Mobile device characteristics

Device	OS	Display	CPU	Weight	Year
iPhone 4	iOS 7.1.2	3.5" 640×960p (~330 ppi)	Apple A4 (1 GHz Single-Core)	137 g	June 2010
Wiko GOA	Android 4.4.2	3.5" 320x480 (~165 ppi)	Mediatek MT6572M (1 GHz Dual-Core)	105 g	May 2014
iPhone 6 Plus	iOS 12.4	5.5" 1080×1920p (~401 ppi)	Apple A8 (1.4 GHz Dual-Core)	172 g	September 2014
Nokia 5.1	Android 9.0	5.5" 1080x2160p (~439 ppi)	MediaTek Helio P18 Octa-Core (4x2.0 GHz & 4x1.2 GHz)	150 g	August 2018
iPhone XR	iOS 13.1.2	6.1" 828x1792p (~326 ppi)	Apple A12 Bionic Hexa-core (2x2.5 GHz & 4x1.6 GHz)	194 g	October 2018
OnePlus 6	Android 9.0	6.28" 1080x2280 (~402 ppi)	Qualcomm SDM845 Octa-Core (4x2.8 GHz & 4x1.7 GHz)	177 g	May 2018

After verifying the existence of these requirements in the target group applications, a descriptive analysis of both the behavior of the requirements in the applications and their inherent consequences was performed.

3.1 Tools and functionalities for evaluating the accessibility of mobile apps

Web accessibility assessment tools can help quickly identify potential accessibility issues and can be used at all stages of the web design and development process [46]. These tools can provide fully automated checks and assist with manual review.

In the case of mobile applications, no tools were found that fully and thoroughly assess accessibility. In addition, no recommendations were found by W3C on this point. However, there are certain tools that can perform an automatic partial accessibility assessment, which will complement the manual assessment. The Accessibility Scanner is an example of such tools, recommending accessibility enhancements for mobile applications in the Android operating system [47]. In the present study, the "Pixel Picker" tool was also used together with the contrast ratio [48], so that it was possible to compare the colors of a screenshot.

In addition to these tools, there are certain features present in the operating systems of each device, which also serve as a complement to the manual evaluation, namely "TalkBack" (on the Android operating system) and "VoiceOver" (in the iOS operating system). "TalkBack" is the Google screen reader that gives voice feedback so that the individual can use the device without looking at the screen [49]. In turn, VoiceOver is a gesture-based screen reader that allows an individual to use iPhone without having to see the screen [50].

3.2 Target group

During the period of the present study, all mobile applications from the tourism sector that were available in the Google Play Store (Android operating system) and Apple App Store (iOS operating system) were downloaded, in order to obtain a sample as wide as possible. All mobile applications that were not available in Portuguese and/or that did not work correctly were excluded.

As such, in the present study 14 Portuguese mobile applications of the tourism sector were analyzed. The first application "Guia de Viagem Visit Portugal" allows to organize a user's itinerary, get real-time tourist information, access personal account and favorite content and even search the national database [51]. The second application "Rota Omíada no Algarve" gives information about places to visit in fourteen places in the Algarve, with photographs and a brief description available for each tourist spot [52]. The third application, "Guia Lisboa de Civitatis," offers information about tourist spots, typical Portuguese products, means of transport, hotels and maps of the city of Lisbon. It is also possible to buy activities [53]. The fourth application, "Guia Porto de Civitatis," is similar to the previous one, but for the city of Porto [54]. The fifth application, "Best Portugal," is a travel and tourism guide for Portugal, offering real reviews, popular destinations, itineraries, maps, restaurants, accommodations and experiences [55]. The sixth application "Porto Guia de Viagem" is a travel guide for the city of Porto, allowing travelers to select places to visit [56]. The seventh application, "oGUia Portugal – Guia da Cidade," provides information on tourist spots, events, restaurants and accommodation anywhere in the country [57]. The eighth application, "Viseu – Guia de Cidade," allows to create an itinerary according to the time available to visit the city of Viseu, containing a description of each tourist spot, as well as an audio guide [58]. The ninth application "JiTT.Travel Funchal" is similar to the previous one, but for the city of Funchal [59]. The tenth application, "Descubra Vila Real," gives information about Vila Real's monuments, cultural programs, restaurants, and hotels [60]. The eleventh application, "SMIITY SMart Interactive cITY," provides events, local news, points of interest, routes and restaurants from various Portuguese cities [61]. The twelfth application, "TripAdvisor," offers travel recommendations for various locations, search and book activities and restaurants, use maps to see popular places with travelers and locals, as well as compare prices for hotels, resorts, flights and cruises [62]. The thirteenth application called "TUR4all" offers information on accommodation, restaurants and activities from various tourist destinations, as well as to score and comment on their accessibility [63]. Finally, the fourteenth application, TPNP My TOMI Go, provides information on the tourist offer of Porto and Northern Portugal, including restaurants, accommodation, events and activities [64].

4 Mobile apps accessibility evaluation results

As mentioned above, the evaluation will be divided into quantitative and qualitative requirements. Initially, all quantitative requirements were evaluated on iPhone 4. Table 3 shows the ratings for that specific device.

From the analysis of Table 3, we can see that the best result was achieved by the "Viseu - Guia da Cidade" application, since this application obtained an average rating of 6 points, while "Visit Portugal" had 4. Therefore, it can be concluded that between the two applications, Viseu - Guia da Cidade was the one that obtained a satisfactory result, and the other application obtained a negative rating.

Table 3 Ratings obtained by applications on quantitative requirements in iPhone 4

Mobile applications	Contrast ratio of at least 3:1	Contrast ratio of at least 7:1	Legible and functional content at 200% zoom	Target size 48×48dp	All content usable from VoiceOver/ TalkBack	Space between elements at least 2 mm	Average ratings
Visit Portugal	6	1	6	6	3	1	4
Viseu – Guia da Cidade	6	6	6	6	5	6	6

Table 4 Ratings obtained by applications on quantitative requirements in Wiko GOA

Mobile applications	Contrast ratio of at least 3:1	Contrast ratio of at least 7:1	Legible and functional content at 200% zoom	Target size 48×48dp	All content usable from voiceover/ talkback	Space between elements at least 2 mm	Average Ratings
Rota Omíada no Algarve	6	1	6	1	*	6	4
Guia Lisboa de Civitatis	6	1	6	2	*	6	4
Guia Porto de Civitatis	6	1	6	1	*	6	4
Best Portugal	6	3	6	5	*	6	5
Porto Guia de Viagem	5	1	6	2	*	6	4
Viseu – Guia da Cidade	6	1	6	6	*	6	5
JITT.Travel Funchal	6	6	6	6	*	6	6
TripAdvisor	6	3	6	6	*	4	5
TUR4all	6	3	6	6	*	6	5

*The TalkBack version available for the device OS is 5.0.7 that does not have active translation to Portuguese language. As so it was not possible to use this feature

Subsequently, the final ratings on the quantitative requirements of the applications tested by the Wiko GOA device were assigned. These assignments can be found in Table 4.

According to Table 4, we can verify that the best result was achieved by the "JiTT.Travel Funchal" application, as this application has obtained the average rating of six points. This was followed by the "Best Portugal," "Viseu – Guia da Cidade," "TripAdvisor" and "TUR4all" applications, both with five points. Finally, the "Rota Omíada no Algarve," "Guia Lisboa de Civitatis," "Guia Porto de Civitatis" and "Porto Guia de Viagem" applications achieved the worst results, with four points each. Therefore, we can conclude that only the JiTT.Travel Funchal application obtained a satisfactory result.

Then, the final scores for the quantitative requirements of the applications tested by the iPhone 6 Plus and iPhone XR devices were assigned. These assignments can be found in Table 5.

According to Table 5, we can verify that the best result was achieved by the "Viseu - Guia da Cidade," "JiTT.Travel Funchal" and "TUR4all" applications, as they achieved an average rating of six points each. This was followed by "Best Portugal," "SMIITY SMart Interactive cITY" and "TPNP My TOMI Go" applications, each with five points and subsequently the "Rota Omíada no Algarve" application with four points. Finally, the "Guia Lisboa de Civitatis," "Guia Porto de Civitatis" and "TripAdvisor" apps scored the worst, with three points each. Therefore, we can conclude that only "Viseu - Guia da Cidade," "JiTT.Travel Funchal" and "TUR4all" applications obtained a satisfactory result.

Finally, the final ratings for the quantitative requirements of the applications tested by Nokia 5.1 and OnePlus 6 devices have been assigned. These assignments can be verified in Table 6.

According to Table 6, we can see that the best result was achieved by the "Viseu - Guia da Cidade," "JiTT.Travel Funchal" and "TUR4all" applications, as they achieved an average rating of six points each. This was followed by "Best Portugal," "oGUia Portugal – Guia da Cidade," "SMIITY SMart Interactive cITY" and "TPNP My TOMI Go," each with five points each, and later the "Rota Omíada no Algarve," "Porto Guia de Viagem" and "Descubra Vila Real" applications with four points. Finally, the "Guia Lisboa de Civitatis," "Guia Porto de Civitatis" and "TripAdvisor" apps scored the worst, with three points each. Therefore, we can conclude that only "Viseu - Guia da Cidade,"

Table 5 Ratings obtained by applications on quantitative requirements in iPhone 6 Plus and iPhone XR

Mobile applications	Contrast ratio of at least 3:1	Contrast ratio of at least 7:1	Legible and functional content at 200% zoom	Target size 48×48dp	All content usable from voiceover/ talkback	Space between elements at least 2 mm	Average ratings
Rota Omíada no Algarve	6	1	6	2	6	5	4
Guia Lisboa de Civitatis	5	1	6	2	1	5	3
Guia Porto de Civitatis	5	1	6	2	1	5	3
Best Portugal	6	6	6	5	1	5	5
Viseu – Guia da Cidade	6	6	6	6	5	6	6
JITT.Travel Funchal	6	6	6	6	5	6	6
SMIITY SMart Interactive cITY	6	4	6	5	6	5	5
TripAdvisor	4	3	6	1	1	5	3
TUR4all	6	3	6	6	6	6	6
TPNP My TOMI GO	6	3	6	6	5	4	5

Table 6 Ratings obtained by applications on quantitative requirements in Nokia 5.1 and OnePlus 6

Mobile applications	Contrast ratio of at least 3:1	Contrast ratio of at least 7:1	Legible and functional content at 200% zoom	Target size 48×48dp	All content usable from voiceover/ talkback	Space between elements at least 2 mm	Average ratings
Rota Omíada no Algarve	6	1	6	2	6	5	4
Guia Lisboa de Civitatis	6	1	6	2	1	4	3
Guia Porto de Civitatis	6	1	6	2	1	4	3
Best Portugal	6	6	6	6	1	6	5
Porto Guia de Viagem	5	1	6	2	4	6	4
oGUia Portugal – Guia da Cidade	6	6	6	6	5	1	5
Viseu – Guia da Cidade	6	6	6	6	6	6	6
JITT.Travel Funchal	6	6	6	6	6	6	6
Descubra Vila Real	6	1	6	4	4	4	4
SMIITY SMart Interactive cITY	6	4	6	5	6	5	5
TripAdvisor	4	3	6	1	1	5	3
TUR4all	6	3	6	6	6	6	6
TPNP My TOMI GO	6	3	6	6	6	3	5

"JiTT.Travel Funchal" and "TUR4all" applications obtained a satisfactory result.

Subsequently, the same process was performed, for the iOS and Android operating systems. Table 7 presents these assignments for the iOS operating system.

From the analysis of Table 7, we can see that "Viseu – Guia da Cidade" is the only application common to the

Table 7 Ratings obtained by applications on quantitative requirements on iOS operating system

Average ratings		
Mobile applications	iPhone 4	iPhone 6 and iPhone XR
Viseu – Guia da Cidade	6	6

three iOS devices. This application got an average rating of 6 points on each of the devices.

For the Android operating system, the assignments can be found in Table 8.

It was found that the nine applications in Table 8 are common to all three Android devices. By analyzing this table, it becomes apparent that the "Rota Omíada no Algarve," "Best Portugal," "Porto Guia de Viagem" and JITT.Travel Funchal applications contain a similar average rating on all devices.

In most other applications, higher ratings were assigned in the Wiko GOA, assuming so these applications are more accessible in this version of the mobile operating system.

After completing the verification of differences in accessibility of mobile applications on smartphones in different versions on the same mobile operating system, we proceeded with the verification of differences in accessibility of mobile applications on smartphones with different screen sizes. That said, a table was built (Table 9), which contains the different devices used in the present study and "Viseu – Guia da Cidade" application, since this is the only common application to all smartphones.

According to Table 9, we can see that Viseu – Guia da Cidade has an average rating of six and five points on iPhone 4 and Wiko GOA devices, respectively. As other smartphones (with different screen sizes) also have a rating of six points, it can be concluded that there are no differences in the accessibility of this application between iPhone 4, iPhone 6 Plus, Nokia 5.1, iPhone XR and OnePlus 6 devices.

Table 8 Ratings obtained by applications on quantitative requirements on Android operating system

Average ratings		
Mobile applications	Wiko GOA	Nokia 5.1 and OnePlus 6
Rota Omíada no Algarve	4	4
Guia Lisboa de Civitatis	4	3
Guia Porto de Civitatis	4	3
Best Portugal	5	5
Porto Guia de Viagem	4	4
Viseu – Guia de Viagem	5	6
JITT.Travel Funchal	6	6
TripAdvisor	5	3
TUR4all	5	6

In the case of Wiko GOA, the average rating of the application in question was lower compared to other devices, which assumes differences in the accessibility of this. However, it was not possible to use the TalkBack feature on this device, which does not allow you to draw exact conclusions as to the differences in accessibility of "Viseu – Guia da Cidade" between this smartphone, iPhone 6 Plus, Nokia 5.1, iPhone XR and OnePlus 6.

After all quantitative requirements were assessed, the qualitative requirements were evaluated. Table 10 shows the results of the evaluation on the iOS operating system.

As mentioned, there are certain applications that are not available or do not work properly on all iOS mobile devices. In addition, it is important to note that some applications do not have certain aspects that are assessed by these requirements (e.g., presence of content containing audio or video with audio, abbreviations or CAPTCHA). In this case, those same requirements have been positively accounted for since the fact that an application does not have abbreviations (for example) does not mean that it contains accessibility issues or that these were not considered at the time of application development.

Therefore, for REQ 07, which concerns the presence of subtitles for all audio or video content with audio, it can be seen that only one application does not satisfy this requirement. Then, REQ 08, which refers to the presence of sign language for all pre-recorded audio content, was verified, with only one application not satisfying this requirement. With regard to REQ 09, which alludes to the presence of media alternatives for all pre-recorded synchronized media and for all video-only pre-recorded media, it can be seen that only one application does not met this requirement. Regarding REQ 10, which concerns the presence of a time-based media alternative for live audio content only, there are eleven applications that met this requirement. However, no application was found that did not comply with it. In REQ 11, which concerns screen orientations, it was possible to find only two applications that supported both orientations, while nine did not satisfy the requirement in question.

For REQ 12, which is associated with the presence of a mechanism to pause or interrupt audio that plays for more than three seconds, no application was found to satisfy this requirement. In REQ 13, which concerns pre-recorded audio-only content, it was found that all eleven applications met this requirement. Regarding REQ 14, which is related to the fact that additional content is not triggered only with focus, all eleven applications met this requirement. Regarding REQ 15,

Table 9 Ratings obtained by applications on quantitative requirements on devices with different screen sizes

Average ratings						
Mobile applications	iPhone 4 (3.5")	Wiko GOA (3.5")	iPhone 6 Plus (5.5")	Nokia 5.1 (5.5")	iPhone XR (6.1")	OnePlus 6 (6.28")
Viseu – Guia da Cidade	6	5	6	6	6	6

Table 10 Summary of results of the qualitative requirements on the iOS operating system

iOS System		
Requirements	Verification	
	Yes	No
REQ 07	10	1
REQ 08	10	1
REQ 09	10	1
REQ 10	11	0
REQ 11	2	9
REQ 12	11	0
REQ 13	11	0
REQ 14	11	0
REQ 15	9	2
REQ 16	11	0
REQ 17	11	0
REQ 18	11	0
REQ 19	11	0
REQ 20	11	0
REQ 21	10	1
REQ 22	11	0
REQ 23	5	6
REQ 24	4	7
REQ 25	11	0
REQ 26	3	8
REQ 27	8	3
REQ 28	0	11
REQ 29	11	0
REQ 30	0	11
REQ 31	0	11
REQ 32	0	11
REQ 33	11	0

which states that color should not be used as the only visual means of conveying information, indicating an action, requesting a response or distinguishing a visual element, it was possible to verify that two applications do not met this requirement, while nine applications did.

In REQ 16, associated with components with automatic movements lasting longer than 5 s, it was found that all eleven applications met this requirement. In the case of REQ 17, which states that no functionality must have a time limit for an action to be performed, it was possible to verify that all eleven applications met this requirement. In the case of REQ 18, which states that the user can continue the activity without data loss after re-authentication, it was also found that all eleven met this requirement. For REQ 19, which states that no content should flash more than three times per second, eleven applications met this requirement. In the case of REQ 20, which has a mechanism for using it to turn animation off, it has been found that all eleven applications met this requirement.

With regard to REQ 21, which states that the purpose of the link must be determined from the text of the link itself, it was found that only one application does not meet this requirement and ten fulfill it. In the case of REQ 22, which concerns functionality that can be operated by device movement or user movement, it was found that eleven applications met this requirement. In REQ 23, which states that no functionality should be based on complex movement, it was found that five applications met this requirement, while six did not. In the case of REQ 24, which concerns the presence of glossary or information informing the user of the meaning of technical words or jargon, four applications were found to satisfy this requirement, while seven did not.

With regard to REQ 25, which concerns the identification of abbreviations, it was found that eleven applications met this requirement. In the case of REQ 26, which is associated with complex content review, only three applications met this requirement, while eight do not. For REQ 27, which is related to the presence of simple suggestions for the user to be able to easily correct input errors, eight applications met this requirement, while three did not. For REQ 28, which states that contextual help should be provided to explain the completion of a field (if the label is not sufficient), it was found that eleven applications do not met this requirement. In the case of REQ 29, which concerns the possibility of canceling the submission or the verification and/or confirmation of the data whenever the user can add any information via the form, it was possible to verify that eleven applications fulfill this requirement.

In the case of REQ 30 (there must be a feature that allows the user to change color content to grayscale without the use of assistive technology), of REQ 31 (there must be a feature that allows the user to invert application colors without the use of assistive technology) and REQ 32 (allowing zooming without the user using any assistive technology), it was found that eleven applications do not met each of these. Finally, REQ 33 is associated with the fact that all users can resolve CAPTCHA. All eleven applications satisfy requirement REQ 33.

Subsequently, the same process was performed for the Android mobile operating system (Table 11).

In the case of the Android operating system, there are also certain applications that are unavailable or not working correctly on all Android mobile devices. In addition, it is important to note that some applications do not have certain aspects that are assessed by these requirements (e.g., presence of content containing audio or video with audio, abbreviations or CAPTCHA). In this case, those same requirements have been positively accounted for, since the fact that an application does not have abbreviations (for example) does not mean that it contains accessibility issues or that these were not considered at the time of application development.

Table 11 Summary of results of the qualitative requirements on the Android operating system

Android system		
Requirements	Verification	
	Yes	No
REQ 07	13	1
REQ 08	13	1
REQ 09	14	0
REQ 10	14	0
REQ 11	4	11
REQ 12	14	0
REQ 13	14	0
REQ 14	14	0
REQ 15	10	4
REQ 16	14	1
REQ 17	14	0
REQ 18	14	0
REQ 19	14	0
REQ 20	14	0
REQ 21	13	1
REQ 22	14	0
REQ 23	5	10
REQ 24	5	9
REQ 25	14	0
REQ 26	5	9
REQ 27	12	2
REQ 28	0	12
REQ 29	14	0
REQ 30	0	14
REQ 31	0	14
REQ 32	0	14
REQ 33	14	0

There are two other things to mention: firstly, the impossibility of having REQ 28 evaluated on the Wiko GOA device, as the version of TalkBack for this device's operating system is 5.0.7 and it has no language in Portuguese and secondly, the fact that there are two applications that differ in the version of the same operating system. The assessment of certain requirements (e.g., REQ 07 and REQ 08) was different in the Best Portugal and TripAdvisor applications for different Android devices. For example, when Best Portugal was evaluated using Nokia 5.1 (version 9.0) and OnePlus (9.0) devices, no content containing audio or video with audio was found. However, when evaluated through Wiko GOA (version 4.4.2), it was already possible to verify the existence of such content. Therefore, the application has been accounted twice for some requirements.

Following the analysis of Table 11, we can see that in REQ 07, there are 13 applications that met this requirement, while one does not satisfy it. For REQ 08, 13 applications were found to meet this requirement, while one application does not satisfy it. In turn, in REQ 09 and REQ 10, 14 applications met these requirements. In REQ 11, it was found that only four applications met this requirement, while 11 do not. Although 14 mobile applications have been analyzed, there is an application that was counted twice in the Android operating system—TripAdvisor. This is because the application supported both orientations on the Wiko GOA mobile device (therefore being counted as an application in the "Yes" column), but not the same on Nokia 5.1 and OnePlus 6 mobile devices (therefore being counted as an application in the "No" column). Regarding REQ 12, REQ 13 and REQ 14, 14 applications met these same requirements. (There is no application that does not.) For REQ 15, 10 applications were found that met this requirement, while four did not. In turn, in REQ 16, 14 applications met this same requirement and one does not. As previously mentioned, 14 mobile applications were analyzed. However, there is an application that was also counted twice in the Android operating system—Best Portugal. This was due to the fact that the application in question does not meet this requirement on the Wiko GOA mobile device (therefore being counted as an application in the "No" column), but this happens on other mobile devices that had the Android operating system (therefore being counted as an application in the "Yes" column). In REQ 17, REQ 18, REQ 19 and REQ 20, 14 applications met each of these requirements.

Regarding REQ 21, it was observed that 13 applications met this requirement, while one application does not. In turn, in REQ 22, 14 applications satisfy this requirement. For REQ 23, five applications met this requirement, while 10 do not. There is an application that was counted twice in the Android operating system—TripAdvisor. This is because the application presented alternatives for complex movements (on the map) on the Wiko GOA mobile device (therefore being counted as an application in the "Yes" column), but not the same on Nokia 5.1 and OnePlus 6 mobile devices (therefore being counted as an application in the "No" column).

In REQ 24, there are also five applications that satisfy this requirement; however, nine do not. With regard to REQ 25, 14 applications were found that met this same requirement. For REQ 26, it was noted that there are five applications that met this requirement, though nine do not. In turn, in REQ 27, 12 applications were found that satisfy the requirement, whereas two do not.

With regard to REQ 28, 12 applications were found that did not met the requirement, and no application that fulfilled it was found. For REQ 29, it was noted that 14 applications met the requirement. Regarding REQ 30, REQ 31 and REQ 32, 14 applications do not met these requirements. In contrast, with regard to REQ 33, 14 applications met this requirement and.

5 Discussion of the results

The main objective of the present study was to evaluate accessibility in mobile applications for the tourism sector. In addition, it was also sought to understand if there were differences in the accessibility of mobile applications on different mobile operating systems, on different versions of the same operating system and, finally, on smartphones with different screen sizes.

Given that the statistical analysis of the results obtained from the evaluation of the mobile applications of the tourism sector is concluded, we can conclude that, in general, these applications obtained unsatisfactory ratings and results. A high overall number of errors were observed in most quantitative requirements as well as non-compliance with most qualitative requirements. As for the ratings obtained in relation to the quantitative requirements, these were quite negative, and in the case of iPhone 4, the "Viseu - Guia da Cidade" application obtained a satisfactory result with the rating six and in Wiko GOA, the "JiTT. Travel Funchal" application was the one with the highest rating (six points). In turn, on iPhone 6 Plus, iPhone XR, Nokia 5.1 and OnePlus 6 devices, the best results were also achieved by the two applications mentioned above together with "TUR4all" (rating six each). Because the objectives of this study also relate to differences in accessibility of mobile applications on devices with different screen sizes and devices with different versions of the same operating system, it is also necessary to discuss these results.

Regarding the iOS operating system, "Viseu - Guia da Cidade" was the only application common to the three devices of this operating system and obtained a rating of six in each of them, thus revealing a satisfactory result. Therefore, in the case of this application, we can state that there are no differences in the accessibility of mobile applications in different versions of the same mobile operating system. On the other hand, the evaluation results of applications common to iPhone 6 Plus and iPhone XR devices are similar. Therefore, we can assume that although these devices have different versions of the same operating system, the applications have the same level of accessibility. Regarding the Android operating system, the "Rota Omíada no Algarve," "Best Portugal," "Porto Guia de Viagem" and "JITT.Travel Funchal" applications also obtained similar ratings on all three devices with this operating system. Therefore, in the case of these applications, we can state that there are no differences in the accessibility of mobile applications in different versions of the same mobile operating system. In turn, "Guia Lisboa de Civitatis," Guia Porto de Civitatis," "Viseu – Guia da Cidade," "TripAdvisor" and "TUR4all" apps all rank higher on the Wiko GOA device, leading to the belief that these apps are more accessible on this version of the Android operating system. However, as the TalkBack feature could not be used on this device (and was an element of accessibility analysis), it is not correct to say that there are differences in accessibility of these same applications between devices running the Android system used.

Regarding the possible differences in the accessibility of mobile applications on smartphones with different screen sizes, it was possible to verify that the only application common to all devices (Viseu – Guia da Cidade) was rated six on iPhone 4, iPhone 6 Plus, Nokia 5.1, iPhone XR and OnePlus 6 devices. Although it was a satisfactory result, we can conclude that there are no differences in mobile app accessibility on these five devices with different screen sizes (since the rating has equal value on the five devices). In turn, this application has been rated five on the Wiko GOA device, which would lead to differences in accessibility of this application. However, as the TalkBack feature could not be used on this device (and was an element of accessibility analysis), it is not correct to say that there are differences in accessibility of this same application between devices with different screen sizes.

In addition to the above, it is also important to analyze the results obtained in the assessment of qualitative requirements. Regarding the presence of subtitles for all content containing audio or video with audio, it was found that only one application did not meet this requirement on both iOS and Android. This should be synonymous with a satisfactory level of accessibility; however, the vast majority of applications do not contain content that contains audio or video with audio, so it is not possible to draw any conclusions about the accessibility status of these applications at this point. In the only application with this type of content, no subtitles are provided, which can create obstacles for users with hearing impairments. The same is true of the requirement for the presence of sign language for all pre-recorded audio content.

Regarding the presence of media alternatives for all pre-recorded synchronized media and all video-only pre-recorded media, there is an application on the iOS system that does not met this requirement, while on the Android system, all applications met it. As noted above, the vast majority of applications do not contain content containing audio or video with audio, meaning that no conclusions can be drawn about the accessibility status of these applications on the Android system. However, on the iOS system, it is synonymous with poor accessibility and can impair users whose vision and/or hearing is too weak.

Regarding the presence of a time-based media alternative for live audio content only, there are no applications (either iOS or Android) that do not meet this requirement. As noted above, the vast majority of applications do not contain content that contains audio or video with audio,

meaning that no conclusions can be drawn about the accessibility status of these applications on both operating systems.

Regarding screen orientations (horizontal and vertical), it was found that few applications support both. The vast majority of mobile applications evaluated in this paper only support vertical orientation, which may be a limitation for users who need to choose the best orientation for them, such as placing devices in a particular orientation in a wheelchair.

As for the presence of a mechanism to pause or interrupt audio that plays for more than three seconds, all applications were found to meet this requirement. However, it is important to note that no application was found that featured audio that played for more than three seconds. As such, no conclusions could be drawn about the accessibility status of these applications on both operating systems. The same is true for the presence of pre-recorded audio-only content and the fact that additional content is not triggered with focus alone.

On the other hand, two and four applications were found on iOS and Android, respectively, where color was the only visual means of conveying information, indicating an action, requesting a response or distinguishing a visual element. In these applications was found a classification system (which allowed to score the various tourist spots) in which the only means of differentiation was the color. This may be a limitation for users with color blindness, for example. For automoving components that last longer than 5 s, it was found that no iOS application met this requirement. In contrast, on the Android system, there was an application where the user could not pause, stop or hide that component. This may be a limitation for individuals with attention deficits.

Another qualitative requirement states that no functionality must have a time limit for an action to be performed. For this category, no conclusions could be drawn about the accessibility status of applications on both operating systems, since this functionality was not found in any application. Regarding the possibility that the user could continue the activity without data loss after re-authentication, the vast majority of evaluated applications provided this continuation. However, some applications were found that could not be registered and/or logged in.

For content that blinks more than three times per second, no application contained this type of content. Therefore, it was not possible to draw any conclusions about the accessibility status of applications on both operating systems regarding this requirement. The same is true of the presence of a mechanism that can be used to turn off the animation in the application.

Another qualitative requirement states that the purpose of the link must be determined from the text of the link itself. On iOS and Android operating systems, only one application does not meet this requirement, as the text of that application's own link was not very clear as to its purpose. Individuals with cognitive disabilities may find a limitation in this aspect.

Regarding the functionality that can be operated by the movement of the device or the movement of the user, it was found that no application contained such functionality. Therefore, no conclusions could be drawn about the accessibility status of these applications on both operating systems with respect to this requirement. Another qualitative requirement states that no functionality should be based on complex movement. In the iOS system, six applications that did not met this same requirement were found, while in the Android system, the number is higher (ten applications). An example of this is that it is not possible to zoom the map of each application without using complex movements, which may be a limitation for users with motor disabilities.

It was also noted that there were seven applications on the iOS system that do not display glossary or information that informs the user of the meaning of technical words or jargon, while on the Android system, nine such applications were found. This may limit the use of these applications by individuals with cognitive disabilities. On the other hand, no abbreviations were found in any application. As such, the requirement for identification of abbreviations has been positively accounted for, since the fact that the application does not have this element does not mean that it contains accessibility issues or was not taken into account at the time of application development. However, this does not make it possible to draw accurate conclusions about the accessibility status of these applications.

Regarding complex content review, there are eight applications that do not meet this requirement on the iOS system and nine on the Android system. This non-fulfillment of the requirement may prove to be a major limitation for users with cognitive disabilities and/or language problems, as these individuals have a marked difficulty understanding complex content. As for simple suggestions so that the user can easily correct input errors, the iOS system displays three applications that do not met this requirement, while the Android system displays two applications. This can be a problem for users with cognitive limitations or visual impairments. With regard to providing contextualized help to explain the completion of a field (if the label is not sufficient), no application met this requirement (in both operating systems). In the case of the Wiko GOA device, the TalkBack feature could not be used, which did not allow this requirement to be assessed and, consequently, to draw conclusions about the accessibility status of the evaluated applications on this device (Rota Omíada no Algarve, Guia Lisboa de Civitatis, Guia Porto de Civitatis, Best Portugal, Porto Guia de Viagem, Viseu – Guia da Cidade, JiTT.Travel Funchal, TripAdvisor and TUR4all). Failure to do so may be a limitation for users who have to use VoiceOver or TalkBack features due to their low vision.

In addition, it was found that, on the iOS operating system, eleven applications allowed the cancelation of the submission or the verification and/or confirmation of the data whenever the user could add any information via the form. In the Android operating system, fourteen applications were evaluated that met the requirement. Therefore, we can state that these applications are accessible on this point and can help users with motor problems. Regarding the existence of a feature that allows the user to change color content to grayscale without the use of assistive technology and a feature that allows the user to invert application colors without the use of assistive technology, no application was found that met each one of these requirements (on both operating systems). As such, we can conclude that all the applications evaluated in this study do not have a satisfactory level of accessibility on this point, which may be a problem for colorblind users. In addition, no application allowed zooming without the user using any assistive technology. This is considered an accessibility issue in these applications and is a limitation for low vision users. Finally, no application in either operating system has shown the existence of CAPTCHA. However, this requirement has been positively accounted for, since the fact that the application does not have this element does not mean that it contains accessibility issues or was not taken into account at the time of application development. Still, this does not make it possible to draw accurate conclusions about the state of accessibility of applications on this point.

It is also important to note that the fact that there are no legal requirements for mobile applications to become more accessible to all users, but especially for those with any type of disability, means that at the moment of application development, the factor more important is their overall smooth operation and not their accessibility [65].

6 Conclusions

With this study, we can conclude that, in general, there are poor ratings and poor results in the tested mobile applications. A high overall number of errors were found in most quantitative requirements as well as non-compliance with most qualitative requirements. On iPhone 4, "Viseu – Guia da Cidade" was the application that got the highest rating, while on Wiko GOA, it was the "JiTT.Travel Funchal" application. In turn, on iPhone 6 Plus, iPhone XR, Nokia 5.1 and OnePlus 6 devices, the best results were achieved by the "Viseu – Guia da Cidade," "JiTT.Travel Funchal" and "TUR4all" applications. Regarding the accessibility of mobile applications on different versions of the same mobile operating system, it was concluded that there are no differences in their accessibility on both operating systems (iOS and Android). Finally, regarding the accessibility of applications on smartphones with different screen sizes, there are also no differences in their accessibility.

During the present study, several limitations were found regarding the evaluation of accessibility in mobile applications. Firstly, there is a dearth of the literature on accessibility in mobile applications, especially in the tourism sector. The most complete study found is the study by Carneiro, Branco, Gonçalves, Au-Yong Oliveira, Moreira and Martins [66] and, however, focuses on the Portuguese public administration and not on the tourism sector in Portugal. This turned out to be a difficulty when comparing the present study with studies by other authors. In addition, there are few legislations around the world that encourage accessibility in mobile applications. Secondly, there are no mobile accessibility requirements, and the recommendations produced by WCAG 2.1 and Best Practices by Google and Apple were adopted in this study. However, even these recommendations are merely an adaptation of the standards for the web, so there is nothing that is solely for mobile applications. Regarding the assessment process itself, no automatic assessment tools were found that performed a full accessibility assessment in mobile applications and a manual assessment method was used.

Another limitation found in this study is that it was not possible to use the TalkBack feature on the Wiko GOA device. As a result, this made it impossible to draw accurate conclusions about the accessibility of the mobile applications tested using this smartphone. In addition, only one application common to all mobile devices of both operating systems was found. Finally, the fact that the vast majority of the applications evaluated in the present study did not contain certain elements (e.g., CAPTCHA, abbreviations, complex content) did not allow to draw accurate conclusions about their accessibility.

Through this study, we can conclude that the mobile applications of the tourism sector in Portugal have an unsatisfactory level of accessibility. These results have consequences, particularly for users with some kind of disability. Not only will these users find it difficult to use mobile applications targeted for tourism, they may also feel excluded from the technological world.

6.1 Final considerations

Although several limitations were found, the main objective of the present study was achieved and fourteen mobile applications of the Tourism sector were analyzed. Two of the limitations found concern the fact that there are no legal requirements to be followed and no tools that automatically assess accessibility in mobile applications. As such, it was necessary to perform a manual assessment by adapting some accessibility requirements to make an assessment model of these same applications. Consequently, assistive tools were

used for this assessment and a manual assessment of all applications was performed. The obtained data revealed unsatisfactory results about the accessibility of the evaluated mobile applications, which evidences the urgency of implementing its own requirements for the accessibility of mobile applications and their adoption by the tourism sector.

It can be concluded that, despite the limitations encountered during the present study, all the initially established objectives were met, hoping that with these results, it was possible to contribute to a better understanding of the current state of accessibility in mobile applications in the tourism sector and as an example for future studies on the subject.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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