

# Barcelona Smart City: The Heaven on Earth (Internet of Things: Technological God)

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## Abstract

Cities are the most preferable dwelling places, having with better employment opportunities, educational hubs, medical services, recreational facilities, theme parks, and shopping malls etc. Cities are the driving forces for any national economy too. Unfortunately now a days, these cities are producing circa 70% of pollutants, even though they only occupy 2% of surface of the Earth. Public utility services cannot meet the demands of unexpected growth. The filthiness in cities causing decreasing of Quality of Life. In this light our research paper is giving more concentration on necessity of “Smart Cities”, which are the basis for civic centric services. This article is throwing light on Smart Cities and its important roles. The beauty of this manuscript is scribbling “Smart Cities” concepts in pictorially. Moreover this explains on “Barcelona Smart City” using Internet of Things Technologies”. It is a good example in urban paradigm shift. Bracelona is like the heaven on the earth with by providing Quality of Life to all urban citizens. The GOD is Interenet of Things.

## Keywords

smart cities; Barcelona City; Internet of Things; smart mobility; open access data

## 1 Introduction

Urbanisation is one of the most glaring realities of the 21st century. Cities are growing very fast owing to a large scale urbanisation across the world. Kingsley Davis (1962) explained: “Urbanisation is a process of switching from a spread out pattern of human settlements to one of concentration in urban centre” [1], [2]. In the last two decades, the world has experienced phenomenal levels of urbanization. In the near future, more than half of the world’s population will live in cities, and the number of cities with five to ten million inhabitants will continue to rise. About 60 cities will have more than five million people, including cities such as Mumbai, Karachi, Mexico, Lagos, Shanghai, and Beijing [3]. Apart from these, now a days in everybody’s mouth, the top most uttering global cities are Vienna, Toronto, Paris, New York, London, Tokyo, Berlin, Copenhagen, Hong Kong and last but not least is Barcelona. What is special about these 10 cities? Recently even the Indian Urban Minister Mr. Venkayya Naidu visited Barcelona to observe the city planning, design, architecture, and urban practises. So what is new

in this city? The business giants like CISCO, IBM, Schneider-Electric, HP, Microsoft etc. are always give talk on new urban models by exempling in the case of Barcelona city. Why they always insist chat on particular Barcelona city only? The reason is Barcelona is a Smart City. Let us see Barcelona.

Barcelona was founded by Romans, way back dated on circa 2000 years to its origins as an Iberian village named “Barcelo.” With more than 2,000 years of history and a singular identity, Barcelona has always been characterised by its spirit of innovation, enterprise and nonconformity. Cerda, the city council, the Spanish government, civil engineers, architects, and land owners-to strengthen their role in the implementation process and gain control over shaping Barcelona [4]. Thanks to Barcelona to the bold to the adventurous spirit of her architectures, builders and the liberal farsightedness of her planners, is developing into one of the greatest wonder cities of twentieth century [5]. Barcelona, the capital of the autonomous community of Catalonia province in Spain, is now called “Barcelona Smart City.” This is the world’s first and full pledged converted Brown Field City into Smart or Green Field. In fact this is the Spain’s second most populated (around 1.6 million) city. At the same time it is also standing the sixth most populous city in the European Union behind Paris, London, Madrid, Ruhr, and Milan. Barcelona city is well known for its rich cultural heritage. Hands up to the 1992 Summer Olympics, a lot of efforts went into modernizing city while keeping its ancient

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charm. This was considered as one of the best modern Olympic games history. It is predominantly renowned for the architectural works of Antoni Gaudí and Lluís Domènech i Montaner. Barcelona is one of the world’s leading economic, commerce, tourist, education, entertainment, media, fashion and Quality of Life centres. Barcelona has a Mediterranean climate. The city has the smallest amount of Green House Gases (GHG) releasing in a newly study documenting how differences in climate, population density and other factors affect GHG emissions in global cities [6]. It is a city of culture, knowledge, business, creativity and wellbeing, pioneering global centre, because it wants to become a role model for Smart Cities.

**2 Concepts on Smart Cities**

Let us define what does mean by “Smart Cities”: Smart Cities are the cities in which they provide Quality of Life to the urban citizens along with economic development, ecologically balance and sustainable for the future generations using complete automated Internet of Things (IoT) technologies. These technologies are generally marry with city sub systems of transportation, security, governance, public utilities like water, waste, gas, power management and other physical infrastructure to bring the operational efficiency. The technologies include Smart Cards, RFID, Quick Response Codes, Electronic Product Code, IPv6, Sensors, Actuators, Wi-Fi, Bluetooth, Zig-Bee, Near Field Communication, Geographical Information System, GPS, Social Media, Business Intelligence, Ambience Intelligence, Cloud Computing, Tele Medicine, Web 3.0, Big Data Analytics etc.

Giffinger, et.al.(2007), defined that “A Smart City is a city well performing built on the ‘smart’ combination of endowments and activities of self-decisive, independent, aware citizens.” This definition is the milestone in the history of Smart Cities, even though there was academic work and importance given to Smart Cities by Laterasse and Gibson et al.,(1992). Smart Cities are engines for the growth of any national economy. These are cities in which, they think for urban citizens, they do the things on behalf of them; monitor and they control the deviations too. These cities deliver the right solutions for urban dwellers at the right time, at the right place and with right mode 24/7. In the future, these cities are going to talk with people, things and even other cities without any global partiality. These are the cities which functions in 365 days without rest in order to provide Quality of Life (QoL) using Internet of Things (IoT) technologies. In order to provide better life for urban citizens, a huge number of Internet of Things technologies have to be deployed in health, education, transportation, governance, security and utility services. Smart management has to be done in public utilities like electricity, water, gas and waste. Besides technological deployment, other key performance indicators (KPIs) are governance (Central, State, Local), land, environment concerns are required. However,

in these cities, first infrastructure will takes place and then people will start to live in, because cities constitute right from scratch. One set of people say that Smart Cities are very Specific, Measurable, Accountable, Relevant, Timely. Some other people say that Smart Cities are abreacted as Sustainable Management Action Resource Tools for Cities. Let we have some explanation about these in **Table 1**.

▼ **Table 1. Smart Cities**

	Explanation 1	Explanation 2
S	<p><b>Specific:</b> All the city functions including mobility, security, governance, public utilities like waste, power, gas should be clearly specify in the software and network. The pre-defined functions, sensors, actuators etc. help to bring right output.</p>	<p><b>Sustainable:</b> These are the cities, generally designed and developed in view of ecologically balanced. Uses renewable energy resources like solar, wind, biofuel, tidal in order to bring carbon free environment and prevent global warming.</p>
M	<p><b>Measurable:</b> These are the cities, in which we can see even consumer power meter at central station. The Smart Grid is one of best bidirectional technology. In this, suppliers also directly find out power leakages, power theft at central level.</p>	<p><b>Management:</b> City with subsystems of smart people, IoT, smart objects (devices) will have unique identities, automation, monitoring and control power. Right things will be done by the right object at the right place at the right time.</p>
A	<p><b>Accountable:</b> The public data will be open. Governance is transparent. Hence corruption by the government will be drastically reduced. These are the cities, in which all the operation of transportation, governance, infrastructure, public utility services should be accountable for the citizens.</p>	<p><b>Action:</b> City Command Control Centers (C4), sitting in the city data centers, will takes action. With the help of smart devices, fully connected City Area Network (CAN), the citizen issues can be solved. There will be solo or inter operable operating systems at each Smart City level.</p>
R	<p><b>Relevant:</b> Because of huge amount of data is generating in zeta bytes by people, devices, objects, with the help of best computing devices and Big Data Analytics, will send relevant data to the concerned object with security mechanisms.</p>	<p><b>Resource:</b> Social: Planners, developers, skilled workers, educators Physical: Roads, buses, railways, rivers, dams, ports Environment: Waste, water, gas, electricity, forest Technological: Hardware, software, networking, IoT, BDA.</p>
T	<p><b>Timely:</b> All citizen services should be in 24x7 in 365 days. On-time transportation facilities for all the city commuters. On-line spot payment systems of telephone, land, tax bills. Automated real time incidents, events, smart health devices. Instantly issuing of date of Birth, Death, other certificates. Real time citizen security using Closed Circuit TV (CCTV) or Internet Protocol (IP) surveillance systems.</p>	<p><b>Tools:</b> Along with hardware, software, networking components and smart devices, the technological God Internet of Things will also plays a vital role in order to get better city operational efficiency. The tools may be sensors, actuators, Wi-Fi, GIS, GPRS, analytics, cloud computing, data centers, web 3.0, Near Field Communication, Radio Frequency Identification, Quick Response codes, robotics.</p>

**3 Literature on Smart Cities**

The authors’ bird eye view of “Smart City” phenomenon is

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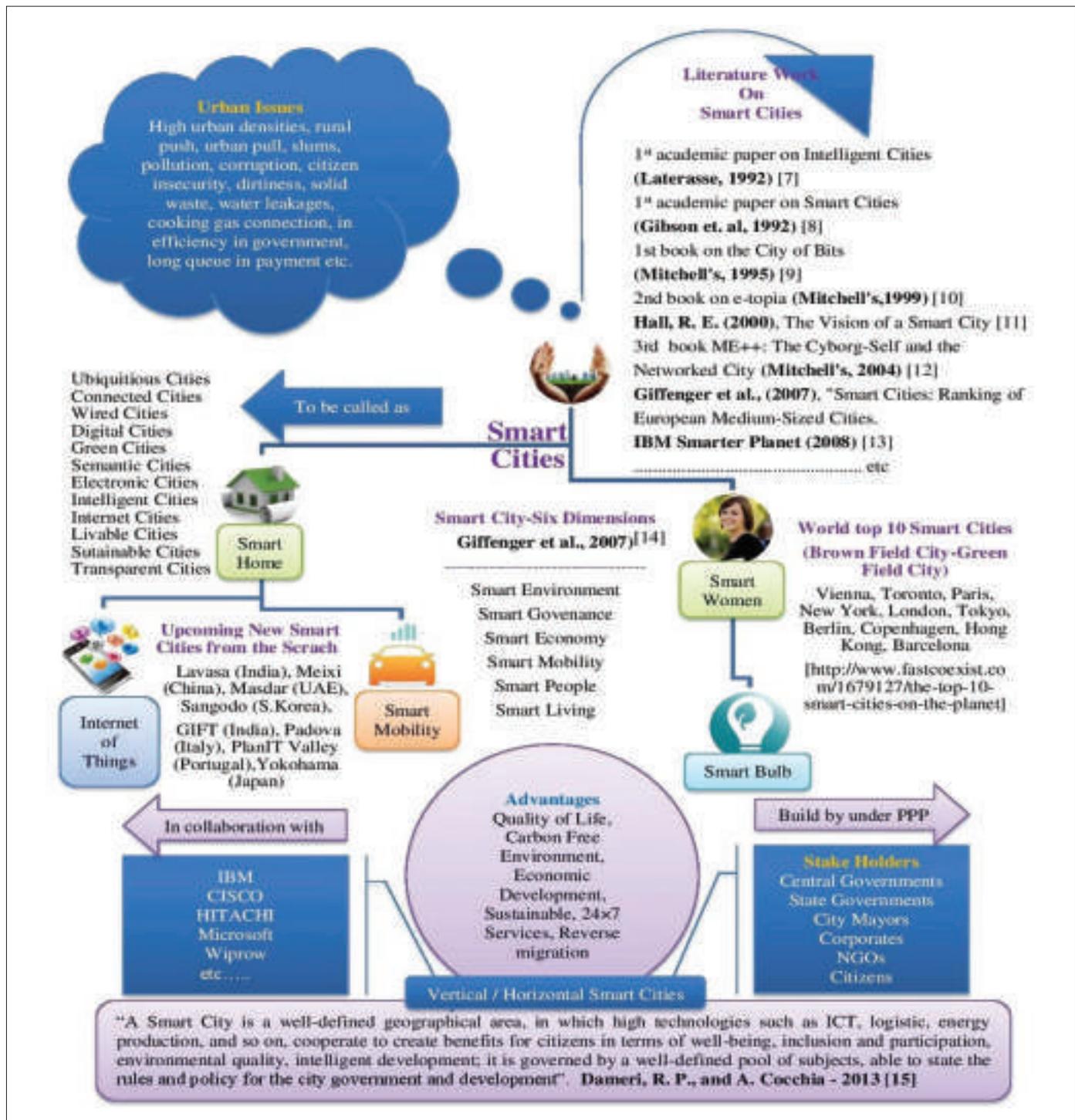
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shown in Fig. 1.

4 Methodology

The methodology is critical for any kind of research, analysis, report writing, and publication. In recent years methodolo-

gy has been increasingly used as a pretentious substitute for method in social, scientific and technical contexts. Research methodology is a systematic way of solving a problem. It is a science of studying how research is to be carried out. Essentially, it is the procedures by which researchers go about their work of describing, explaining and predicting new phenomena.



▲ Figure 1. Author's bird eye view of "Smart City" phenomenon.

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It aims to give the work plan, design and action of research. The beauty of this research is a modern way of data collection using Future Internet (FI) media. The use of Future Internet to aid research practice has become more popular in recent years. In fact, some believe that Internet surveying and electronic data collection may revolutionize many disciplines by allowing for easier data collection, larger samples, and therefore more representative data [16], [17]. The research has been carried out through exploratory study.

#### **4.1 Data Collection**

The time taken for data collection is nearly two years. The data collected in a modern methodical way is mainly searched from Google with the key words “city”, “smart city”, “Barcelona City”, and “Barcelona Smart City”. The searching was done with the extension format of words (doc, docx, pdf, ppt, pptx). The biggest online database “Google” and “Google Scholar” is the base for lettering this conceptual article Barcelona Smart City. “Knimbus” Indian based online database stands for Knowledge Cloud and is a dedicated knowledge discovery and collaborative space for researchers and scholars. It is also used in searching articles on smart cities. Around 20 YouTube videos are also used for data about some of Smart Cities and Barcelona City. Lots of technical conferences, such as SecureIT-2012 and Smart City: Delivery of Civic Services-2015, workshops, such as IT Innovations for Smart City-2015 and Smart City: India-2015, and symposiums, such as Smart Cities Summit-2014 and TENSYP 2015: Internet of Things, which are conducted during August 2012-May 2015 to now in India and abroad, have helped us a lot to gather knowledge and share via technical discussions.

#### **4.2 Samples**

Since this is an exploratory study, there is no specific sample size. Exploratory research is defined as the initial research into a hypothetical or theoretical idea. Barcelona is a new concept; this phenomenon is trying to prove by several methods of data collection. This data is in different formats including Barcelona city videos, write up articles, city pictures and audios. The authors went for the some samples of corporate top level management video talks and not in traditional in-depth interviews. These are some of interview samples given about Barcelona Cities in different context which talks more in civic services of city:

- 1) Wim Elfrink, EVP & Chief Globalization Officer (CISCO);
- 2) Anil Menon, President Smart + Connected Communities (CISCO);
- 3) Manel Sanroma, CIO, Barcelona City Council;
- 4) Judith Romera, In City Promotion Director, Barcelona City Council;
- 5) Toni Vives, Deputy Mayor for Urban Habitat, Barcelona City Council;
- 6) Mariano Lamarca, Project Leader Smart Cities & Corpora-

tive, Wireless Projects, Barcelona City Council.

#### **4.3 Narration**

This is a qualitative case study and is an approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources. This ensures that the issue is not explored through one lens but rather a number of lenses that allow for multiple facets of the phenomenon to be revealed and understood [18]. We can go ahead with data analysis using ATLAS.ti or N-Vivo software because data is in qualitative format. However, the analysis of data went thematically after 360 degree level of online data observations. The narration went on some particular writers’ and research authors scribbling and speeches. The main themes of description about Barcelona Smart City in this paper includes city open Wi-Fi, Smart Mobility using e-vehicles, Smart Water Management System, Smart Lighting System and last but not least Open Access Data. Apart from these, some dimensions are left without any narration, because of page limit.

### **5 Barcelona Smart City**

The European Commission awarded the European Capital of Innovation (“iCapital”) prize to Barcelona (Spain) “for introducing the use of new technologies to bring the city closer to citizens” [19]. In 2008, Barcelona faced challenges as the economy crashed. There were some city mayors, architects, planners, and designers who decided that they wanted to mount city at the global level, which can sustain on par with global cities even in economy crises. They started Internet of Things (IoT) deployment in each and every city dimension for the operational efficiency. The technological advancement also made city planners deploy IoT technologies for better civic services. The Smart City project included Open Data initiatives, offering valuable information to urban citizens and corporate people. The city is providing sustainable growth via resourcefulness on smart lighting, smart mobility and residual energy as well as social innovation. The city is also delivering ‘smart services’ in a flexible, continuous and smart way through Internet of Things in different parts of Barcelona. As the title of the article “Barcelona Smart City: The Heaven on Earth” implies, the Quality of Life in this city is very high. Here, people are economically rich and with the help of technological GOD (Internet of Things), all the citizen services are providing in round the clock in every corner of the city through City Wi-Fi network. The city is also promoting alliances between research centers, universities, private and public partners through work. Barcelona is a stylish city in Spain with one of the highest densities in Europe. Barcelona is to walk through mile after mile of narrow streets embraced by beautiful old buildings, fronted by small shops. But to hang out in Barcelona is also to taste a form of urban livability almost unknown in North America. People can sit for long hours in some of the best cafes and bars in

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Europe, eating some of the best food in the world, and surrounded by a city designed to make the street a second living room [20]. Barcelona is one of the best economic, social and environmentally sustainable cities in the world. **Fig. 2** shows that the Smart City initiatives consisting of Wi-Fi, Open Access Data, Smart Mobility, Smart Water Management System, Smart Lighting System, Smart Waste Management System and Smart Allotment. These technologies are described in detail in the next sections in sequence and demonstrating how they are bringing Quality of Life to citizen.

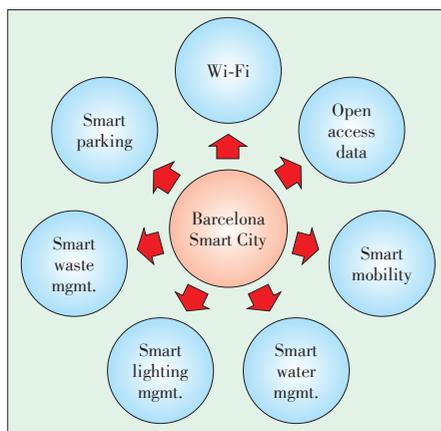
**6 Internet of Things**

**6.1 Wi-Fi**

Barcelona City Council aims to encourage citizens to access the internet and make it easier for citizens to incorporate this technology into their everyday lives. Mozilla Firefox, Microsoft Internet Explorer, and Google Chrome any browser can be used to access the internet through citizens’ laptop, Smart-phone, or computer. Wi-Fi service provided by Barcelona City Council enables citizens to connect to the Internet through Wi-Fi access points, in hotspots located several municipal amenities and various public access places. These places include centers for the elderly, civic centres, cultural centres and museums, sports centres, local authority and citizen advice offices, libraries, municipal markets, residential block interiors and enclosed parks with established opening times, night - time study rooms and neighbourhood centres. The government deployed its telecommunications network in 2007-12 with a wireless extension to reach any point of the public space. This network aims to provide services to the citizens and corporate workers. This network can be used as a backbone of a sensor and actuator network. This allows a better control of the city and the possibility to build applications [21]. Cisco is backbone network for City Access Network.

**6.2 Open Access Data**

This facility is free for smart phones including Android and



**◀ Figure 2.** Barcelona Smart City dimensions.

iPhones. This allows all urban people to communicate with municipal mayors, concerned representatives and give their opinions, assess municipal rules, regulations and policies. This crowd sourcing became involved in the different participatory processes established in the city through on-line, on any topic that affects it. It could be bad situation about road, damage of street light, water leakage in particular place, accident, and in convenient law to citizens and so on. The app is designed to be very easy to use with rich GUI interface. The Open Data services collect all the public information from Barcelona’s City Hall systems in Windows Azure SQL Database. The data includes street maps, details about public facilities, population, contractor profiles, city calendars, economy, businesses, travel and election results [22]. The huge amount of data gathered from different departments will be analyzed using Big Data Analytics software.

**6.3 Smart Mobility (e-vehicles)**

Barcelona people really enjoy pleasant journeys with travel choices. In the trains, buses, city Wi-Fi connectivity is fully accessed. The city bus stops (**Fig. 3**) mounted with electronic displays or kiosks, give information automatically to passengers about buses arrival and departure timing. The touch screen facilities and Graphical User Interface facilities are really easy to operate. Manuel Sanroma, the Chief Information Officer (CIO), Barcelona City Council says that Smart bus stops change the typical experience of wasting passenger’s time waiting for a bus. Payment of parking for cars, bikes on public places and road sides, will drastically bringing down the use of cars. This will indirectly reduce traffic jams in the city. Parking spaces are equipped with sensors and GIS integration leading to the commuter’s easy way to park in free spaces with the help of Smart Mobile, PDAs. Bicycle, the last mile connectivity links different means of transportation stations and places. These bicycles will be available at all stations with annual usage payment. To date Barcelona [23], city has circa 500 hybrid taxis, 294 public electric vehicles, 130 electric motorbikes, an estimated 400 private electric vehicles on its streets, 262 re-charging points. This leading public loveble journeys.

**6.4 Smart Water Management System**

The efficient consumption of water in cities is a basic ele-



**▲ Figure 3.** Smart bus stop.

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ment in sustainability programmers nowadays. The Smart Water Management System has become a key policy issue for the 21st century, as a growing number of factors are impacting the delivery of already scarce fresh water. Economic growth, seasonal climatic conditions and rising population are all mainly affecting availability of water resources. Moreover, a number of effects linked to climate change, such as lengthy droughts and extreme weather events, are worsening the situation [24]. In this light, Barcelona Smart City project is doing well for the city's green spaces and theme parks with smart water management techniques. The Smart Water Management system will optimize water consumption because it will irrigate with the proper amount of water according to weather conditions and plant needs. The four principles (4Rs: Reduce, Recycle, Reuse, Restore) are best practices of municipality for better water consumption. The Graphical User Interface (GUI) is user friendly. Sensors gather information about humidity, salinity, temperature, wind and several other factors that automatically regulate the amount of water by means of a program that can be managed with tubes, computers, smartphones, tablets and actuators. So far, nearly 77 fountains have been mounted in the entire city. District heating and cooling is one more kind of water technology in which two networks provide hot water in 64 buildings spanning an area of 21 km. Water theft and leakages can be tracked automatically. The Barcelona Smart City Deputy Mayor Antoni Vives, indicated that Barcelona is saving \$58 million annually using Smart Water technology and stated that this new Smart Irrigation System in the city, will enable up to 25% saving of the water. So Smart Water Management System is efficient way to use the water in our daily life.

**6.5 Smart Lighting System**

In the name of Smart Lighting System project, Barcelona developed a master plan in 2012. This project includes (1) remote control street level lighting, (2) transitioning 50 streets, and (3) connecting 1155 lamp posts to LED technology. From Smart Grid to self-sufficient blocks, Barcelona has developed a programme to achieve greater energy efficiency. We know that Smart Grid is a combination of information and communication applications that link generation, transmission, distribution, and customer end-use technologies. Internet of Things [25] has been boosted by Cisco in Barcelona, especially into more Smart Grid technologies. The city has deployed over 19,500 smart metres in the Olympic Villa. They are now extending the same project in city in conversion from Barcelona Brown Field City into Smart City. With Smart Grid technology, the city's entire power generation, transmission, distribution and consumption happens in efficient way. The power leakages will be detected and power theft be controlled. With its low power consumption LEDs, the Barcelona city night is shown in **Fig. 4**.

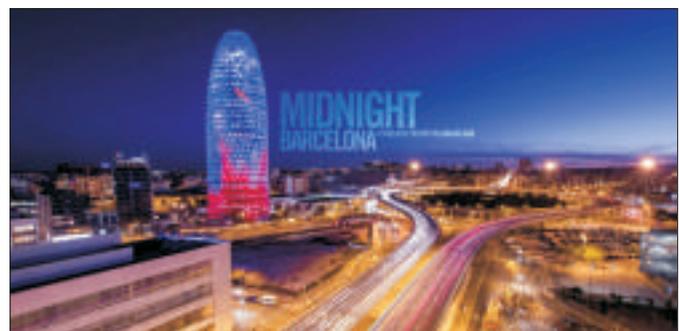
**6.6 Smart Waste Management System**

Barcelona's Smart City project's Waste Management Sys-

tems is now a reality. Garbage vessels transmit signals to indicate they are over 80% full and should be emptied. Using Smart Mobile applications communication network, the signals are sent to a web-based software application used by the private MOBA's Smart Waste Management System. Sensor Technology 4.0., deliver a differentiated image of reality, and can transmit this image in real time via the web or internet. The garbage is collected separately in solid and liquid sorts with very high speed from homes and offices. In the software, the capacity of the container is visualized in a traffic light system, which is taken as the basis for planning the best route for waste collection-garbage trucks travel only to those containers that actually need to be emptied. Smart ultrasonic technology is combined with GSM communication technologies. Waste is recycled systematically and efficiently without environmental harm. Smart Waste Management involves [26] (1) regular reporting of measured fill levels and sensor data via mobile communication network, (2) robust ultrasonic sensor detects fill level regardless of the kind of waste, (3) fill level measurements as a basis for optimized routes for waste collection, and (4) reducing gas emissions and noise levels. These kinds of new waste management solutions even prevent the bad smells in residential.

**6.7 Smart Parking System**

Barcelona Smart City includes around 500 parking wireless Fastprk sensors within Gran Via de Carles III, Av. Sarrià and Travessera de les Corts, at Les Corts District. This smart project uses Sigfox telecoms technology. It aims to reduce congestion in the area and to improve the drivers' experience while reducing CO<sub>2</sub> emissions. World sensing revolutionises traffic management and the industrial world through solutions based on wireless sensed networks allowing traffic detection and data capture in real time. The Smart Parking System based on electromagnetic sensors installed in each parking bay that senses the occupancy of each space, sending the information to a Central Management Unit (CMU). To deliver this information, Fastprk sensors are connected to the IoT network owned by Cellnex Telecom. This information is available in real time and is displayed through different panels in Pl. Neruda, Pl Hispanitat and Pl. Gaudí. Drivers will also be able to check this



▲ **Figure 4. Smart lighting.**

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data through a mobile phone apps, through a Web Application and on the website portal [www.zonabus.cat](http://www.zonabus.cat) [27]. Smart parking payment drastically reducing unnecessary travellings.

## 7 Conclusions

For more than 2000 years, Barcelona has its own culture, customs, architecture, entertainment, business opportunities, and education facilities. Barcelona has its own vision and mission in which its architects, municipality representatives' and city dwellers jointly plan, design, invest in continuously for the development of city and for its citizen's services. In recent years, progress with Internet of Things technologies deployment in water, waste, gas and power kind of public utility services, made it number one Smart City in the world. Barcelona City Council encourages the use of mobile to access city services. The city has been pro-environment since the 1980s, and today it is a mature city concerned with environmental issues like waste, recycling, saving water and energy, and energy recovery. The striving for self-sufficient, with productive neighborhoods, living at a human speed and producing zero emissions motto and neighborhood has ensured quality of life to all citizens. Hence this city is a productive, open, inclusive and innovative city. This is the living city with enterprising people and healthy organized communities. Now it is the need of hour to construct such beautiful 100 more Barcelona Smart Cities, which are nothing but like Heavens on the Earth. With the help of technological God, IoT, anybody can reap all the civic services at any time, from any part of city, through any network via any device in these Heavens for Quality of Life.

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## Biographies

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**Ramaswamy Ramachandran** (ramaswamy2008@gmail.com) is a professor of National Institute of Industrial Engineering (NITIE), Mumbai with more than 30 years. He is expertise in the subject areas of Management Information System, Data Communications, Computer Networks, programming in C++, programming methodology, software engineering, IT strategy & Knowledge Management, Internet of Things and Smart Cities to name a few. He has vast experience in teaching, research and administrative work. He has made good corporate consultancy and written research papers, publications, and presentations in both national and international conferences. He bagged many prizes and awards during his rich academic periods including Best Professor too. He also trains the corporate people, public sector employees in Management Development Programmes (MDP) and Unit based Programmes (UBP).