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The Smart City Concept in the 21st Century

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Abstract

The quality of life was significantly improved in the last century mainly as regards the access to services. However, the heavy industrialization and the increasing population in the urban areas has been a big challenge for administrators, architects and urban planners. This paper provides a brief presentation of the evolution of the "smart city" term and the most representative characteristics of it. Furthermore, various alternative terms that were proposed to describe the multiple characteristics of the future cities are analyzed. A connection between smart city and smart grid is also presented.

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1. Introduction

The urban development has resulted in a change of paradigm in the 21st century, and the research activities for smarter cities became priority task with direct participation from industrial and political entities, practitioners, and the scientific community. Although the information technology and communication has advanced exponentially, and the smart cities become real, this concept is still under development.

The United Nations estimates that between 2015 and 2050 the world population will increase by 32%, i.e. from 7.2 to 9.7 billion inhabitants, while the urban population will increase by 63%, from 3.9 to 6.3 billion inhabitants. The current estimations suggest that until 2030, over 60% of the world population will live in cities, and the significant growth will be in Africa, Asia and Latin America [1][2].

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The need for urbanization is due on one hand to the migration of population from rural areas to cities – in hope for a better life (for jobs, education, medical care, access to culture, etc.), and on the other hand to the migration from poor countries or under social and military conflicts toward the industrialized countries. Under these conditions, in 2050, India will reach 1.7 billion inhabitants, with its mega-cities Mumbai (42 millions) and New Delhi (36 millions), China will be steady at ~1.34 billion inhabitants, with the city of Shanghai (21 millions), while Nigeria and Indonesia will reach up to 399 million and 321 million inhabitants, respectively [1].

As our planet becomes more "urban", the cities have to become smarter. The extended urbanization requires new methods and ways, innovative, to administrate the complexity of the urban life: overpopulation, energy consumption, resources management and environment protection, etc.

The first mega-cities in the world (with over 10 million inhabitants in 1970) were New York and Tokyo; these cities owned necessary infrastructure and resources to ensure the needs of their citizens. However, most of the new mega-cities are located in developing countries, having a large number of poor people and limited resources, infrastructures or systems that cannot satisfy the increasing demand. These mega-cities, wide in surface, are not capable of appropriately develop to meet the rate of increase of the number of inhabitants, are chaotic and dangerous, having limited health and education services. Under these conditions, the competition for food, water and energy resources will rapidly increase. The number of mega-cities in 2014 was 28, three times bigger than in 1990, and for 2030 the estimation is for 41. Of the 28 mega-cities, 16 are located in Asia, 4 in Latin America, 3 in Africa and Europe each, and 2 in SUA, respectively [2].

While in 2015, the urban population in the European Union was 72% of the total population, it is estimated that in 2050 this percentage will increase to 80%. In Romania, for instance, where urbanization degree is only 55%, the municipalities are looking for solutions to develop the business environment and ensure the best living conditions for their citizens.

Although the cities occupy only 2% of the planet's surface, they accommodate about 50% of the world population, consumes 75% of the total generated energy, and are responsible for 80% of the greenhouse effect [3]. This is the reason why the urban development and its associated problems have been intensively discussed in the last years at many international and national conferences. Some of the most important events are *Shanghai World Expo* (2010), *Ecocity World Summit Montreal* (August 2011), *Smart City Expo World Congress in Barcelona* (November 2011), *International Conference on Smart Grids for Smart Cities/ Smart City 360 Summit 2015 in Toronto* (October 2015), *World Smart City Forum in Singapore* (July 2016), *IEEE International Forum on Smart Grids for Smart City at Paris* (October 2016). As a conclusion, the preoccupation for smart development of cities is a hope for reducing poverty, inequality and unemployment, and also for efficient management of energy resources.

2. Evolution of the smart city concept

The preoccupation for sustainable development of the urban settlements has been a major preoccupation since ancient times for both architects and administrators. In the book "Garden Cities of To-morrow" published in 1898 by the British urban planner Ebenezer Howard, the *urbanism* is treated as a distinct category, which is the way of transforming the slums into neighborhoods capable of providing opportunities and comfort. The Frenchman Eugène Hénard, who was one of the first urban planners who influenced the development of the future European cities, said in his speech at his Royal Institute of British Architects: "My purpose is to inquire into the influence which the progress of modern science and industry may exercise upon the planning, and particularly upon the aspect, of the Cities of the Future. The Cities of Tomorrow will be more readily susceptible to transformation and adornment than the Cities of Yesterday" [4].

The aspects that characterize the cities of the future have been adopted over the years. In the interwar period, the modernist planners and architects have launched ideas with the intention of alleviating the mistakes generated by the industry strategy and transform the cities into green ones. Among them we mention Le Corbusier in the work "The City of Tomorrow and its planning" (1929) [5] and Gottlieb Eliel Saarinen in the book "The City: its growth, its decay, its future" (1943), both having a long lasting influence on the architecture of cities from Europe and Northern America. Subsequently, the French urbanist Raymond Lopez has revised the meaning of the urbanism term in the book "L'avenir des villes" stating that the urbanism is "indispensable instrument for life and the vitality of men",

while the Spanish architect Miguel Fisac proposed in his work "La Molecula Urban" the replacement of the current model of cities with "friendly/agreeable cities".

The lexicon that describes the characteristics of the cities of the future was significantly improved in the last decades to better explain the large number of concepts promoted by stakeholders and interest groups. The popularity of the various specific terms has changed in time, depending on the ideas promoted by universities, the business environment, political entities and civil community.

Specialists from various domains suggested definitions for smart city, such as:

- A „smart city" uses information and communications technology (ICT) to enhance its livability, workability and sustainability [*Smart Cities Council 2014*];
- A city that monitors and integrates conditions of all of its critical infrastructures – including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings – can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens [*US Office Technical and Scientific Information*];
- A smart city can be seen as a determined geographical space able to manage resources (natural, human, equipment, buildings and infrastructure), as well as wastes generated by life style; it should be sustainable and must not be harmful to the environment. [6].

Table 1 presents a part of the terminology used over time in general by the actors involved in specific fields related to the „future cities" [7].

Table 1 „Future cities" – conceptions of success [7]

Domain	Social	Economic	Governing
Garden cities	Participative cities	Entrepreneurial cities	Managed cities
Sustainable cities	Walkable cities	Competitive cities	Intelligent cities
Eco-cities	Integrated cities	Productive cities	Productive cities
Green cities	Inclusive cities	Innovative cities	Efficient cities
Compact cities	Just cities	Business-friendly cities	Well-run, well-led cities
Smart cities	Open cities	Global cities	Smart cities
Resilient cities	Livable cities	Resilient cities	Future cities

Table 2 presents the geographic trends in future city term usage.

- **„Sustainable city"** become after 1950 the most popular term related to the future urban development, a strong influence coming from the United Nations Brundtland Commission report (1987) in the field of sustainable development. In become the most commonly-referred-to term in English, especially in U.K., Canada, Australia, USA, and India, probably given the strategies for taking emergency decisions to limit the climate changes.
- **„Digital cities"** became the second most popular term used in disclosures in late 90s, as it suggests a strong connection with the exponentially growing information and telecommunication technology and the large amount of information. The European Commission founded program called „European Digital Cities" (1996-1999) was one of the first actions that inspired for publication of several books. The project promoted the idea of digitalization to support the complex environments of a city by means of informatic platforms and digital networks, aiming to provide services to local community and ensure active participation of citizens to city decisions [8].
- However, since 2009, the interest for the term "digital cities" was significantly reduced, as it was gradually replaced by the new term "**smart cities**". This term incorporates elements of sustainability and social inclusion, at the same time being suited to the evolutions of the new internet technologies [9]. Some observers indicate that the term "smartness" is more neutral from the political point of view than the term "sustainability". Therefore, various combinations of the term "smart" ("smart city", "smart growth", "smart development") were more easy accepted in countries were a large part of the public opinion associates the terms "sustainability" and "greenness" with strongly liberal or progressive policies [7][10].

- The term „**eco-cities**", on the other hand, proposed by the Urban Ecology – a group founded by Richard Register in California, become more popular in the mid-90s. It promotes the idea of eliminating all carbon waste, producing energy through clean resources, and developing the city in balance with the nature. Eco-city earned more notoriety since 2011 when the smart city concept started to gain an exponential interest. The cities are in competition to ensure high-quality life conditions to their citizens, while „Eco-city" projects have been proposed from the sustainable innovation point of view, among which Abu Dhabi and cities from China [8].

Table 2. Geographic trends in future city term usage [7]

Term	Trend	Regional popularity	Popularity in countries	Popularity in cities
Future cities	Stable	Global	India, USA, Canada, Australia, UK, Mexico, Brazil	Minneapolis, Singapore, Mumbai, New Delhi, Phoenix, London, San Francisco, Pune
Eco City	Stable	Asia	Philippine, Singapore, Malaysia, India	Chandigarh, Tianjin
Smart cities	Fluctuating interest	Europe, Northern America	Italy, Spain, Belgium, UK	Barcelona, Bologna, Torino, Roma
Intelligent cities	Stable	Northern America	USA, UK	London
Sustainable cities	Stable	Commonwealth	Australia, UK, Canada, USA, India	Vancouver, Singapore, Washington, Auckland, Portland, Dubai, London, Austin
Compact cities	Stable	Mixed	Australia, UK, USA	Salt Lake City, New York City
Liveable cities	Rarely used	Commonwealth	Australia, UK, Canada, Singapore	New York City, Singapore, Melbourne, Pittsburgh, Vancouver
Digital cities	Stable, after a decreasing interest	Mixed	USA, Ireland, Philippine, UK	Kansas City, Oklahoma City, Dublin, Minneapolis
Innovative cities	Stable	Mixed	USA, UK, India	Bangalore
Green cities	Stable	Northern America	USA, Australia, Canada	New York City

The study elaborated by *Catapult Future Cities* [7] presents the city in two general forms, that is "future cities" and "future of cities", which are used by academia, as well as by practitioners and politicians:

- *i*) **Future of cities**: term adopted in order to suggest the way of ensuring the needs of cities in the future taking into consideration their role in the future and the pressures and threats that they will have to face so that to help the citizens to successfully adapt to any condition.
- *ii*) **Future cities**: reflects the vision/goals of people regarding the characteristics of the cities (how they will function, what systems they will rely on and how they will interact with the citizens, the authorities, the business environment, the investors and with the environment in which they will live).

By combining these two terms, a third most used term will result, after „sustainable cities" and „smart cities". It is important to note that the term "future cities", which is less used to define the technological dimension, has replaced the expression „future of cities" starting with 2009. This ascension of the term „future cities" is linked to the trend of separation of the urban domains into new disciplines – engineering, civil constructions, energy, IT and ecology. On the other hand, the expression „future of cities" is connected to the traditional thinking, planning and policy. This term is widely used in United Kingdom, North America, Southern Asia and in Latin America. At the city level, there is an interest for the term "future cities" in the large cities from west and east, including Singapore, Mumbai, London and San Francisco.

In Japan, taking into consideration the demographic future of the cities (the average age of the population will reach a very high record), more is accepted the concept of compact city and comfortable with high population density.

According to Google Trends, the term „Eco City" had a wider acceptance in South Asia, Australia, West Europe and Northern America, while „Smart City" has been extensively accepted in Europe and Northern America. The terms „Green City" and „Compact City" are relevant in companies from Northern America and Australia, while in India terms like „Sustainable City" and „Innovative City" are widely used. At London, the term „Intelligent City" (a synonym with Smart City) is more frequently used, while in New York a visible interest is shown for the terms „Compact City", „Liveable City" and „Green City". Additionally, Table 2 specifies the frequency of use of the terms in various countries [7].

However, irrespective of the name, the cities of the future must adapt in order to mitigate the effects of / to contribute to: climate change; population growth; globalization of economy, demographic, risks and ecological dependencies; technology development; geo-political changes; human mobility (including migrations); population aging; social conflicts and inequality; insecurity (as regards energy, food, water); changes in the governmental and institutional sectors.

3. Characteristics of the smart cities

The intelligence of a city is given by the set of physical and legislation infrastructures that support the economic development, ensure social inclusion and allow environment protection. Figure 1 illustrates the main characteristics of a city and its tools, available for both the municipality and citizens, that can transform a city into a smart one.

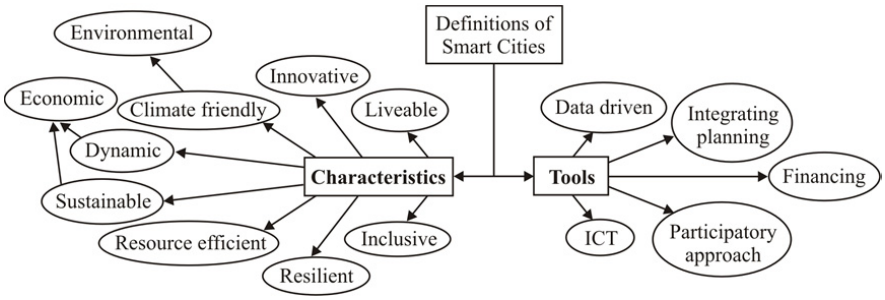

Fig. 1. Characteristics and tools used to define the Smart City [12].

The ISO Standard 37120/2014, titled *Sustainable development of communities*, defines 17 key indicators for evaluation of performances of cities from the point of view of ensuring urban services and quality of life, that is: economy, education, energy, environment, finance, fire and emergency response, governance, health, recreation, safety, shelter, solid waste, telecommunications and innovation, transportation, urban planning, wastewater, water and sanitation. These indicators, that can include several sub-indicators, are reference for city managers, politicians, researchers, business leaders, planners, designers and other professionals to focus on key issues, and put in place policies for more livable, tolerant, sustainable, resilient, economically attractive and prosperous cities.

Table 3 presents the directions of development of a city and provide examples of various applications by means of which the main objectives of a smart city can be achieved. The directions of development refer to infrastructures, services and administrative systems necessary for creating a suitable environment in order to achieve various characteristics of the smart city.

The information technology and communications (IT&C) is essential in the smart city in order to: (i) efficiently use the infrastructures and allow a sustainable development from economic, social and cultural point of view; (ii) involve the citizens at local administration level by employing an e-participation system; (iii) support learning from experience, adaptation and innovation so that to react more efficiently and more rapidly to various changes. The IT&C domain is continuously evolving allowing strong integration of all dimensions of the smart city, which refers to the human intelligence, the collective intelligence as well as to artificial intelligence of the physical components of the city. The intelligence of the city is created by interconnecting digital telecommunication networks (nerves),

the intelligence integrated into systems (brain), sensors and physical components (sensorial organs), as well as software tools (knowledge and cognitive characteristics) [13].

Table 3. Directions of development of smart cities

Area of application	Description	Examples
Smart buildings	Smart buildings that incorporate the advantages of communication and control systems.	Optimizing the heating systems, ventilation, and air conditioning.
Education, medical and social care	Applications that allow improving the activity in these domains and ensure the access to all citizens to high-quality services.	Monitoring systems of the old people, monitoring by telemedicine.
Smart energy	Smart electrical energy system that interconnects all utilities and end-users via a smart infrastructure.	SmartGrid applications, optimization of network operation, comply the environment standards, smart lighting.
Smart grid (smart metering of natural gas, water, electrical energy)	Real-time consumption metering of energy, water, and natural gas.	On-line information of the consumption; Wireless smart meters.
Smart utilities (smart water distribution and smart waste management)	Intelligent management of the water distribution system and wastewater.	Smart wastewater systems; Real-time solid waste monitoring.
Smart parking	Managing the parking places using sensors, CCTV	Monitoring systems of the vehicles.
Integrated supply systems	Synchronizing the supply with the demand; measurement, monitoring and organization of the transportation around the supply chains of the cities.	
Smart and integrated transport	Traffic monitoring and real-time optimization using and combining all transportation means.	CCTV for traffic; Smart parking networks; Minimizing the impact on the environment.

For easier use of the databases and software applications, a new concept was born, which is called “Internet of Things” (IoT). Information gathered by means of sensors and software platforms are stored on cloud servers, which are then accessed by various users (both human and automatic systems) by means of software tools. However, under this open environment for access to information, data security is critical in order to avoid economic or social losses.

4. The connection between Smart Grids and Smart City

Smart cities integrate both vertically and horizontally various infrastructures or systems, and for this reason they are sometimes referred to as “system of systems”. While the IT&C infrastructure is the support level for management and control applications, the smart grid is the system that makes all the other systems to function [14]. At the same time, the pylons for a smart city is the way in which various components of the city work together as a single entity and „adapts” when working under extreme conditions.

The electrical energy infrastructure is one of the most important tools of any city. Unavailability of the electrical energy for an extended period of time will eventually cause the unavailability of all the other utility networks. “Smart Energy” is an expression frequently used today, taking into consideration the importance of energy in the cities’ activity. In particular, the electrical energy consumers and producers devise strategies for energy saving and energy efficiency to optimize the use of energy resources. Efficient development of electricity networks is critical when aiming to achieve the goals of the two sides. In other words, the expression Smart Energy is based on the philosophy of adopting for the long term the most effective strategies from the economical point of view while meeting the requirements related to environment protection. A conference titled “How to build Smart Energy Regions” took place recently at Karlsruhe focusing on innovative concepts and best practices for smart energy solutions at local and regional level.

Development of smart grids in cities relies on five basic directions [14]:

A. *Promoting clean energy sources*. The smart cities are evaluated from the point of view of using clean energy. The smart grid solutions are key factors for supporting the development of renewable energy sources (RES) and

high-efficiency cogeneration power plants. Integration of distributed sources in a safe and reliable manner provides flexibility in supplying electrical energy to the consumers.

B. *Smart metering*. Developing the Advanced Metering Infrastructure (AMI), one of the key factors for smart city strategy, will allow, through remote data reading and bi-directional communication, an active participation of the consumers to load balancing in critical situations and implementation of dynamic tariffs in order to stimulate the integration of renewable energy sources and electric vehicle. On the other hand, AMI will allow the operators (distribution operator, energy supplier or the municipality) to elaborate load forecasts for various load intervals.

C. *Efficient public lighting*. The municipalities show an increased interest to adopt sustainable solutions as a measure to improve the *energy efficiency*. Some examples are the use of low consumption and high-efficiency lamps for the street lighting (for instance, the LED-based lamps) or the use of sensors to automatically switch on/off the light when necessary, including the lighting in the administrative buildings.

D. *Integration of the electrical vehicle*. The air pollution in cities is one of the most important public health problems. Large scale integration of electrical vehicles requires intelligent solutions to be adopted in electrical networks. Management of battery charging is essential to avoid network overloading and to support optimized use of clean energy. The electrical vehicle is a mean for handling the surplus of energy from renewable sources, mainly during the night periods.

E. *Active involvement of consumers*. The new smart grid applications are oriented toward the consumer; smart grids are customized to inform, educate and assist the consumer in taking the best decisions. By integration of electrical vehicle and supporting the small power energy sources, the consumers may become prosumers, having thus the possibility of injecting power into the electrical network during the peak load periods. The consumers can, therefore, be actively involved in the efficient use of energy.

In order to achieve the objectives above presented, a smart grid must be developed on three levels:

(i) *Physical infrastructure*. Smart grid is a necessary industrial and economic revolution taking into consideration the advanced aging that can be still found in substations, electrical lines and transformers. With the advent of computation techniques and the innovations in the electrotechnical materials it is now possible to manufacture electrical equipment and advanced automation, protection and control systems.

Currently, most of these technologies are already available, which allows doing the first steps in developing the smart grid [15]:

- The important levels of automation, communication and information technology which are today available can ensure a high-reliability level of the distribution networks in cities;
- It is obvious the trend for equipment modernization both in substations and field installations so that the reaction time is very much reduced in the case of fault isolation, fault location and restoration, network reconfiguration and voltage and reactive power control;
- The increase in the share of renewable energy sources requires the employment of new protection equipment adapted for these situations and special circuit configurations in substations. More than ever, installation of equipment and protection schemes complies with specific standards (such as Standard IEC 61850, which covers the substation automation), and the principles of integrating the information data driven applications are becoming essential elements in the modern design.

(ii) *IT&C Infrastructure*. The intelligence of an electrical network is given by the software applications and the communication infrastructure that connects the operators with the network components. Smart grid development is thus possible because of the innovation in the IT&C domain, visible mainly in the last 15 years.

The large scale implementation of the IT&C infrastructure inherently allows the possibility of remote access to information, including the access to the command and control systems thus existing the risk of unauthorized access. Under these conditions, *protection against cyber-physical attacks* is critical to prevent economic losses. The American Standard *NISTIR 7628 Revision 1* [16] presents an analytical framework that organizations can use to develop effective cyber-security strategies tailored to their particular combinations of smart grid-related characteristics, risks, and vulnerabilities.

(iii) *Standardization*. The novelty of the smart grid and smart city concepts is a barrier for compatibility of the large number of equipment provided by many companies in the field, in their goal of rapidly providing innovative solutions at the same time with sustainable economic development. In order to ensure a harmonized integration of all equipment and to reduce the operation costs, a suitable standardization is required.

The International Electrotechnical Committee (IEC) provides standardization in Europe. In order to simplify the identification of the standard(s) suitable for a specific application, IEC has created a connection map of the smart grid domains and applications [http://smartgridstandardsmap.com/]. Similarly, standardization in USA is provided by the National Institute of Standards and Technology (NIST), and the large number of standards already issued demonstrates the complexity of this domain. One of the reference NIST documents for smart grids, available at [17], provides the framework for standards utilization. Taking into consideration the large number of domains associated with the smart city concept, standardization in this domain is a major challenge.

5. Conclusions

The development of smart cities is highly dependent on the level of intelligence of electrical networks that have to ensure the electrical energy supply to all consumers and to ensure that some city characteristics are achieved, among which improving the efficiency, but the most important aspect is the easy coordination between the urban administration, the operators of the various infrastructures and those responsible for the public safety and health.

The smart grids will be capable of stimulating the consumers to modify their load in critical conditions to maintain the electrical infrastructure unaffected (the most important being the policy, firemen, and hospitals, all of them being electricity dependent). The automation systems for self-diagnosis will assist restoration of electricity supply from areas with back-up paths. The local generation will be used to meet the demand for short periods of time. The community (industry, commercial sector, residential sector) will respond, automatically, by reducing the electricity load in such a way to contribute to the fast restoration of electricity supply. The transportation and the traffic systems will be synchronized with the energy system in order to ensure the functioning of the critical roads. The daily logistic information will be collected and provided to the public community by all available means, especially using the social media networks. The efficiency and safety will be improved significantly by virtue of accuracy of information.

This paper provides a general description of a smart city as regards the terminology and their characteristics, while a suggestive connection is created between smart city and smart grid.

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