Urban and Building Accessibility Diagnosis using 'Accessibility App' in Smart Cities
A Case Study

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Abstract: In the context of economic and technological changes arised from globalization, cities face the challenge of conceiving models capable of combining both competitiveness and sustainable urban development. The increasing body of knowledge in the field of Information and Communication Technology (ICT) offers methods to exploit the huge potential of technological advances, enabling to increase productivity of industrial and business processes and improving the liveability of cities. One of the most important aspects that influence the liveability of cities is the ability to be an inclusive city. Thus, Smart Cities require an inclusive urban life, and they are characterized by being accessible cities. In this regard, this paper describes a method using the latest ICT for the analysis and diagnosis of the accessibility in buildings and urban environments. This method allows the collection of information on accessibility issues through the collaboration of citizens, as well as to organize and display it, so that administrations and institutions responsible for addressing accessibility issues can use it in order to take actions. In this context, a practical application of the method has been performed through a case study in the University of Alicante, with the objective of showing a real diagnosis of urban and building accessibility.

1 INTRODUCTION

In the context of economic and technological changes provoked by globalization, cities face the challenge of conceiving models that can combine both competitiveness and sustainable urban development (Book et al., 2010; Taylor et al., 2006; Taylor et al., 2012). This challenge that cities face has an important impact on urban quality issues, especially on social and environmental conditions. In this sense the challenge involves both an opportunity.

The increasing body of knowledge in the field of Information and Communication Technology (hereinafter ICT) offers methods to exploit the huge potential of technological advances and enables organizations to manage both industrial and business processes in a different way in order to increase productivity and user satisfaction (Etro, 2011). In addition, ICTs have a decisive influence on roving the liveability of cities and the quality life of citizens.

In this global context of competition and cooperation between cities and territories, Smart Cities (hereinafter SC) should be able to create competitive advantage for the various economic, residence, leisure, culture and social relations activities (Caragliu et al., 2011). In this sense, people are the main resource that SCs have to create competitive advantage. Citizens are the basic raw material of the 21st century's economy (Martinez-Fernandez et al., 2012). That is why SCs must strive to attract highly prepared people, both intellectuals and workers (Landry, 2012). Professional opportunities, connectivity, educational infrastructure, innovative environment, residential options, quality of life, social balance, citizen security, cultural and leisure offer, quality urban spaces are key factors of competitiveness to attract human capital (Newman and Thornley, 2011).

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Among these factors, quality of life is one of the main urban issues and a recurrent demand of all citizens. A model of sustainable urban development draws an intelligent projection of the future city and answers the following fundamental questions: What kind of place do we want cities to be and how should the quality-of-life objective be defined? (Abdoullaev, 2011). One of the most important aspects that influence the quality of life that a city can offer is the ability of that city to be an inclusive city (Colantonio and Dixon, 2011).

The commitment to sustainable development involves defending a model of inclusive development to ensure social sustainability (Vallance et al., 2011; Wolbring and Rybchinski, 2013), i.e., equity, cohesion and social communication, autonomy and equal opportunities for all citizens. Sustainable urban development cannot exclude part of the individuals of a society (Beall, 2002). Thus, SCs require an inclusive urban life and an inclusive society, and they are characterized by being accessible cities (Steinfeld and Maisel, 2012). Accessibility is an element of quality of life of universal interest and a right of all citizens (United Nations, 2006). In addition, an inclusive and accessible city can make the most of their human capital (Cossetta and Palumbo, 2014), which is a key factor to guarantee and optimize their future development (Batty et al., 2012).

In this context, our research delves in the possibilities offered by the last ICTs to obtain urban and building accessibility diagnoses with the objective of promoting inclusion and participation of all citizens. The remainder of the work is organized as follows: Section 2 describes the objectives of the work and the methodology. Section 3 gives an overview of the related work on technology used for obtaining information of accessibility in cities. Section 4 explains a case study in which a diagnosis of urban and building accessibility has been obtained. Finally, in Section 5, some conclusions of the work are drawn.

2 OBJECTIVES OF THE WORK AND METHODOLOGY

Our proposal is part of the objectives of the *European Disability Strategy 2010-2020: A Renewed Commitment to a Barrier-Free Europe* (European Commission, 2010a), developed in the framework of the strategy *Europe 2020: A Strategy for smart, sustainable and inclusive growth* (European Commission, 2010b).

To this end, in the field of research and development of the SC concept, we propose a method focused on people with or without disabilities for the analysis and diagnosis of the accessibility in buildings and urban environments, without excessive cost and respectful with the environment. The proposed method allows the collection of data and information on accessibility issues through the collaboration of citizens, as well as to organize and show this information collected so that administrations and institutions responsible to addressing accessibility issues can use it. Our main objective is to contribute to improve the accessibility of cities promoting collective participation and using the latest ICT.

In this context, a practical application of the method has been performed through a case study in the University of Alicante, with the objective of showing a real diagnosis of urban and building accessibility.

2.1 Description of the Proposed Methodology

The proposed method is composed of two parts. A first part consists of establishing mechanisms to collect information from citizens about accessibility issues. A second part is to organize this information and display it so that responsible bodies can use it. The two parts of the method are described below.

2.2.1 Method to Collect Information from Citizens

An important aspect of CSs is that they must be community-designed cities, i.e., cities designed according to the needs and priorities of the citizens and not by the exigencies of the markets. To this end, active communities are needed to reach consensus on future projects. Therefore, SCs need a strong leadership, the participation of the population as a mature civil society and mechanisms that activate processes that ensure innovation (Carley et al., 2013).

In this sense, the methodology proposed in this work promotes an active process of collective participation as a mechanism against social exclusion, with the aim of working to achieve the social balance and an inclusive and accessible city.

For addressing accessibility issues in buildings and urban environments, responsible administrations and institutions need to know, in a previous phase, what are the real problems of accessibility in cities.

Among the possible ways of obtaining this information, it is a challenge to involve citizens in the process. The methodology proposed in this work allows obtaining information about accessibility problems directly from citizens, based on their own experience. The idea behind this proposal is that the citizens can notify in real-time the accessibility deficiencies found in any place when they go around the city (Figure 1).

Figure 1: Methodology proposed to obtain information about accessibility problems and improve accessibility of cities.

In order to collect information on accessibility issues from citizens, an Android application, "App" for Accessibility Claims Report, has been designed. This application is oriented to the end-user. Its purpose is to provide a user interface for mobile devices to enable adding, in real time, those citizens' accessibility experience while moving into the buildings and around the urban environment. The "App" for Accessibility Claims Report has been described in an own previous research conducted by this research group (Mora et al., 2016). The way the application works is shown in Section 4.

2.2.2 Method to Organise and Show Information to Responsible Bodies

In the context of the current knowledge society, access to information is often not a problem. However, information, in general, is not and does not produce knowledge in itself. Knowledge does not simply come from having access to large amounts of information. It is necessary to understand the databases and to experiment their use to guarantee an adequate use of them. For this reason, one of the main challenges for information management is to facilitate the process of understanding and using data on a large scale (Beaverstock et al., 2000).

The methodology proposed in this work allows the structuring of the information provided from the citizens to be shown, in an easy way, to the administrations and institutions that need to have access to this information.

The way to organize and show the information collected from citizens to the responsible bodies for addressing accessibility issues in cities is through the Urban Accessibility Information Service. The results obtained can be presented through a Web-Application for Accessibility Monitoring. The way the results are organized and displayed is shown in Section 4. The general overview of the proposed system (Figure 2): (1) Urban Accessibility Citizen Application; (2) Urban Accessibility Management Government Application; and (3) Accessibility Information Service, has been described in an own previous research (Mora et al., 2016).

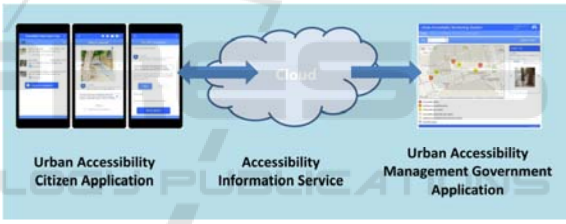

Figure 2: Method to obtain, organise and show the accessibility information to responsible bodies.

2.3 Case Study

A case study has been carried out as part of this work in the University of Alicante in Spain. The experience has involved different groups of people with and without disabilities, administrative staff, teachers and students.

A route was proposed to identify the real problems of accessibility existing in it, and to communicate these problems using the "App" for Accessibility Claims Report. Participants installed the application on their own mobile phones.

The experience carried out is described in Section 4. In addition, this Section 4 also describes how the results obtained are shown through the *Web-Application for Accessibility* Monitoring.

3 RELATED WORK: TECHNOLOGY USED FOR OBTAINING INFORMATION OF ACCESSIBILITY IN CITIES

Traditionally, the methods used to obtain information about the status of urban accessibility have been mostly based on surveys (Beale et al., 2006; Le-Klähn et al., 2014), interviews (Hashim et al., 2012; Venter et al. 2016), audits or direct observation (Mackett et al., 2008). Other studies have provided mathematical or statistical analysis of these data (Church and Marston, 2003).

Recently, applications have been developed to inform users about the accessibility in urban environments (Inada et al., 2014; Prandi et al. 2014). The proposals are based on the use of Global Positioning Systems (GPS) and Geographic Information Systems (GIS) technologies. Most of the proposals offer an application for users' mobile devices in order to interface and interact with the system. In addition, self-reporting tools have allowed obtaining information from certain places with the collaboration of users (Shigeno et al., 2013). Finally, other proposals use social network communities to generate and complement the information about accessibility issues in cities (Menkens et al., 2011; Prandi et al. 2014). These proposals also obtain information from the user by means of self-reporting tools.

Increasingly, the methods for assessing aspects that affect the functioning of the city are based on evidence, i.e., the study of the citizens´ behaviours and opinions (Gilart-Iglesias et al., 2015; Pérez-delHoyo et al., 2017). Cloud computing paradigm is one of the most promising technologies to build new services for users and enterprises (Targio et al. 2015; Marston, 2011). Mobile devices enable access to a wide range of applications and services (Mora et al. 2015; Makris et al., 2013). The proliferation of systems and the high penetration rate of mobile devices in the hands of citizens provides users an opportunity to conduct a citizen-centric digital revolution in many aspects of daily life.

In this way, urban accessibility finds an optimal scene of opportunity in the context of SCs. The concepts of ubiquitous and SCs make use of processing technologies, sensing and communications to provide intelligence to the city while offering connectivity resources, power supply and interoperability (Yigitcanlar, 2014). These conditions facilitate the deployment of interconnected smart elements that provide services to citizens for efficient decision-making and to make better use of resources (Neirotti et al., 2014).

4 CASE STUDY: A CONTROLLED ENVIRONMENT IN UNIVERSITY OF ALICANTE

This section focuses on a study within the Campus of the University of Alicante (hereinafter UA), specifically in the inaccessible points detected in the German Bernácer building and the routes among the different connections of this building with the nearest leisure areas and places for study inside the UA campus. In this context of social inclusion, it has been possible to obtain information about the building and its usual connections with other buildings that are part of the students' university life.

The developed application has allowed us to map the different points that prevent students with mobility disabilities to have both a complete integration into the university environment and participation in university social life.

4.1 Physical and Social Context

The present experimentation was performed at the UA campus (Gutiérrez and Martí, 2014), which is located in San Vicente del Raspeig (Alicante, Spain). With a current area of more than a million and a half square meters and under an important expansion process, the UA campus has been built on an old military airfield. It includes several green spaces and 54 buildings –new construction buildings as well as the reuse of the pavilions of the old aerodrome that date from 1930.

In the UA campus more than twenty thousand students are currently studying. The teaching staff consists of more than two thousand three hundred people. In addition, more than one thousand two hundred people compose the administration and services staff.

The case study area was focused on the Germán Bernácer building as the core building of the research. The building date from 1994 and it is composed of basement floor, ground floor and first floor located in U-shaped. It is identified by the number 0036 within the UA Geographic Information System (SIGUA) (Figure 3) (Figure 4).

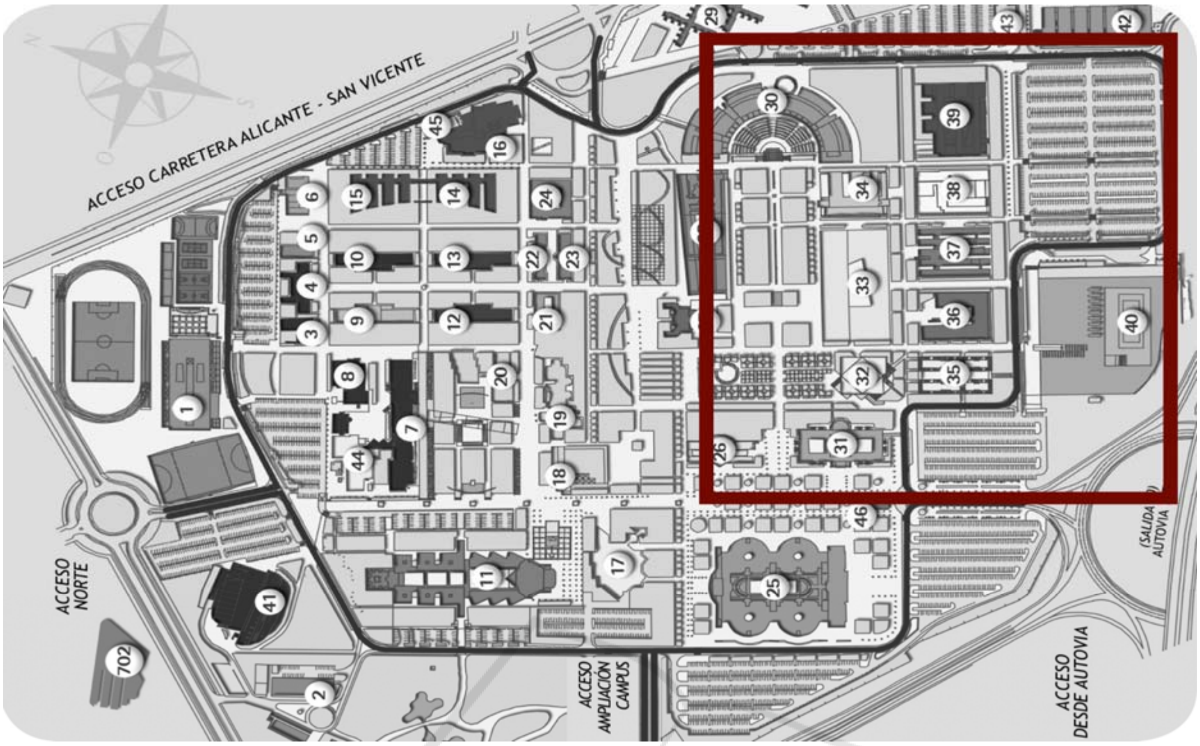

Figure 3: Experimentation context at UA campus.

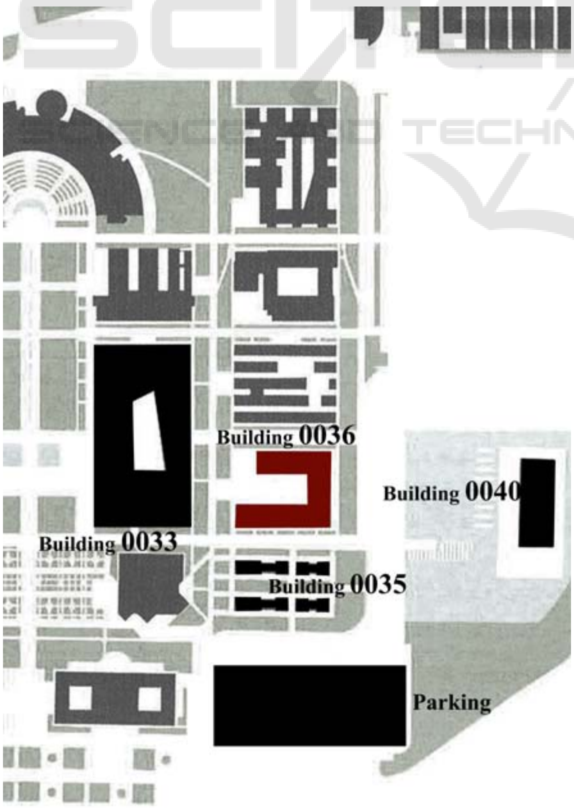

Figure 4: Experimentation context at UA campus.

It includes several classrooms for degree and postgraduate classes for local and international students; and several departments for the different management services of the UA campus, like the School of Doctorate, the Institute of Education Sciences, the Language Centre, the Technical Office Department and the Infrastructure and maintenance service, The Centre for Continuing Education, etc. I.e., it is used by numerous local and international students and teachers as well as administrative staff.

The Germán Bernácer building was selected as the core building of the research due to the high flow of people throughout the day and the diversity of users; in addition to its location and proximity to the leisure areas and spaces for study that allow a geographically narrow experimentation.

In addition, the case study was extended to different routes from the building Germán Bernácer (Building 0036) to the leisure areas inside the UA campus commonly used by participants such as the commercial area identified in Figure 4 with the SIGUA code Building 0035 that includes a bookshop, a stationery shop, a post office, several bank offices and a restaurant.

Also, it was the route from Building 0036 to the UA Museum (hereinafter MUA) with the SIGUA code Building 0040, as another relevant leisure area integrated in the university social life.

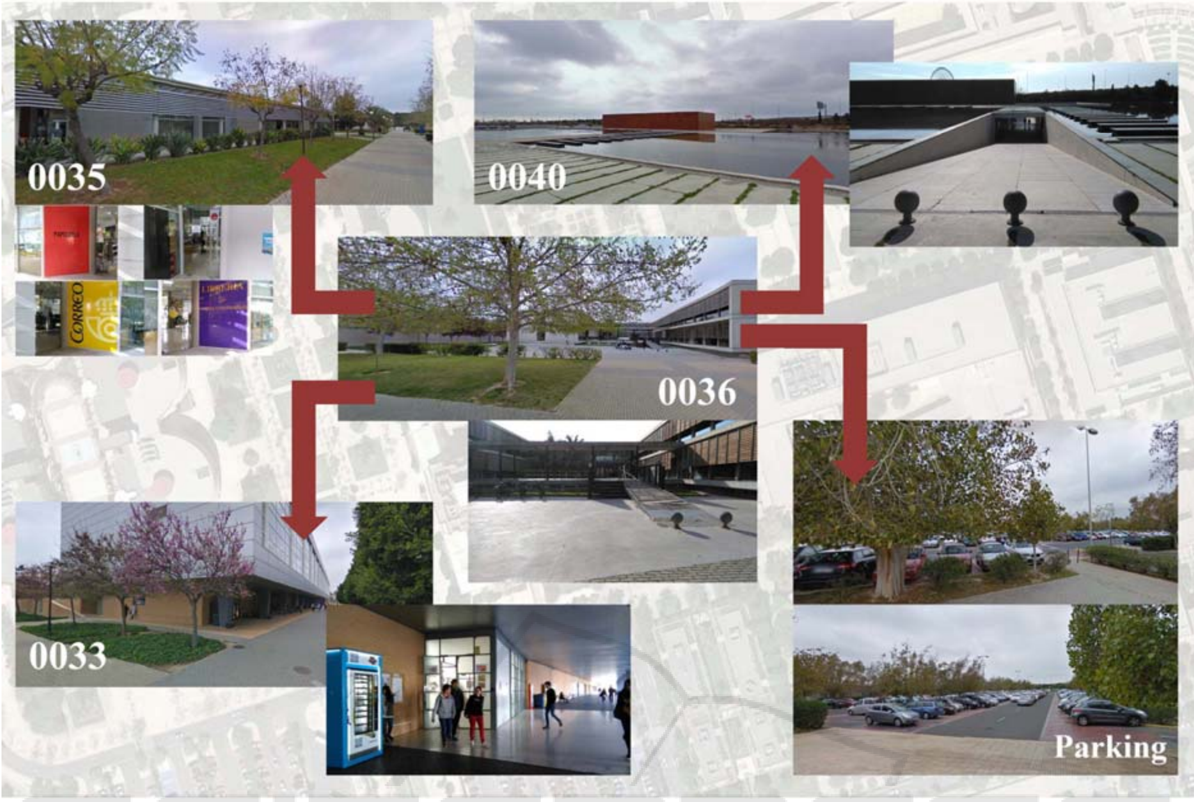

Figure 5: Experimentation context at UA campus.

Moreover, the case study also covered paths from the core Building 0036 to the main areas for study such as the General Library building with the SIGUA code Building 0033.

Finally, it was included in the test the route to the nearest parking highlighted in Figure 4.

The monitored routes in UA campus are also shown in Figure 5.

4.2 Diagnosis

Figure 4 and Figure 5 shows the scene used to carry out the monitoring tests and accessibility analysis that will allow us to identify the degree of inclusion in the test scene. As it was previously described in Section 2, the experimentation was performed through the Android App designed in an own previous research (Mora et al., 2016), which also includes the functionalities of the Accessibility Claim Report System, and a cloud platform. This allowed us to monitor and analyse the accessibility and its efficiency of the daily habits of different users in German Bernácer Building (0036) and its close spaces for leisure and study to detect incidences that impede a complete integration into the university environment of people with physical disabilities.

The test was carried out both indoor and outdoor. Both scenes were validated through the Accessibility App, which allows the emission of complaints in the smartphones of the participants in the routes and its location via GPS.

The obtained results are represented by the Urban Accessibility Information Service, which uses a web-based user interface from a third party application (Google Maps JavaScript API v3)- that show the accessibility problems by means of Key Accessibility Indicators (hereinafter KAI)- from users-routes analysis and reported claims of users (Figure 7). Depending on the degree of inaccessibility of each situation, the incidences of accessibility are categorized as Claim, Inefficient with Claim, Inaccessible with claim or Inaccessible (Table 1).

4.2.1 Experimentation at Building 0036

The experimentation process started with the identification of incidences, and its sending by the claim report App (Figure 7).

The route followed in the test highlighted in yellow in Figure 6, started in the access of Building 0036 where four outdoor incidences of accessibility were detected on ground floor and identified as Point Number 253, 254, 255 and 256 as it is outlined in Figure 6.

Point number 253 was related to lack of maintenance in building access, while Point number 254 was described as uncomfortable materials for wheelchairs because floor is composed of wooden slats with open joint.

Likewise, there was an incidence in the building access -identified as Point number 256- due to the excess weight of the manual opening door. The same situation was repeated in Points number 260 and 262 (Table 1).

Also, Points number 257 and 261 were reposted due to the high front desk height of the public attention service, which made the info point inaccessible.

Finally, three Points were reported (255, 258 y 259), Point number 255 owing to impossibility of access to basement in that point. Likewise there was an impossibility of access to basement and first floor in Point number 258. And one last point (259) was claimed due to the lack of handicapped WC in this part.

The KAI obtained are represented by the Urban Accessibility Information Service, as it is shown in Figure 7.

The following table (Table 1) summarizes the KAI identified in the experimentation at the German Bernácer Building (0036).

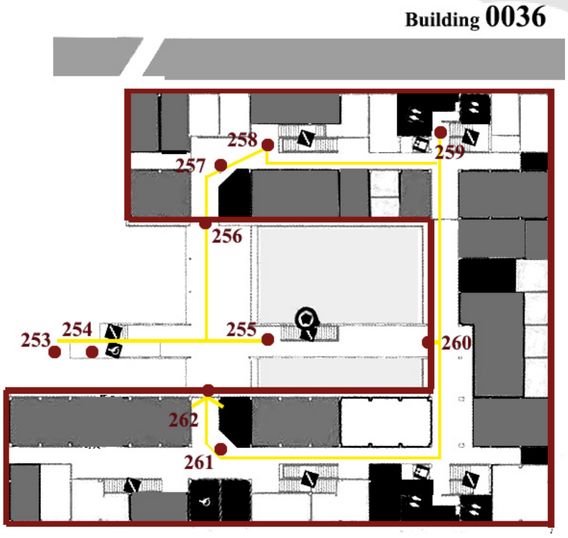

Figure 6: Incidences reported in building 0036.

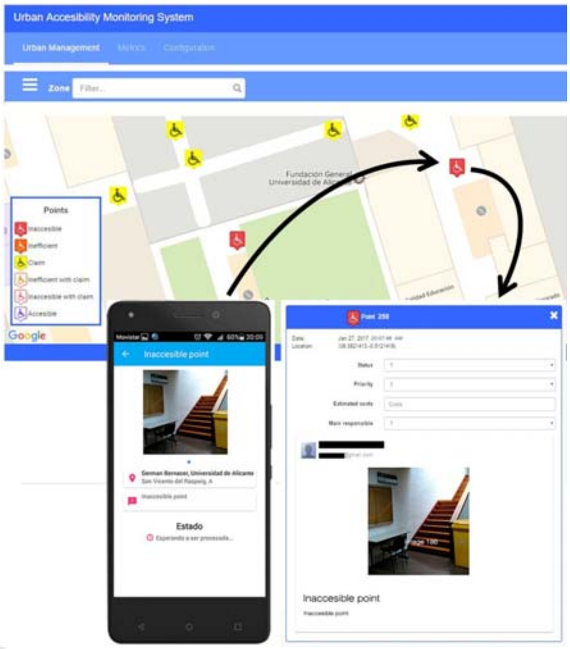

Figure 7: Example of claims provided by users in German Bernacer Building (0036).

Table 1: Incidences of accessibility in building 0036.

Point Number	Location	Description	KAI
253	(38.38256, -0.51241)	Lack of maintenance in building access	Claim
254	(38.38254, -0.51241)	Uncomfortable materials for wheelchairs in ramp	Claim
255	(38.38232, -0.51231)	Access is not available for wheelchair	Inaccessible
256	(38.38242, -0.51218)	The access door is too much heavy	Claim
257	(38.38242, -0.5121)	Not accessible info point.	Claim
258	(38.38214, -0.51214)	Access is not available for wheelchair	Inaccessible
259	(38.3822, -0.51197)	Absence of handicapped WC	Inaccessible
260	(38.38216, -0.51225)	The exit door is too much heavy	Inaccessible
261	(38.38234, -0.51246)	Not accessible info point	Claim
262	(38.38237, -0.5124)	The exit door is too much heavy	Claim

4.2.2 Experimentation from Building 0036 to Relevant Areas of the University Social Life

Once data was collected by GPS inside Building 0036, the experimentation continued with the path from Building 0036 to the relevant areas of the university social life, such as leisure areas inside the UA campus.

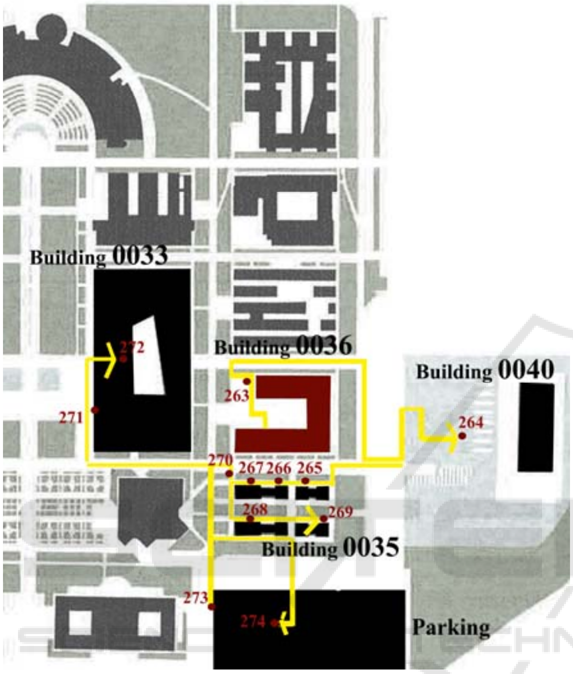

Figure 8: Incidences reported in routes to relevant areas of the university social life.

The first route was between Building 0036 and MUA (Building 0040) highlighted in yellow in Figure 8. In that outdoor path, two claims were reported and identified as Point Number 263 and 264. The first one (263) consists in a sand shortcut, while the second one (264) is a ramp of access to MUA with too much slope and length.

The second route was from MUA (Building 0040) to the commercial area (Building 0035), which includes a bookshop, a stationery shop, a post office, several bank offices and a restaurant. Accessibility incidences (265-269) were reported in the access doors of all the previous services, due to the weight of the manual doors.

The third route was from the commercial area (Building 0035) to the General Library (Building 0033). Accessibility incidences (270-272) were reported in the pathway and the access doors of the General Library, due also to the size and weight of the manual doors.

Finally, from the General Library (Building 0033) to the parking, two new incidences were reported. The first one (273) was an insurmountable curb. The second incidence (274) was reported due to the lack of sidewalk from the crosswalk to the space reserved for handicapped.

In this context, the following table (Table 2) summarizes the KAI identified in the experimentation from Building (0036) to the relevant areas of the university social life.

Table 2: Incidences of accessibility in routes to relevant areas of the university social life.

Point Number	Location	Description	KAI
263	(38.38236, -0.51214)	Sand shortcut	Inaccessible
264	(38.38157, -0.51239)	Too much slope in ramp	Claim
265	(38.38195, -0.51271)	The access door is too much heavy	Claim
266	(38.38206, -0.51275)	The access door is too much heavy	Claim
267	(38.38219, -0.5128)	The access door is too much heavy	Claim
268	(38.38213, -0.51308)	The access door is too much heavy	Claim
269	(38.38188, -0.51298)	The access door is too much heavy	Claim
270	(38.38253, -0.51276)	Lack of maintenance	Claim
271	(38.38341, -0.51251)	The access door is too much heavy	Inaccessible
272	(38.38355, -0.51198)	Access is not available for wheelchair	Inaccessible
273	(38.3824, -0.51364)	an insurmountable curb	Inaccessible
274	(38.38195, -0.51357)	Lack of sidewalk	Claim

The obtained points are represented by the Urban Accessibility Information Service, as it is shown in Figure 9.

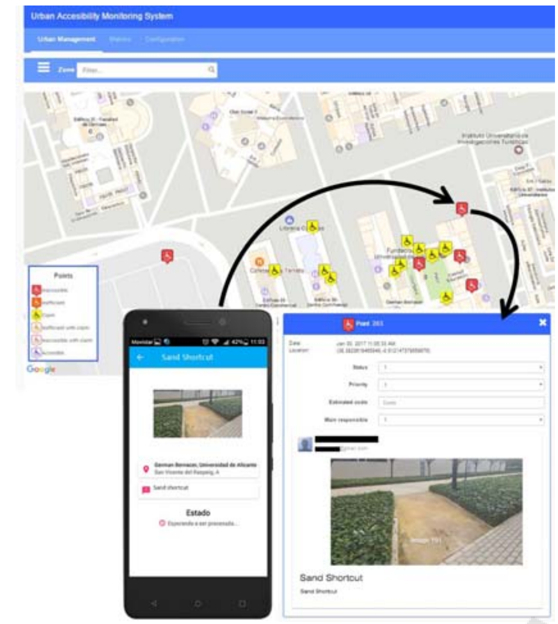

Figure 9: Example of incidences in routes to relevant areas of the university social life.

5 CONCLUSIONS

The present work shows a research based on a system that allows the analysis of the urban environment to detect problems related to accessibility, integrating the citizen as a main participant by including mechanisms to give voice to people with and without disabilities.

The system monitors urban accessibility for citizens through a mobile application with the aim of detecting incidents that prevent people with disabilities to have a complete integration into the urban environment.

In addition, this system provides support in making decisions to prioritize improvement actions in public space. The obtained data will enable a better design for improving pedestrian mobility in cities.

A practical application of this system has been carried out in a controlled environment at the University of Alicante. From the experience performed the advantages of the system are deducted that promotes an active process of collective participation for the collection and recorded of spatial data and information about the real state of accessibility as a mechanism against social exclusion.

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