Making Smart and Accessible Cities
An Urban Model based on the Design of Intelligent Environments

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Abstract: Improving citizens' quality of life is one of the main goals of Smart Cities development. Accessibility of urban public spaces absolutely determines the living conditions for people. Technology provides new opportunities of autonomy for an increasing group of inhabitants with specific disabilities. This work proposes an urban model for improving accessibility based on the design of intelligent environments, with the automation of processes and functions in urban spaces, as a safe and effective way to promote inclusion and participation of all citizens. Finally, the most appropriate technologies to implement the model are discussed.

1 INTRODUCTION

Over the last decade, the extraordinary development of Information and Communication Technology —ICT— is transforming both: the way we communicate with others and how we relate to the environment (Townsend, 2013). Constantly, new technologies provide us with information on the living context, mainly in the cities in which we live. They offer us new and better opportunities to interact and participate at urban environment, substantially improving mobility and liveability of cities (Dodgson and Gann, 2011).

Elderly and people with disabilities, among other groups, are at the greatest risk of being excluded from technological development but they are also the most favoured by the impact of ICT in improving their standard of living. ICT are enabling move forward achieving personal autonomy, greatly reducing dependency situations, as never before had it been possible.

Technologies have much to offer, targeting the constraints on universal design. Urban environments are the scenes where can be achieved autonomy levels much higher than the mere barrier-free construction allows.

Thus, technological developments should not be excluded from urban accessibility solution proposals. It is imperative to implement innovative technology solutions, preferably integrated into the functioning of cities, able to facilitate participation in urban life for people with the greatest difficulties of development (Macagnano, 2008).

In this way, universal accessibility finds an optimal scene of opportunity in the context of Smart Cities (Neirotti et al., 2014).

This work is structured as follows: Section 2 describes the motivation and objectives. Section 3 gives an overview of the related work on urban actions and technology used to improve accessibility in cities. Section 4 explains the proposed urban model for improving accessibility. In addition, the most appropriate technologies to implement the model are discussed. Finally, in Section 5, some conclusions are drawn.

2 MOTIVATION AND OBJECTIVES

Smart Cities are a concept of urban design proposals, characterized by the research of active

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participation in achieving sustainable development through an intelligent, efficient and rational management —without harming the environment— of infrastructure, urban services and resources; focused in improving the quality of life of the citizens. All this, based on widespread use of ICT (Angelidou, 2014). The level of accessibility of urban streets and public spaces absolutely affects the citizens' standard of living and limits their possibilities of relationship and social integration. Accessibility is an element of quality of life of universal interest and a right of all citizens (United Nations, 2006), therefore, implementing proper urban design solutions becomes one of the main challenges of the Smart Cities.

In this context, our research delves in the design of intelligent environments as a safe and effective way to promote inclusion and participation of all citizens. Thus, Smart Cities concept can make the most of their human capital (Cossetta and Palumbo, 2014); a key to guarantee and optimize their future development at the present time.

The World Health Organization estimates that more than a 1,000 million people in the world live with some form of disability; about 15% of the world population in 2010 (World Health Organization, 2011). In the context of the European Union, one out of six people has a mild to severe disability, which means that over 80 million people, more or less often stop participating in social and economic life. More than a third of people over age 75 suffers some type of disability (Eurostat, 2015). In addition, we are facing unprecedented demographic changes due to general aging of the world population, which suggests that these figures will increase. Therefore, it is urgent to rethink environments, maximizing the opportunities offered by technologies; so that, they are actually accessible and respond to XXI century's social needs (Reeves, 2005).

Our proposal is also part of the objectives of the *European Disability Strategy 2010-2020* (European Commission, 2010a), developed in the framework of the strategy *Europe 2020* (European Commission, 2010b). To this end, we propose to implement, in the planning under the Smart Cities concept, a model of integrated technologies which offered a set of automated processes that could adapt a specific urban space conditions to each user needs. Our main objective is to research and propose some design guidelines for really smart and inclusive environments through the implementation of a sustainable technological model, without excessive cost and respectful with the environment.

Considering that currently over 50% of the world population lives in cities, and this proportion continues increasing (Vojnovic 2014), we believe that improving urban accessibility, taking into account social diversity, are not only an essential issue, but also a priority one, in order to confer cities the quality of smart.

3 RELATED WORK

3.1 Integrated Technologies in Cities for Improving Urban Accessibility

Inside the context of Smart Cities, the field of management of urban basic services and including transport, has been the one that have developed technological processes (Riva, 2014). Beyond this field, the presence of technology is not so evident in urban areas. Current urban design incorporates such passive technologies that configure the urban setting —i.e. non-slip flooring or standard curb ramps—. Another type of technology is that one introduce by each citizen —wheelchairs, prostheses or implants, assistive devices such as canes or walkers— known as autonomous technology. Furthermore, active technologies are those that endow spaces the smart category, but they have been developed more inside buildings than in urban environments. However, the combination of both types of technology, passive and active, are necessary to improve the accessibility of cities.

In some cases, individually, active technologies have been incorporated into the elements of street furniture, in order to develop different functions. For instance, to organize pedestrian and vehicular traffic flow, automatic bollards are arranged. This elements can stay or hide allowing the passage of vehicles or not. They can also be driven by remote control, by authorized people and even can work in connection with traffic lights. Another device to inform about the time that pedestrians have to cross the traffic routes, traffic lights that emit sound and light signals can also be operated with remote control. Thus, the times of the acoustic signal can be adjusted at the beginning and end of the action and it is only activated in the presence of the person with visual impairment. Remote controls and other mobile devices can also receive information from other transmitters, for example: about a particular route guidance or on the nearest accessible transport.

Also, to accommodate the use of mechanical stairs to the needs of different people, mechanisms to transform several rungs on a platform have been

incorporated. Other mechanical ramps also have devices to stop and activate the operation, as well as systems of audible, tactile and visual warning. Additionally, the snapshot must considered: exterior lifts with accessible cabins, automatic opening doors, that are mechanisms already integrated. It must be considered also other lifting equipment such as: platforms attached to stairs that by crushing, automatically stop; or platforms located even under stairs that are collected to allow their use when required by people with disabilities.

In connection with some of the technologies described, proposals based on the detection of people with disabilities to implement devices for facilitating their actions, occasionally have also been implemented in cities. Such is the case of some acoustic traffic lights or some pedestrian crossings, which have incorporated sensors or cameras capable of detecting the crossing intention to activate light signals to alert drivers; there have also provided sensors to inform real-time availability of parking; or even containers that activate automatic opening system for easy use when identifying people with disabilities. Although these individual proposals are not yet sufficiently implemented in cities.

3.2 Accessibility Enhanced by Information and Communications Technology —ICT—

The development of Technology of Information and Communications Society contributes to new opportunities for improving accessibility in modern cities. The concepts of smart and ubiquitous cities make use of processing technologies, sensing and communications to provide knowledge and intelligence to the city (Yigitcanlar, 2014) while offering connectivity resources, power supply and interoperability (Jackson et al, 2011). These conditions facilitate the deployment of smart interconnected elements that provide services to citizens for efficient decision-making and make better use of resources (Neirotti et al., 2014). For example, interactive street maps that display in real time elements of interest, or automatic identification and traffic management (Mora-Mora et al., 2015a).

The use of technology to improve urban accessibility has been traditionally associated with information accessible proceedings to the citizens. Public administrations keep a large number of web applications on accessibility of places according to the user's position mainly based on the calculation of proximity relationships and intensities of use (Comai et al, 2015). The position and location on the map are normally obtained by combining Global Positioning Systems —GPS— and Geographic Information Systems —GIS—. Their services allow us to locate nearby resources and to plan itineraries (Ford et al., 2015). Disability is taken into account showing different routes and route times for people with and without disabilities. However, the main challenge of these systems is the evaluation of resources and the analysis of their dynamics of use to know if the urban environments that result from actions to improve accessibility are used or they cease to be used at some point (Church and Marston, 2003). To get this information, it is need to know the habits of city movement paths for citizens with and without disabilities. In this way, this information is relevant to identify potential mobility difficulties and to plan on necessary corrective actions (Gilart-Iglesias et al., 2015). A study of this type has been made in the public transport system in London (Ferrari et al., 2014).

Locating and tracking people is an issue of great interest as evidenced by the volume of research on the subject (Mora-Mora et al., 2015b). In fact, there is some concern among users and the authorities about maintaining the privacy of individuals due to the large number of devices connected at the users' hands (Isaak, 2014). There are many benefits to design cities that are obtained from the knowledge of the habits of movement of citizens, for example, to plan transportation lines, decide strategic situation for urban utilities, or public safety.

4 PROPOSAL OF AN URBAN MODEL FOR IMPROVING ACCESSIBILITY

From individual proposals which have been described in the previous section, this work outlines an urban model of integrated technologies, able to identify a pedestrian need in a specific city space context, and manage a number of processes, in order to facilitate an effective adaptation for this person.

The proposed model presents, as major innovation, its ability to be integrated in the everyday functioning of Smart Cities system; as well as, its working capacity to improve access for people with disabilities to urban contexts in a personalized way. Thus, intelligent urban environments are those that can be adapted to people with disabilities, and not vice versa, as with the exclusive or majority use of autonomous technologies, which are introduced in the city by the citizens themselves.

4.1 Conceptualization of the Model

Concepts that have served as the basis for designing the model, and are used with a specific meaning in this work, are defined as follows:

- *Urban situation* is understood by the set of factors affecting the development of people in a particular time and urban context.
- *Urban context* is understood by the physical environment or the situation in which people develop an action or everyday urban activity; such as crossing a street.
- *Urban element* is understood by each of the parts or components that may be involved in an urban context; such as traffic lights or a traffic signal at a pedestrian crossing.

Basically, the model proposed allows *urban elements* involved in a specific *urban context*, in certain *urban situations* where people with a particular type of disability are detected, can set in motion their own automated processes to accommodate the particular needs of those people.

4.1.1 Urban Situations

Obviously, there is a close relationship between the different urban situations that can be generated in the city and the forms of disability that people may suffer. Therefore, the model has been designed from the differentiation of these forms of disability that determine the different urban situations.

The World Health Organization considers the concept of disability as a comprehensive term comprising impairments, and activity limitations and restrictions participation. According to this idea, which is developed in the *International Classification of Functioning, Disability and Health* —ICF— (World Health Organization, 2001), it has been done a selection of different forms of disability, related to different urban situations. As a result, Figure 1 shows the forms of disability which have been taken into account in designing the model, as well as the process for their determination.

4.1.2 Urban Contexts and Urban Elements

Similarly, diverse urban contexts, encompassing all the elements which define public space, have been taken into account when developing the model. The manual: *Accessibility for the Disabled: A Design Manual for a Barrier Free Environment* (United Nations enable, 2003) provided by the United Nations, has been a basic reference for this task.

Table 1 shows the set of urban contexts which has served the basis for designing the model and the urban elements associated with each of these contexts. In addition, every urban context is accompanied by a brief description of the main problems encountered by people with disabilities.

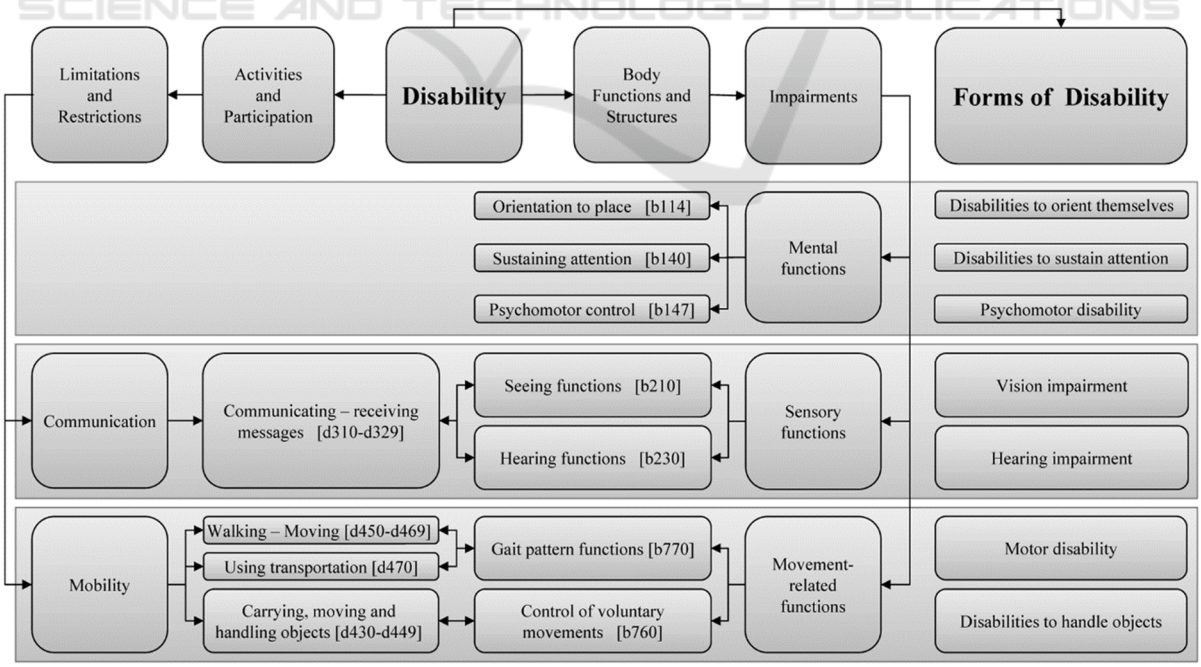

Figure 1: Forms of disability taken into account in designing the model. Source: Own preparation based *on International Classification of Functioning, Disability and Health* —ICF—.

Table 1: Proposed Urban Model for Improving Accessibility. They are indicated by (*) actions that need to be requested by people with disabilities. Source: Own preparation.

Urban contexts —Problem identification—	Urban elements	Barriers and Hindrances → Facilitators
Pedestrian crossings —Lack of safety and personal autonomy to cross—	Traffic lights	Disabled people are given the right of way
		The crossing time interval is extended according to the needs of individual people
		Both visual and acoustic or vibration signals are provided during the crossing
	Pedestrian crossing signs	Drivers are given flashing light signals (in the absence of traffic lights)
		Disabled people are given flashing light signals
	Lack of curb ramps	Mechanical ramps as a transition between the pavement and the street are driven (*)
	Street lighting	Street lighting intensity is increased
Keep clear areas —Lack of safety to cross keep clear areas which interrupt the path of travel on pavements—	Keep clear areas signs	Disabled people are given flashing light signals when the garage door is open
		Additional acoustic or vibration signals are provided
	Street lighting	Street lighting intensity is increased
Roadwork zones, maintenance works and other constructions —Lack of safety around temporary obstructions within the path of travel—	Warning signs	Flashing light signals are provided
		Additional acoustic or vibration signals are provided
	Indication signs with alternative routes	Voice messages are provided (*)
	Street lighting	Street lighting intensity is increased
Access to public buildings —Improper or inexistent transition between the pavement and the public building entrances—	Stairs	Retractable stairs and platform lift are driven (*) (in case of space and architectural image problems)
	Steps and other small differences of level	Mechanical ramps as a transition between the pavement and the building entrance are driven (*)
	Automatic doors	People are detected and doors are opened
	Lack of curb ramps near public buildings	Mechanical ramps as a transition between the street and the pavement are driven near the public buildings (*)
Street furniture —Street furniture and facilities are not accessible for all. Obstructed pathways—	Hindrances (in general)	Acoustic or vibration signals are provided and are intensified with proximity
	Garbage bins	They are automatically opened and closed
		An additional automatic opening on the ground is driven
	Postboxes	A bigger slot is automatically opened
	Ticket vending machines	Voice messaging systems are available (*)
	Street lighting	Street lighting intensity is increased
Signage —Signage is not effective for all—	City information signage	Personalized information is displayed on digital signage
		Information about accessible routes is displayed on digital signage
		Voice messaging systems are available (*)
	Warning signs	Additional acoustic or vibration signals are provided
		Additional flashing light signals are provided
	Street lighting	Street lighting intensity is increased
Public transports stops Bus stops —Lack of synchronicity in actions for more effective use of public transport—	Information panels and displays (on routes, bus stops, arrival times…)	Voice messaging systems are available (*)
	Waiting area	Disabled people are detected and bus drives are advised to prepare assistive devices to access
Parking areas —Lack of accessibility. Improper use of parking spaces—	Lack of curb ramps between parking areas and pavements	Mechanical ramps as a transition are driven (*)
	Bollards / Access control equipment	Disabled people are detected and bollards allow them access to the parking
	Information displays (on free parking spaces, traffic flows)	Voice messaging systems are available (*)

According to the ICF, urban elements are considered external factors that can have a negative or positive influence on the development of individuals. Therefore, the proposed urban model is designed to implement the necessary automated processes, associated with each urban element in relation with different type of disabilities, in order to improve its effects on individuals and enabling it to act as facilitator element. A context with barriers, or without facilitators, limits the participation of the individual, comparing with other contexts where the inclusion of facilitators increase it. In this regard, the city can limit the participation of citizens both: creating barriers and not providing facilitators. The main target of the urban design model proposed, is to provide enhanced solutions in order to reduce and prevent these situations, maximizing ICT potential.

Most of the processes covered by the model are done automatically by detecting the presence of people with disabilities. Several processes may be associated with a single urban element in order to facilitate different situations to different people. However, certain actions —shown in Table 1 with (*)— have been designed to be necessary demand by disabled people before starting functioning.

4.2 Types of Intelligent Environments

In respect on specific improvements on accessibility introduced by this model, it must be emphasized the ability to configure two types of intelligent environments: those that increase the options of movement and personal development; and, those that decrease personal insecurity problems. Integrated urban aids in Smart Cities offer citizens new opportunities and facilities for movement and participation. They decrease the insecurity problems in the use of urban spaces and provide information to citizens related to different environments, adding additional safety to their actions.

Finally, to show the possibilities of the proposed model, the simulation of specific cases in real urban environments is proposed. Figure 2 shows three possible scenarios or urban situations. By the time that people with disabilities are detected trying to access to a specific urban context, urban elements involved in this context are informed to initiate automatic mechanisms and processes to facilitate their use and helping to improve environment accessibility.

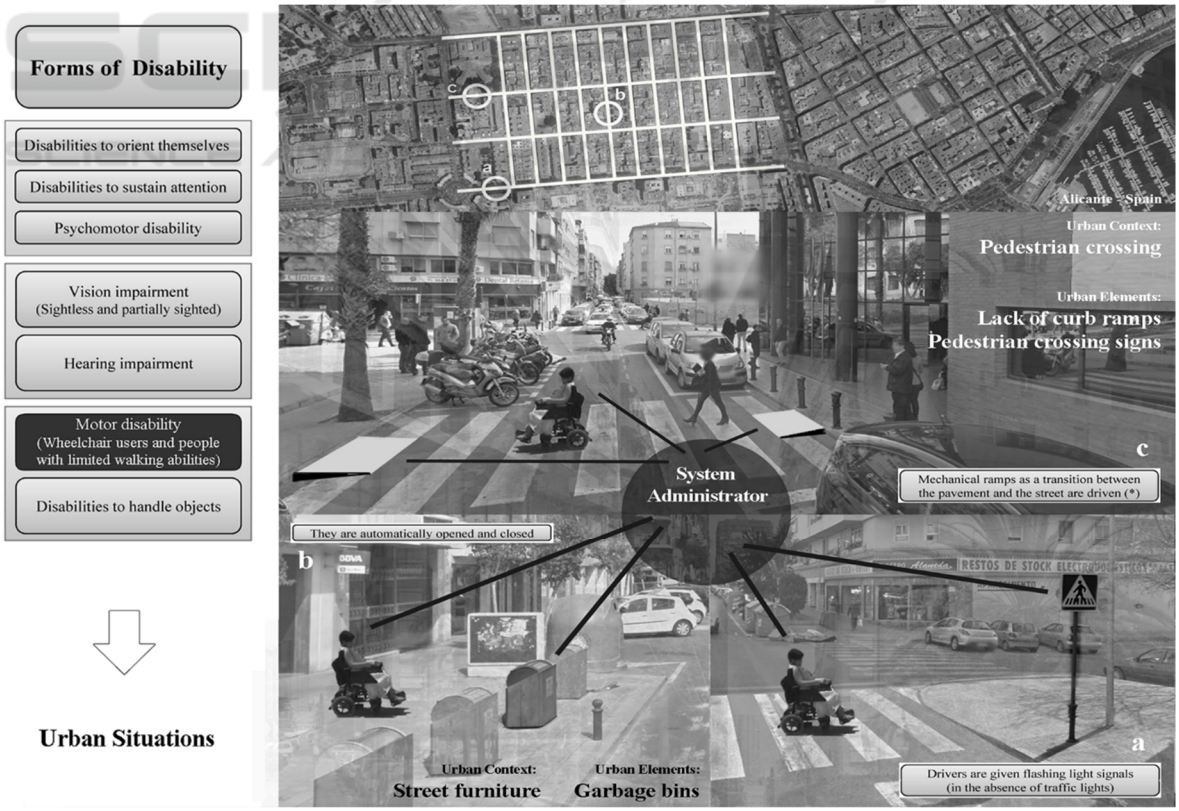

Figure 2: Simulation of specific cases in real urban environments that show the possibilities of the proposed model. Source: Own preparation.

4.3 Discussion on Appropriated Technologies to Implement the Model

The main technology to know the position and infer the movement in an accurate manner is GPS. However, only the use of GPS has disadvantages to consider. The first one, it is related with the fact that this technology only works outdoors and, therefore, impedes the design of valid comprehensive solutions for any scenario. Another aspect to consider, related to the users, is the circumstance that they should allow their devices to inform their position to a third-party application (Chen, 1999). Finally, although the GPS functionality is present in many mobile devices, most of the time is off because of the energy it requires.

Other wireless communication technologies such as Global System for Mobile communication —GSM— or local area wireless computer networking —WIFI— and Worldwide Interoperability for Microwave Access —WiMax—, can also take advantage of the high penetration rate of mobile devices in modern societies. These networks are not designed for tracking and tracing process, but, by the time that base stations are aware of the presence of connected devices, it could be calculated their route from one station to another (Clarke and Wigan, 2011). However, they also present some problems of implementation. First, the accuracy for tracking tasks may not be sufficient. To overcome this disadvantage, redundant infrastructure that allows triangulate positions accurately at each time, must be installed. Another problem is related to privacy, since a unique identification of the device occurs and can lead to knowledge of its user. Finally, they require continuous power consumption and mobile devices must be active even when users are not using them.

A recent diffusion technology are the Bluetooth Low Energy —BLE— beacons that allow communicate with mobile user devices (Gomez et al., 2012). These systems require little energy to operate but also require the authorization of the citizen to access their mobile (Talasila et al., 2015). Other alternatives tracking such as video surveillance cameras circuits, Closed-circuit television —CCTV— cameras, have serious technical difficulties to implement automatic tracking methods and can cause a strong effect of rejection by invading the privacy of people.

An alternative to the above methods is —RFID— Radio Frequency Identification technology (Ni et al., 2011). This technology is playing an increasingly important role in the design of user-centric applications, both indoors and outdoors scenes. Currently, new mobile devices are equipped with RFID readers. In addition, a great display of RF tags among users, distributed in multiple formats, such as prepaid plastic cards, tickets, electronic keys and even clothing labels.

Several investigations seek to use this technology for tracking people. The works have been done both in indoor (Xiong et al., 2013) and outdoor environments (Lin et al., 2010). The information collected allows knowing the patterns of movement of people through the studied scenarios and designing strategies to improve user satisfaction. Thus, RFID technology overcomes the disadvantages of GPS methods on user cooperation and energy costs. However, the scope of this technology is not comparable to the GPS, which coverage since it depends on the position of the antennas and their scope. This tracking method does not get exactly the position of the user, but the position of the RF antennas located along the scenes, so that, the received information should be processed to obtain the effective route.

5 CONCLUSIONS

The urban model proposed enables the implementation of various automated processes associated with the functioning of different urban elements. All of them are involved in specific contexts and to diverse urban situations, that is, when a person with a particular type of disability is detected trying to develop an action in a specific context. Thus, the spaces that form the city become more kind and intelligent and are capable of providing a wide range of actions to people with difficulties who need it.

In summary, our proposal is presented as an essential model of integrated technologies. First, by becoming part of the urban environment and the global system which Smart City is, in some way improving its current technological weakness as accessibility solutions provider. And secondly, to encourage and promote the design of intelligent and accessible solutions, capable of fostering autonomy and independence of people with disabilities, with the added value and appeal of having this action-detection technology available in urban environments.

This is an open urban model which should be further developed to respond to new real demands of society in the short, medium and long term.

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