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How to Enhance the Future of Urban Environments Through Smart Sustainable Urban Infrastructures?

According to the United Nations (UN), about 70% of the world's population projected to live in urban areas by 2050. Therefore, cities are experiencing an enormous urban transition the world has ever seen, accounting for 80% of global carbon dioxide emissions, consuming over two-thirds of the world's energy, and producing 1.3 billion tons of waste per year. Leaders, governments, architects, urban designers, developers, planners and business leaders need to make decisions and find solutions for how billions of urbanites will live in the future. Therefore, future cities will require new design principles to face their urban challenges and problems such as pollution, poverty, poor environment, land use management, greenhouse gas emissions and socio-economic and environmental risks. In this context, the case study area of this paper will be El Raval district, which is in a medieval quarter of Barcelona. This area considered as one of the oldest and a significant part

of the city that contains many heritage buildings and unique traditional urban context going back to hundreds of years. The district has an influx of immigrants, which has transformed its label from an industrial neighbourhood into a residential one and low rents that have attracted many people of low income, making it a vibrant and multicultural community. Therefore, the main aim of this paper is to address the implementation of innovative solutions, advanced technologies, ICT and IoT that might enhance people participation in the urban design processes and respond to urban futures challenges. The result of this research will lead to creating a platform to resolve the conflicting values of architectural heritage and smart cities principles, sourcing new sustainable technologies and the integration of the smart infrastructure systems.

Keywords:
Urban Environments; Urban Heritage; Smart Cities; ICT; Future cities challenges

1. INTRODUCTION

Over the last five decades, many research and projects have been made through UNESCO, ICOMOS, and other organizations to conserve historic places in different cities of the world (Al-Saffar, 2018). Spain is one of these cities that has many historic areas, which faced significant challenges in the mid-twentieth century. Thus it has collaborated in the efforts of UNESCO for the preservation of its architectural heritage, traditional urban places and cities identity. El Raval district is one of the oldest parts of Barcelona, and it is one of the densely populated areas where the majority of its population are immigrants. This area was Built in the middle ages, and it contains many historic buildings; the oldest of which dates to the 12th century (Fig. 1 and 2). The status of EL Raval has changed dramatically since the mid-19th century, from the political, industrial and financial centre of Barcelona in the mid-19th century to the most deprived area in 2019. Nowadays, EL Raval faces many urban challenges to transform itself to be part of the smart city development in Barcelona. Barcelona's municipality has introduced a series of urban renewal programs to deal with these challenges Since the mid-1980s (Scarnato, 2014). Government action has concentrated on improving infrastructure, district facilities, housing, employment, health, education, social services, sports facilities, and restricting criminal and secondary activities. This has led to demolish many old blocks to create new city public squares such as the whole new Rambla de Raval between 1996 and 2001 and to build many modern buildings like the Centre de Cultura Contemporania in the 1994 and Museum of Contemporary Art in 1995. Barcelona University also has expanded its buildings to open a new library (Ubieto, 2019). These regeneration programs initiated by the government have dramatically altered the social, environmental, transportation, conservational and land use characteristics of some parts of the district. However, the effects of these schemes have not fully reached many areas.



2. METHODOLOGY

In this paper, various strategies at different levels of the research were implemented. The nature of the design of this research can be called multi-strategy study. This paper will implement a mixed research method that endeavours to bring information from both qualitative and quantitative methods. Qualitative and quantitative approaches are two different broad methodological systems

Fig. 1 - El Raval Traditional Urban Context

Source: Author, 2019

Fig. 2 - El Raval Architecture Heritage (Church of Saint Mary of Bethlehem)

Source: Author, 2019



selected to accomplish the aim of the research study. As this research considered El Raval as a case study, thus, mixed research method approach has been implemented, and many requirements have appeared when surveying the current situations in the old core of Barcelona. Also, the mixed research methods design requires to be synchronised with the information gathering. This research has utilised processes drawn from concurrent embedded forms of gathering information, in which both the quantitative and qualitative data are collected at the same time. This research employs various methods called a multi-method of gathering and analysis data within a single study paradigm. We may proceed with a qualitative approach in which we observe an area (Al-Saffar 2018). Mixed methods research is defined by Johnson and Onwuegbuzie (2004) as "A class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study" (Johnson and Onwuegbuzie, 2004). Creswell and Plano Clark (2011) say, "Mixed methods research is practical in the sense that the researcher is free to use all methods possible to address a research problem. It is also practical because individuals tend to solve problems using numbers and words, combine inductive and deductive thinking, and employ skills in observing people as well as recording behaviour" (Creswell and Plano Clark, 2011).

The information has been collected from diverse sources associated with various academic literature. Fieldwork has examined the case study architecture styles, transportation, land use, interview of the local people and assess the physical urban context. Significant steps were taken to gather information during the visit in October 2019. The first one is various actions, which were commenced, including:

1. Determining the case study area, which is the El Raval district.
2. Gathering comprehensive maps of El Raval and illustrating the Barcelona urban transformation.

3. Visiting the case study area and taking photos for many various traditional and modern buildings from different parts around El Raval.
4. Using a combination of the walking and the serial vision method as a qualitative approach for gathering information.
5. Preparing a map for each zone, to take a sequence of photos and to show the walking sections that were produced after the researcher had walked in the main components of the case study.
6. Analyzing field notes, photos, videos, sketches to have a deeper understanding of the El Raval in Barcelona.
7. The assessment of the information collected was the last part of these stages

Olascoaga, (2003) asserts, "The consistency of visual survey depends on the use of similar and objective categories in the assessment of townscapes". He mentions the, "Method of visual survey provides a list of concrete sensory, formal, and expressive categories against which a townscape can be appraised. The understanding and correct application of these categories allow consistent results among teams during and after the visual survey. There should be an agreement in the application of categories, and a group revision of findings". He argues, "The method of visual survey is useful for exploring and evaluating small areas of cities (such as neighbourhoods or districts) or small towns. However, when dealing with an inventory of the city as a whole, the exploration of the city demands large inputs of time, effort, and people. Therefore, the practical application of the visual survey is relative to the size and complexity of a city". He concludes, "Visual survey is useful for perceiving the characteristics and spatial relationships of human-made and natural elements of the urban form. This research utilised a camera as a capturing device for the collection of visual data (Al-Saffar 2018). The researcher walked through El Raval area and used a map as a beginning point for each zone, to take a sequence of photos. All pictures in the linear series were connected. The data collection, site visit, observation, walking and

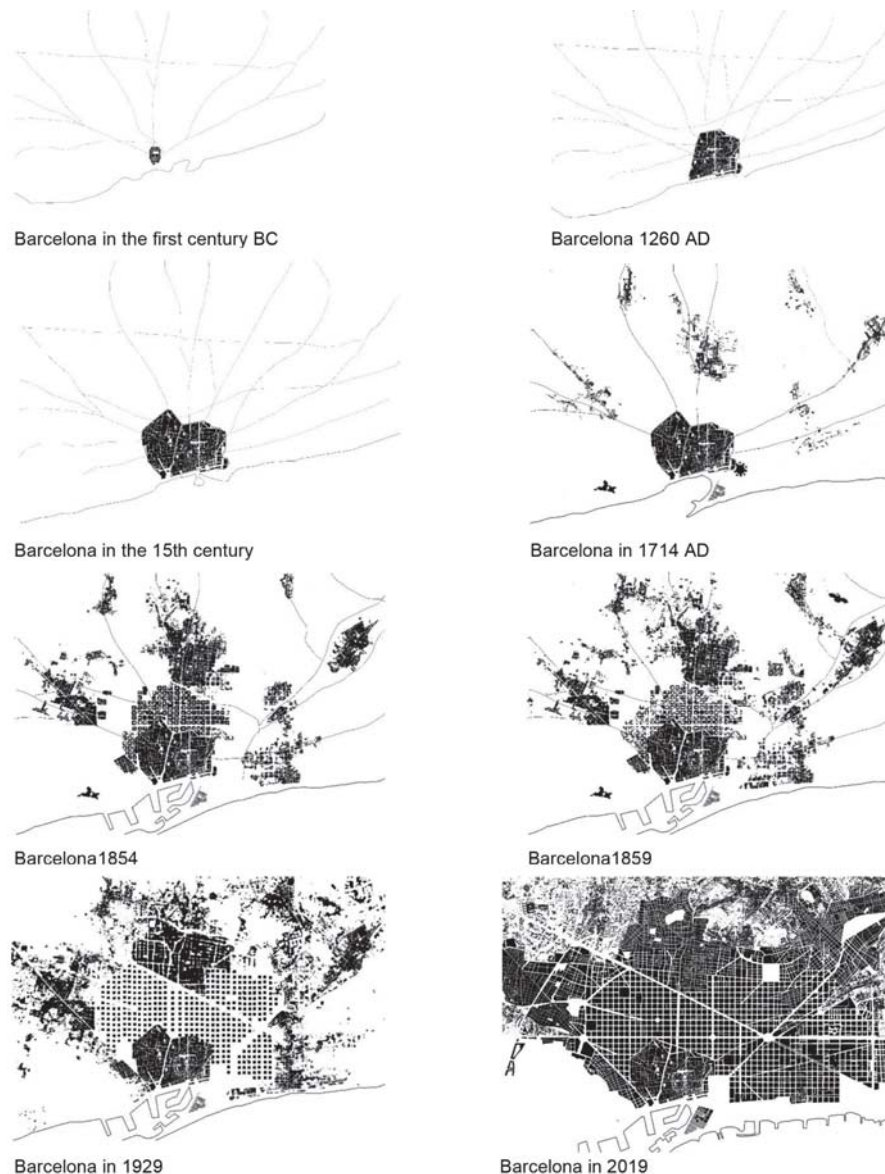
serial vision were prepared to evaluate the historical centre of Barcelona.

3. BARCELONA CITY STRUCTURE AND URBAN TRANSFORMATION

During the 21st century, as Al-Saffar, (2017) says "urban transformation of cities has been intensely affected by flows of socio-economic and technological processes" (Al-Saffar, 2017). Therefore, understanding a city structure, urban heritage and the process of urban transformation will provide a clear vision of how we might develop the context of the urban futures of El Raval by applying smart systems and new design methods. The analysis of the urban growth and transformation of Barcelona city in Figure 3 started from the first century BC when the area of "Barcino" was still small settlement and then developed to be a city with organic patterns and paths. Batty stated that "the city has grown in some direction instead of others is largely due to a combination of physical and accidental historical factors, it does not imply any differences in the way growth has occurred from one-time period to the next" (Batty et al., 2006). Exploring the city transformation and structure of the Barcelona city are significant to understand the unique growth, planning and architecture style of the El Raval that might help to propose a future strategy of regenerating and to improve the quality of life in the district (fig. 3). The origins of Barcelona can be traced back to 15 BC when the Romans settled in the area and built the medieval city in the first century BC. At that time, the old city was called "Barcino" and was surrounded by a 1.5-km wall. (Roberts, 2019). In 1260, the city started to expand beyond its wall and a new area called El Raval was developed with a new wall into the industrial support system to the Central Business District of Barcino. This expansion in the 15th century grows into a high-density industrial district with residential areas for the workers. The surrounding of the two old districts was allocated for agricultural production. The Spanish throne war started in 1714 that has led to building a fortress to protect the old town of El Raval and

Fig. 3 - Barcelona City Structure and Urban Transformation Between the First Century and 2019

Source: Authors, 2019



prevent any development outside the wall. Due to the high population density combined with poor sanitation, infrastructure and living conditions led to the spread of many diseases between 1834 and 1870, with approximately 3% of the population dying each time.

The Spanish government in 1854 authorized the demolition of the city wall for future city development and assigned the engineer Ildefons Cerdà in 1855 to plan the new city. The Cerdà expansion plan was implemented in 1859 and changed the city of Barcelona (Bernis, 2001). Due to that, the city witnessed another type of growth and different method of urban form and pattern. The transformation of Barcelona city is a sophisticated method driven by various elements affecting the homogeneity of the old urban fabric. The production of new urban typologies that surrounded the heritage fabric was the most fundamental effects. The result was diverse spatial languages competing with each other. This transformation changed the relations and hierarchies among spaces, which allowed more flexibility and accessibility between private and public space (Al-Saffar, 2017). In the mid-19th century, the population density in El Raval was very high and not only the highest in Spain but also one of the highest in Europe; reaching 856 people per hectare, compared to the same period in Paris were there 400 people per hectare (Aibar and Bijker, 2017). Barcelona upgraded its infrastructure again by hosting a large city exhibition. However, an unstable political situation, especially after the civil war of 1939, has led to suspend the city future development plan. Later, Barcelona hosted the Olympic Games in 1992, which turned the city into a modern city that attracted tourist from different places. Even though Barcelona flourished, the El Raval district remains as one of the black points in the city with inadequate water supply, poor services and infrastructure and low economic conditions that have led to move many people from the traditional centre to the modern districts. The old city nowadays is occupied by low-income families; most of them are immigrants who come from South America, Pakistanis, Filipinos and Romania.

4. EL RAVAL URBAN HERITAGE CONTEXT

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Urban heritage as Al-Saffar, (2016) mentioned “involves a vast set of aspects, including archaeological sites, ancient monuments, individual buildings or groups, streets and ways connecting those groups, and places surrounded by buildings. Due to these aspects, we cannot narrow down the urban heritage to monuments of historical interest or individual buildings. Urban heritage exists in the physical features of buildings, public spaces, and urban morphology. Thus, a better understanding of urban heritage will depend on understanding both heritage context, and the categories of heritage values derived from modernity” (Al-Saffar, 2016). El Raval has a large number of historical buildings that show the characteristics of different architectural style and heritage cultures. The influx of immigrants and low rents have transformed the area from an industrial area into a residential one making it a vibrant and multicultural community. The government of Barcelona has divided the traditional centre, which has many historical sites, into four levels of protection. Level A was to conserve the Cultural Assets of National Interest of Catalunya, such as Catalonia library, lyceo theatre and maritime museum in this region. Level B was to preserve the Catalan architectural features such as the Palau DE la Virreina and the church of saint paudegump (the oldest church in Spain). Grade C was to protect buildings with urban benefits, such as Arts Santa Monica. Grade D was to remove buildings that will not cause ahistorical preservation problems, and future renovation and demolition must be recorded to preserve their memory (fig. 4) (Maria and Salvado, 2017).



Fig. 4 - El Raval Architecture Heritage
Source: Aauthors, 2019

The architectural of El Rava area between 44 BC and 476 AD mainly based on the ancient Roman architectural style that uses Roman Ionic forms and arch vouchers. The city witnessed Rome architectural type between 800 and 1200 such as St. Paul’s church, which is characterized by thick walls and small windowing area and its building plan mostly adopts the structure of Greek cross (fig. 5) (Wilson, 2003). Gothic was another architectural style emerged in the historical centre of

Fig. 5 - St. Paul’s church
Source: Authors, 2019



Barcelona between 1100 and 1450 such as Maritime museum and Catalan library that their structure represented by a pier, large windows and flying buttresses were invented to make the building taller (fig. 6) (Frankl and Crossley, 2000). Renaissance, Baroque and Neoclassical architecture styles emerged in El Raval between 15th and 19th century. Among these styles, baroque is the most luxurious type, whereas the Renaissance and Neoclassicism are more symmetry and rigorous architectural design (Norberg, 1972).

In the 19th century, the modernist architectural style appeared in many locations of El Raval, such as the Museum of Contemporary Art that show the use of new materials and design methods (fig. 7). Thus, the historic part of Barcelona has witnessed different architectural style through centuries architectural style that all have left their influence (fig. 8).

5. EL RAVAL ARCHITECTURE AND URBAN CONTEXT PROBLEMS

The main challenge in El Raval area is how to create a platform that might solve the conflict between different architectural styles and modern design models that neglect the urban heritage context. Moreover, traditional abandoned buildings, decaying and land used problems have led to the confusion and chaos in the case study area. Even though Barcelona is the 8th best smart city in the world, El Raval district still suffers from being one of the backward regions of the European Union that requires the EU Cohesion fund for its development. The crime rate of this area is much higher than the surrounding region, and residents and visitors feel insecure when they are working or enjoying the civic landscape here. With a low-income level, people here, mostly foreign-born, endure poverty, living joyless life for their family. There are five different forms of family in this area which reflect people's living state. About one-third of residents are single people, and more than half of the household are married while only 40 per cent of them are coupled with children. Most Foreign residents here came from six countries, Ecuador,



Morocco, Colombia, Peru, Pakistan and Dominica. They came to this country hoping for a better life for themselves and their children, but the truth is they have to deal with long working hours to pay the rent and tax without the right to vote. The main problems in the case study area of this research are as following (fig. 9):

1. Transportation problems: the new roads in the traditional part of Barcelona have led to

Fig. 6 - Maritime Museum
Source: <https://www.eventoplus.com/en/find-suppliers/supplier/2744/museu-maritim-de-barcelona/>

Fig. 7 - Museum of Contemporary Art in El Raval
Source: Authors, 2019

Fig. 8 - El Raval Architecture Heritage Styles
Source: Authors, 2019

increasing in air pollution, noise pollution, traffic congestion and lack of car parking area.

2. Health problems: due to the high population growth and immigrants, many diseases have emerged such as malaria, tuberculosis and drug addiction. There are only two hospitals in this area which are apparently cannot provide services they deserve to all the inhabitants.
3. Social problems: the lack of social services and the low-income issue have increased the rate of crime and affected the quality of life of residents.
4. Infrastructure problems: the case study area has inadequate infrastructure systems such as poor water management, poor sewage, low quality of housing, inefficient electricity system.
5. Legal issues problems: conflicts between landlords and tenants, lack of work permits.
6. Living systems problems: lack of a good quality of education infrastructure, social services, sports facilities. The land use in El Raval is residential with fewer community facilities, open space, community facilities and outdoor activities (Fig. 10 and 11).
7. The lack of clear urban heritage development plans that would give a positive motive to develop design principles.

6. EL RAVAL SMART URBAN ENVIRONMENT STRATEGY

El Raval area is facing many challenges such as high rate of crime, lack of a useful stander of infrastructure and poor living environment. Therefore, the old city of Barcelona requires new design methods that might develop the physical urban environment to be more sustainable and smart. The move towards a smart city is currently a trend for major cities in the world. The city as a centre of human civilization cannot be separated from problems related to excess capacity and a matter of convenience. More and more people are moving from rural to urban areas which increasingly

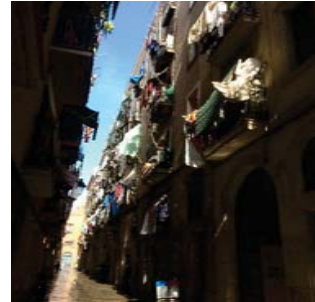
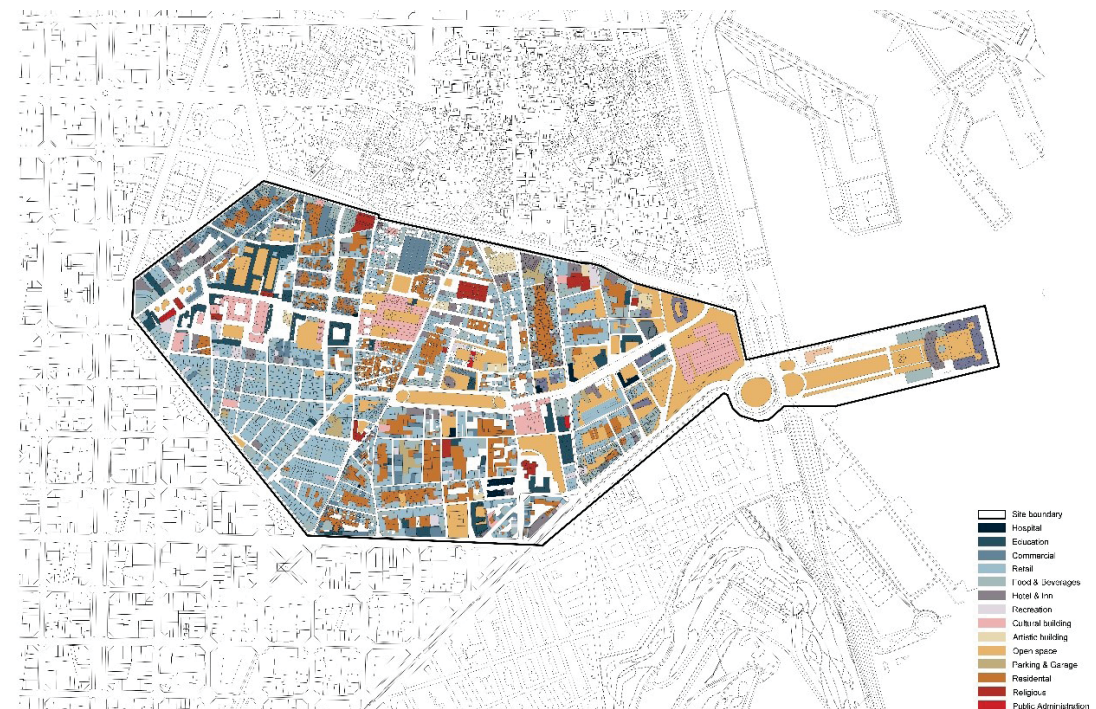


Fig. 9 - El Raval Area problems
Source: Authors, 2019

Fig. 10 - El Raval Area Land Use (Ground Floor)
Source: Authors, 2019



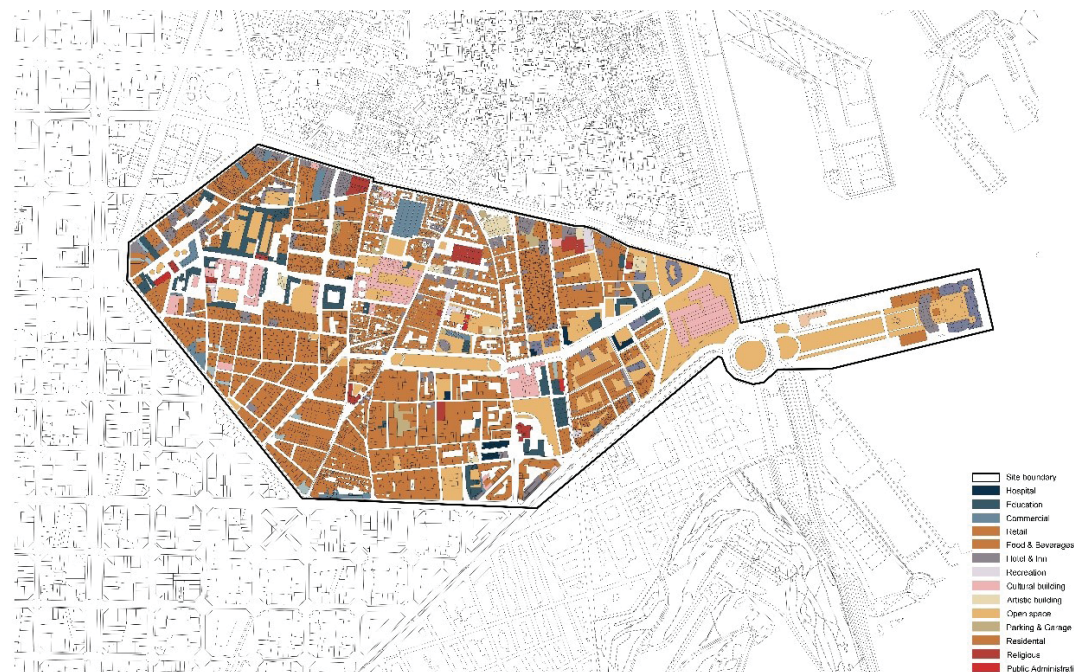


Fig. 11 - El Raval Area Land Use (first and up Floors)

Source: Authors, 2019

poses new challenges in the city. The origin of the concept of smart cities mention can be traced back to at least the smart growth movement of the late 1990s, and namely from what they call the “cybernetically planned cities” of the 1960s, and in proposals for networked or computable cities in urban development plans from the 1980s onwards. The idea of smart cities is only becoming known after 2009, and even today, it is still a somewhat ‘fuzzy’ concept. The concept has developed out of livable, creative, digital and knowledge cities, drawing heavily on the idea of the sustainable city and having in common a significant technological component. Due to challenges facing contemporary cities of losing their previous features, the concept of the smart city has become remarkable as a significant policy to reshape our behaviour towards the built environment. Thus, the smart city concept might be an appropriate solution and play a vital role to determine technologies and innova-

tions that allow us to promote socio-economic and environmental development in El Raval (Al-Saffar, 2018). The following table we have compiled the results from different sources such as books, journal papers and conference papers to understand the term “smart cities” that would develop this research to find fundamental approaches that might be implemented in the old city of Barcelona (table 1).

6.1 INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

In recent years the smart city concept has transformed into a new aspect of utilising ICT to produce and combine critical infrastructures and services of cities. The concept aims can be achieved by advancing and integrating ICT with different systems in the city such as water, waste, gas, electricity, transportation and mobility, cooling

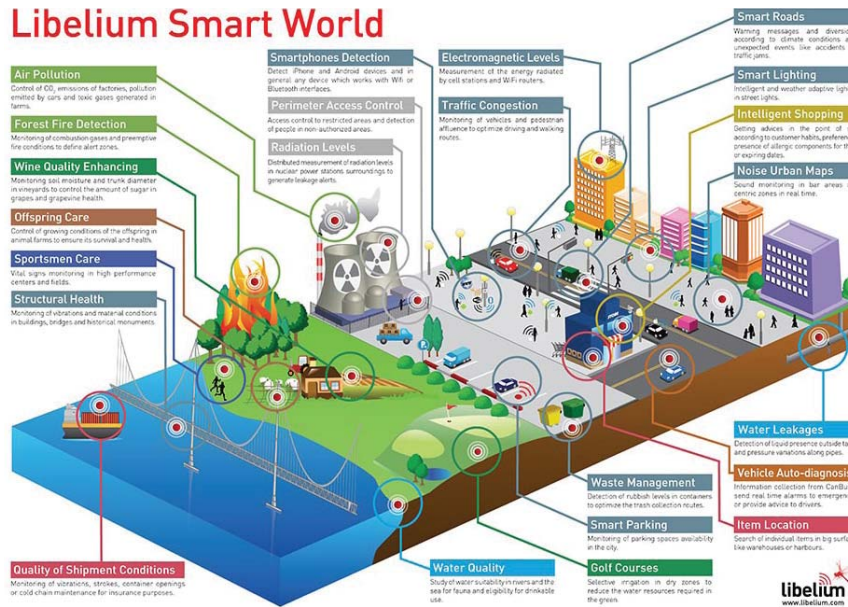
and heating systems. The fabric of the city nowadays is beginning to embrace the ICT in terms of its materials and infrastructure while wireless solutions are invading our cities in ways that are hard to understand. Therefore, we will need to show how such developments can be combined so that cities can become smart in the way their urban designers and citizenry can utilise such technologies to promote the quality of life in El Raval area. ICT has become an essential tool for the city to improve the efficiency, equity and quality of life for its citizens, and to support socio-economic aspects to reach their goals. Information and Communication Technologies also can promote the city system by providing accurate information about different sectors such as transportation, environment, health, education and economical, for instance, to solve problems and make intelligent decisions. There is powerful evidence from research, studies, articles and case reports of the ability of ICT to support cities and meet their challenges. The two parts, information and communication, are playing an important role together. Information technology involves everything about how to process and manage data, while communication technology includes everything about how to use tools to transfer data from one system to others. Thus, ICT utilises computer-based systems as well as telecommunication technologies for the information and data storage, processing, and communication. The combination of ICT devices and humans will characterise future urban scenarios and advance urban services. Such services will have the ability to inform the new vision of the smart sustainable city, and it will affect our way of living in urban environments. The progress of technologies and the availability of different sensors can provide and generate massive data about various sectors such as transport in our cities. Sensing capabilities will play a fundamental role as a part of ICT infrastructure to improve the city life in El Raval (fig. 12) (Al-Saffar, 2018). Barcelona is seeking to advance the use of tech-

Definitions of Smart City	Source
1 A smart city means how the urban infrastructure is evolved through the Information and Communication Technologies. The goal of promoting the use of innovative technologies from the Information and Communication Technologies area is to satisfy the challenges of the cities in terms of sustainability (e.g., water, gas and energy), to the social demand for real time information(e.g., parking, public transport and weather) and to the emergence of the Future Internet-related technologies.	(Jara et al., 2015)
2 A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability.	(Chourabi et al., 2012)
3 A smart sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.	(United Nations, 2016)
4 Smart cities as places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems.	(Townsend, 2013)
5 A smart city is a city which takes advantage of ICT in order to ensure its growth and attractiveness.	(Granier and Kudo, 2016)
6 A smart city is a broad concept that involves ICT design and development, the delivery of integrated ICT services, and the engagement of a wide range of users in adopting, applying, and continually adding value to a city's economic, social, and ecological dimensions.	(To et al., 2016)
7 Smart cities is a future notion that will permit their citizens governments, businesses, urban designers, planners, architects and professionals to contribute their opinion through complex system or "systems" in terms of making decisions, sharing big data, promoting urban environment, implementing equity, promoting efficient energy resources, constructing intelligent infrastructures and administrating complex information through utilizing ICT.	(Al-Saffar, 2018)

Table 1 - Definitions of Smart City
Source: Authors, (2019)

Fig. 12 - Sensors for Smart Cities that Might Be Implemented in El Raval Area.
Source: <http://www.libelium.com/libelium-smart-world-illustration-smart-cities-internet-of-things/>

Libelium Smart World



<http://disegnarecon.univaq.it>

nology in its physical urban arrangement by implementing efficient and sustainable urban mobility, creating a sustainable environment, business-friendly and attracts capital, encourage people participation, gaining in transparency and democratic culture and improving education and health care. Barcelona's vision for becoming 'smart' is to implement the concept of "the city of the people" (Al-Saffar, 2018). This initiative is not only about creating "futuristic images of a 'smart' in terms of technology and design Barcelona, but it also promotes the area as a place where significant scale collaboration and knowledge exchange among the city's people and businesses advance the knowledge and innovation economy" (fig. 13) (Angelidou, 2015). The concept of a smart city in Barcelona endeavoured to apply four main initiatives control of lighting zones, smart parking, smart and sustainable architecture media-tic building and e-governance. The city's aim to become the first self-sustaining city in the world by employing ICTs as an essential aspect to become active, achieve a sustainable environment, create new job opportunities, and be effective in city resource management. Citizens' participation plays a vital role in the success of these initiatives. Manville et al., (2014) say, "The Fab Lab Barcelona, which brings ICT and Smart City technologies closer to the inhabitants and demonstrates their relevance to the 'real world'. The projects are funded by all citizens (crowd-funding), and the public is also involved in deciding which projects to follow" (Manville et al., 2014).

6.2 THE INTERNET OF THING (IOT)

In the recent decade, the analysis of information has gained massive attention through the use of IoT, which allow different disciplines to record an enormous amount of data that requires being clarified. These disciplines have been integrated to assess and manage big data by using various approaches. El Raval might gain many benefits and solve various problems by using real-time systems assessment to analyse its information obtained from diverse aspects such as water,



Fig. 13 - Futuristic Image of Barcelona Smart City
Source: Al-Saffar, 2018 according to (Angelidou, 2015)

electricity, traffic, and gas. However, smart cities initiatives in Barcelona are facing a big challenge on how to build a holistic approach or model that can combine all systems to assess big data.

The enormous amount of information and big data methods are designed as an effective tool to contribute all the possibilities of IoT and the smart city. Jara et al., (2015) state that "Future Internet is the engine to reach the next generation of infrastructure, services and solutions to facilitate the sustainable development of its industry, buildings and citizens. Initial proofs of the potential of the Future Internet are found in the integration of the real-world on the Internet through smart objects". Jara et al., (2015) argue that "The challenge, for the big data and IoT, is to take benefit of this insight to understand how things are interconnected. Then, we will be able in the near future, not only to understand or able to predict, act, manage and prevent these situations. Thereby, evol-

ing from areas partially overlapped such as big data, IoT, Cloud Computing, physical devices and humans to a natural ecosystem, that will be able to act/operate, enhance and fix based on all this emerging knowledge and understanding, that is, insight. This fusion among areas to build solutions able to solve real problems and act/operate is denominated Cyber-Physical Systems" (Jara et al., 2015). IoT has been defined as a platform for communication between citizens and as an efficient method of running the machines and big data, it also about the use of advanced technologies in a collaborative way (table 2). Huang et al., (2016) point out that the integration between Internet of Things, smartphones, computers and the enormous amount of information in the cloud will lead to creating new path of integration between the physical and cyber world, produce sophisticated infrastructures and advance many creative applications (Huang et al., 2016).

Khatoun and Zeadally, (2016) assert that the IoT is one of several models that has been suggested to assess the smart city concept. They also indicate that the broadband infrastructure is a crucial component to implementing the smart city concept, which is providing a platform for connection between citizens, firms, and different government foundations. They debate that both wired and wireless networks are significant to advance the smart city' services and information volume. They say, "Wireless broadband is important for smart cities, especially with the explosive growth of mobile applications and popularity and the connectivity of smart devices" (Khatoun and Zeadally, 2016). Pouryazdan & Kantarci (2016) debate that the Internet of Things has played a significant role to empower citizens' smart devices and develop smart cities infrastructures. They argue, "Wireless sensor networks, RFID tags, and built-in sensors in smartphones and wearable devices will help realize device-level connectivity in smart cities. Integrating IoT devices, cloud computing, and data analysis into the smart city architecture accelerate the improvement of smart city services" (Pouryazdan and Kantarci, 2016).

6.3 SMART URBAN HERITAGE IN EL RAVAL

Manville et al., (2014) say, "The most successful Smart City strategies might be expected to adopt a multi-dimensional approach to maximise such synergy and minimise negative spill-over effects, as might happen, for example, if a Smart Economy strategy were prioritised which was detrimental to the environment. For this reason, we might expect to see more than one characteristic present in the most successful Smart Cities" (Manville et al., 2014). Smart cities require smart city indicators (SCIs), as Marsal-Llacuna et al. (2015) state. They assert that these smart indicators should be gained from physical and non-physical information in real-time to manage a city's technological and analytical data accurately, enhance the prosperity, and advance urban sustainability. The new

Definitions of Internet of Things		Source
1	Internet of Things is the marriage of minds and machines, that is, the union of big data running on the cloud computing platforms and physical devices/things.	(Jara, Genoud, & Bocchi, 2015)
2	IoT is generating prodigious amount of data, increasing sophisticated analytics mechanisms and tools that are providing insight that allow us to operate the machines in entirely new ways, more effectively and in a collaborative way.	(Jara et al., 2015)
3	IoT is all about digital technologies, semantic languages, and virtual identities. IoT improves the efficiency, accuracy, and effectiveness in operation and management of such innovation ecosystem aiming at guaranteeing high quality of life and stimulating innovation process of firms.	(Scuotto, Ferraris, & Bresciani, 2016)
4	The Internet of Things (IoT) is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet.	(Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014)

Table 2 - Comparative Definitions of Internet of Things
Source: (Al-Saffar, 2018)

technologies nowadays are producing the most updated information on cities' physical recognition is remote sensing imagery. They mention, "In the urban context, remote sensing imagery has been used not only for pattern recognition but also for building features extraction and automatic reconstruction" (Marsal-Llacuna et al., 2015). The research team propose an Index Wheel for the case study area (El Raval) according to previous studies, literature review, smart cities examples. This Index-Wheel has considered the architectural heritage and urban environment that requires particular solutions to produce suitable facilities and services for the case study stakeholders and participate in drawing the future vision of Barcelona and the old city advancement in particular. The Index Wheel has been divided into seven parts that will be the foundation to achieve smart urban heritage in the case study area (fig. 14). Various tangible performance measurement systems have been determined that will help to show the success of the development of smart systems, concept, products and services in El Raval area. This Index Wheel for the urban heritage environment contains a combination of the leading performance indicators for smart cities that might be implemented in other traditional areas that seek to be developed smartly. Moreover, it will be the guide and the basis for Barcelona future urban advancement. It will assist policymakers, plan-

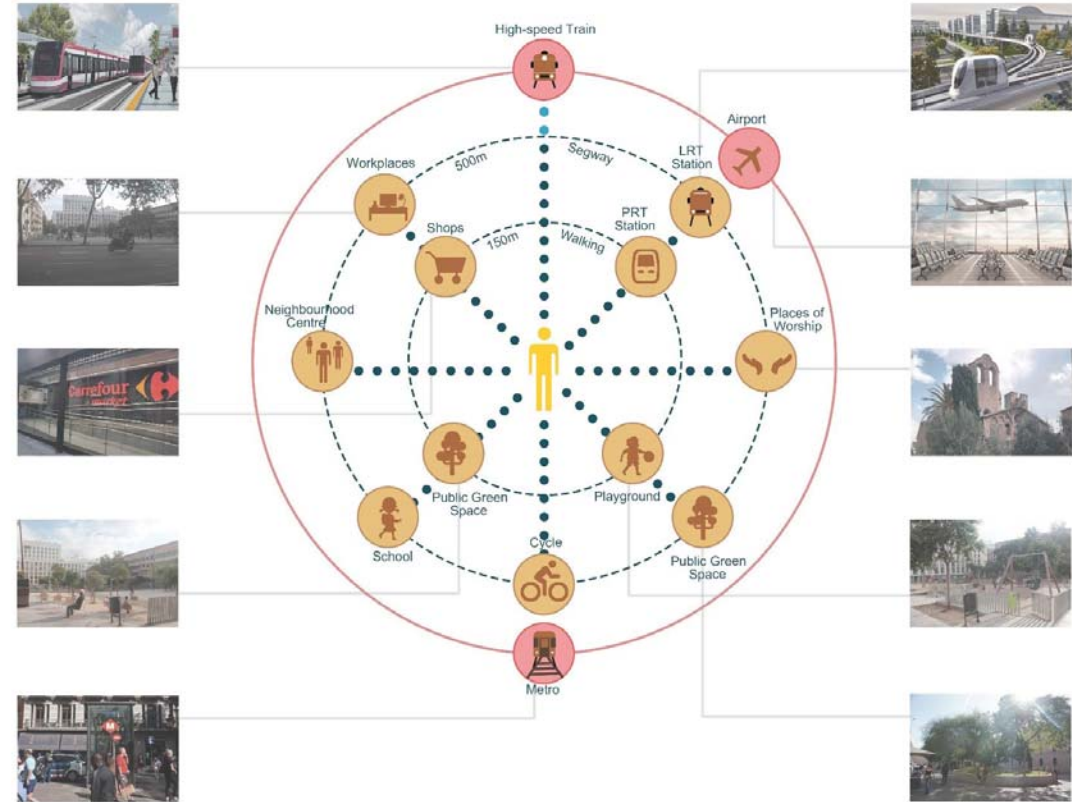
ners, urban designers, and architects to prioritise goals and allocate resources that promote the implementation of the smart urbanism in the old city. These indicators play an essential role in the assessment of the implementation of smart systems methods in the case study area based on various aspects such as innovation on urban performance, socio-economic and environmental cases, mobility, health care, education, ICT infrastructures, quality of life and energy. The case study area indicators should enhance an integrated advancement of these diverse elements in the evaluation of smart urban Heritage (Al-Saffar, 2018). Smart mobility is another essential aspect, which is a method that decreases congestion and fosters faster, greener and cheaper transportation choices. The majority of smart mobility systems utilise information gathered from a diversity of aspects about mobility patterns to assist the optimisation of traffic situations in a holistic method. Albino et al. (2015) point out that the dimension of smart mobility indicates the use of ICTs in contemporary transport to advance traffic in urban places (Albino et al., 2015). Bifulco et al., (2016) state that "smart mobility focuses both on sustainable and intermodal transport systems offering safe and secure conditions through the use of ICT, and on local, national, and international accessibility" (Bifulco et al., 2016). Smart mobility systems

as United Nations, (2016) mention contain mass transit systems as well as individual mobility systems that feature bicycle sharing, ride-sharing (or carpooling), vehicle sharing and, more recently, on-demand transportation. Smart transport systems integrate merge the whole array of multi-modal transport choices in cities, containing both individual mobility and mass transit, in an effective method. Modern smart transport systems usually include among other things a network of sensors, automatic vehicle registration plate readers, closed-circuit television systems, navigation facilities, passenger information panels, signalling systems and, most importantly, global positioning system-tracked public transportation, dynamic traffic lights, the capability of integrating live data from most of these sources. This might lead to developments in traffic congestion, environmental performance, accessibility, safety, network management, convenience and public perception. A modern smart transport system is currently operating in Poznan and Poland, for example. However, many challenges that emerged in implementing this plan contained a lack of skilled staff, cases related to interoperability and unexpected delays in the construction of hard infrastructure aspects (United Nations, 2016). The research team create a new smart system framework that seeks to implement clean, efficient and non-motorised transportation options in the old core that might reduce CO2 emissions. Creating a comfortable and efficient transportation scheme in El Raval is the first stage of formulating efficient and environmentally sound transportation systems. Walking and cycling are the keys to the Transportation Framework (fig.15). Most journeys begin and end with a walk, so no matter what form of transportation people ultimately will choose. This will demand to increase the width of sidewalks, adding the shade of trees and shading devices, and comprehensively designing the entire public realm. Encouraging people to walk or to cycle, providing suitable ways to access to the old city and reducing the need for a car will reduce the impact on the environment and minimise air pollution. A smart mobility system framework in the



Fig. 14 - El Raval Smart Urban Heritage Index Wheel
Source: Authors, 2019

Fig. 15 - El Raval Smart Mobility Framework
Source: Authors, 2019



old part of Barcelona will propose organised aspects of interventions to develop the quality of life and urban services through implementing ICT in the case study infrastructures systems. In another aspect, ICT will support and integrate different transport systems such as trams, personal rapid transit (PRT), and light rail transit (LRT), buses, trains, metros, cars, cycles and pedestrians to be safe and interconnected transportation systems. These new models of mobility that employ ICT will advance traffic in the urban context of El Raval district and offer reliable, efficient and secure conditions of transport.

7. CONCLUSION

This paper has endeavoured to understand the city structure and identity of Barcelona by exam-

ining the process of its urban transformation and urban development, and by analyzing its physical structures at different stages and periods. Moreover, the research has illustrated the architecture heritage styles in the physical urban context of the old city of Barcelona. It also has investigated the topics of smart cities, smart urbanism, internet of things (IoT) and information, communication technology (ICT). The initiative of smart cities tries to measure what is happening in the current time in a city in terms of urban information technology, quality of life and sustainability. Even though controlling the quality of life and sustainability depend on static historical statistics, it can be advanced

with the use of real-time data, allowing the better and more accurate design of social policies. Smart infrastructure systems have the potential to develop inclusive advancement in cities and especially in Barcelona by helping to generate data on informal settlements and informal sectors and other marginalized groups in society. Such data can then be used to design smart infrastructure systems that specifically address the needs of people. The essence of the debate in this research is the identification of the new principles and criteria of the smart cities concept such as the use of ICT, IoT and advance technology to fill a gap related to implementing these methods in a historic

environment. Thus, urban designers, policy-makers, architects and governments should consider devising regeneration solutions and endeavours dealing with historic cities, aiming to integrate traditional principles with contemporary needs and provide a new vision for rethinking the way cities are designed, built, and managed. Moreover, we should seek to find new methods of regeneration that might help to find the positive and negative aspects that can serve as a platform to resolve the conflicting values of traditional urban form and contemporary design models.

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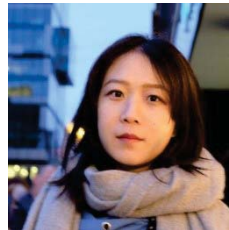
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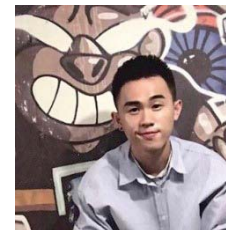
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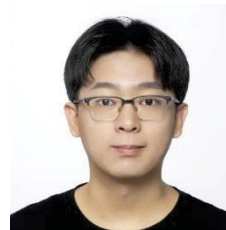
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