Smart Cities as a Driver for Sustainable Development

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Abstract: *Cities are, according to the European Commission, the most agile and relevant sub-national level entity, capable of creating economic, societal, and human development value. From their birth, almost 10.000 years ago, cities acted like living organisms, going through transformational changes. In the last 2000 years, the urban population grew from 10 to 60% of the world's population, raising sustainability, security, health, and environmental challenges. From market or factory-centered approaches to technology and people, Cities and currently Smart (Sustainable) Cities have evolved stimulating the uptake of digitalization, technology, creativity, and innovation. This article proposes an overview of smart city evolution, metrics, and key performance indicators aiming at shaping, comparing, and supporting the development of climate-change, self-aware, economically viable, and high quality of life participatory urban ecosystems. 3 generations of Smart Sustainable Cities are presented and compared.*

Keywords: *open innovation, smart city, sustainable city, sustainable development*

1. INTRODUCTION

"What is the city, but the people."
– W. Shakespeare, Coriolan.

Harris and Albury stated in 2009, following the financial crisis, that public services will require redefining, to offer improved performance, while significantly reducing costs. The natural option identified is leveraging on innovation to provide a better answer to major social and economic challenges. This approach needs to be supported by a more systemic and robust integration if innovation in public services. [1]

Innovation in public services requires multiple experiments, mostly at a local level, to bring to the foreground the innovators able to find new solutions and trans-disciplinary approaches for the public sector, socially responsible companies, or social enterprises. Positioning users and citizens as transformation vectors and co-creators in the center of innovative approaches for public services represents a turning point. [1]

Collaborative innovation in the context of smart cities requires an efficient strategy to create synergies between actors able to create solutions to community problems. [2]

One of the main risks associated with small and medium cities (including most of the Romanian municipalities) is the "medium income trap" [3]. The "medium income trap" means that as the economy of production and services develops, alongside productivity, an increase of salaries occurs, leading to a decrease in the city's attractivity for activities requiring intense/hard labor or low skills/abilities, leading to migration for these types of activities towards other cities, leading to job losses, unemployment and a general decrease of the quality of life. Escaping this trap implies transforming the city into one attractive for high added-value activities, which, in turn, requires improvements in the business ecosystems, public institutions, infrastructure, as well as the rapid development of entrepreneurial ambitions and initiatives and labor-force skills improvements through life-long quality education. [3]

2. EVOLUTION OF HUMAN CITIES

Starting 9000 years ago, mankind created cities, large settlements whose main purpose was defense and trade. Çatalhöyük in Anatolia, Jericho, Uruk, Ur or Babylon were the first cities to flourish, creating safety for their citizens, as well as for merchants coming to sell their product. These cities were surrounded by defensive walls and slowly became seats of power. This type of city lasted for almost 8 millennia through antiquity and the dark ages of Europe, bringing development, power, money, and fame. The first generation of cities – the city as a market brought its inhabitants sanitation, better health conditions, prosperity for most.

The industrial revolution reshaped cities entirely, as their defensive role became obsolete, while factories attracted more and more people around the city walls. The second generation of cities was shaped around factories, providing straight streets, often perpendicular. Sewerage and urban planning became relevant. However, cities were not seats of power and prosperity for the masses but rather challenged by urban poverty, disease outbreaks, and famine. The main role of the city became production, thereby this generation's name – the city as a factory.

The modern age of stock markets, investments, and the second industrial revolution helped reshape cities across more administrative roles. The generation of City as an Office brought back prosperity, good quality of life, high income, and an important administrative role. Most cities drove factories in the suburbs while creating administrative institutions, increasing public safety, developing diverse public services, and optimizing resources.

The fourth generation of cities are the Cities as Event Arenas, cities where co-creation processes happen, and citizens, administrations, and businesses work together towards sustainability and high quality of life. It's cities that undertake smart initiatives and offer opportunities for self-development, social inclusion, and boost creativity and entrepreneurship.

3. SMART (AND SUSTAINABLE) CITIES

The Technical University of Vienna (TUV) updated in 2014 its 2007 model that defined the Smart City as a city that performs well in 6 domains [economy, mobility, governance, living, population, and environment], build on the smart endowment of activities and supply for self-aware, independent and self-decisive citizens. [4]

The United Nations through ITU-T (Telecommunication Standardization Sector of International Telecommunication Union), have analyzed, in 2014, over 120 definitions of smart cities, has identified keywords and grouped them into 8 categories:

- ICT, communications, intelligence, information (26%)
- Infrastructure and service (17%)
- Environment and sustainability (17%)
- People, citizens, society (12%)
- Governance and administration (10%)
- Economy and finance (8%)
- Quality of life and lifestyle (6%)
- Mobility (4%)

In 2014, the United Nations, through ITU-T defined **Smart Sustainable Cities** as innovative cities using information and communications technology to improve the quality of life, public service efficiency, competitiveness, ensuring that the needs of present and future generations needs are met, in the economic, social, environmental, and cultural domains. [5]

The different vision between the previous definitions is obvious. The main difference comes from centering the Smart Cities on technology (ITU-T) or the city (TUV). ITU-T introduces 2 new characteristics to TUV's definition of Smart Cities, mainly technology and infrastructure, probably due to e desire to strengthen technology's role in designing, developing, and implementing Smart Cities.

According to Cohen [6] and others throughout the history of implementing Smart Cities, there were already 3 generations, classified on the main orchestrator, as well as the focus of development and implementation:

3.1 Smart Cities 1.0

Smart Cities generation 1.0 are centered on technology, where the orchestrator is, generally, a technology supplier or integrator, preaching the impact that technology can have on transforming cities in exceptional environments, high-tech and efficient for investors, entrepreneurs and solutions providers. The main characteristic is that technology providers fight to convince cities to adopt their technical solutions, while the cities are, most often, unprepared for the downstream implications and effects of using these technologies on their citizens, local stakeholders, and the general quality of life. The most important issues regard the lack of vision of public administrators and difficulties of integrating existing workflows for citizen interaction with the processes designed by the technology provider from a strictly technical viewpoint. Although they were the first to appear and were considered, at the time, great practice examples, worthy to follow, most of these first-generation smart cities failed due to a lack of vision and citizen interest, as no significant improvement to the general public's quality of life was achieved. Santander is Europe's first Smart City to implement this concept, but, fortunately for them, it has migrated to a second-generation model. In the Romanian Context, 2018 Alba Iulia Smart City is the perfect example of Unsustainable Smart City generation 1.0.

3.2 Smart Cities 2.0

Smart Cities generation 2.0 is centered on the local authorities and based on technology, where the orchestrator is usually the city, through visionary city managers or mayors, supported by innovation departments. These cities solve community problems with support from technology. The results of implementing the model have direct and positive consequences on citizens', tourists' and visitors' quality of life. The approach is usually project-based, while cities identify multiple directions for optimization through digitalization and technology. Most functional Smart Cities world-wide are at this stage, while the most suited example is Barcelona, with over 100 distinct Smart City projects that begin to integrate.

3.3 Smart Cities 3.0

Smart Cities generation 3.0 is centered on citizens, where co-creation processes are positioned in the middle of the city's smart development. Citizen involvement in Smart City initiatives boost creativity and stimulate cooperation among local actors and the local ecosystems, favor local economic development and increase participatory approaches. The cities of the third generation are sustainability champions that take into account the needs and preferences of their citizens while modeling instruments and processes based on the local specific. Vienna, the world's city with the highest quality of life is a perfect example for Smart Cities 3.0. Citizens' participation as co-creators of urban sustainable development projects is a key element.

We propose a classification of cities based on the Technical University of Vienna, respectively the 6 pillars of sustainable development (Economy, Environment, People, Mobility, Governance, and Lifestyle), and the 3 generations of Smart cities aforementioned:

Table 1

	Smart City 1.0	Smart City 2.0	Smart City 3.0
Generation Specific	Centered on technology	Centered on data and administration	Centered on people
Mobility	Sensors for traffic monitoring,	AI-Based smart traffic lights.	Ridesharing, electric vehicles, co-ownership of transport means

	Automated and manual control systems High predictability	Smart mobility Adaptable and highly used public transport	
Environment	Pollution monitoring Automated watering systems	Rooftop gardens, urban gardens. Traffic routing and limitations based on pollution sensors. Climate change mitigation	Climate change adaptation
People	The object of the city. People are monitored. Things are being done **for them**.	The subject of the city Citizens are consulted. Things are done with them	Co-creators of the city Citizens are involved in most aspects and processes of the city. Things are done with/by them.
Living	Smart homes Smart metering Emergency monitoring	Social housing with remote management Process automation Advanced emergency monitoring and response	Co-ownership, Airbnb, smart neighborhoods, Energy positive cities (neighborhoods) Disaster resilience.
Governance	Cost reduction Administrative process digitalization Resource monitoring Information based decision making.	Process automation Citizens involvement through public consultation, participatory budgeting, or investment prioritizing	Digitally enhanced democracy. Public spaces and services co-creation and co-ownership. Placemaking, Innovation Hubs, makerspace.
Economy		Fablabs, Makersplaces	Living Labs
Strengths	Technology testbeds Technology testing laboratory	Social inclusion, participatory democracy, social capital building, partnership, and local ecosystems development	Sustainable cities
Weaknesses	A strong influence of large companies Based on technology Low interoperability of different systems	Reduced citizen involvement, partial response to citizen's needs	
Description	Cities maximize the use of technology to increase viability, sustainability, and control of the city. Technology providers encourage cities to adopt their technology to improve urban management efficiency.	Technical tools are created to solve specific problems (pollution, sanitation, health, traffic). Public consultation occurs. Local administrations use technology to identify and transform the city's future. The purpose of technology usage is the improvement of the quality of life.	The city as a platform or co-creation space, strengthening the ability of local administrations to focus on citizens as key actors in urban development. Participatory approaches stimulate creativity and innovation while materializing important societal projects such as social inclusion or administrative and development costs. Open Innovation, co-creation of public space and services, Public-Private-People Partnerships are the pillars of city development. Technology is adopted and adapted depending on the local community's needs, problems and expectations.

Huovila et al have identified as a common ground for most smart city definitions the usage of methods, processes, digital solutions, and innovative technologies as facilitators of a sustainable urban environment. [7]

4. SMART (AND SUSTAINABLE) CITY METRICS

Numerous standards and metrics for evaluating smart cities are in place worldwide. The most recognized are:

- ETSI TS 103 463 (2017) Access, Terminals, Transmission and Multiplexing (ATTM);. Key Performance Indicators for. Sustainable Digital Multiservice Cities
- ITU-T Y.4901 (2016) – Key performance indicators related to the use of information and communication technology in smart sustainable cities.
- ITU-T Y.4902 (2016) – Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities.
- ITU-T Y.4903 (2016) – Evaluation and assessment
- Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals.
- UN IAEG SDG 11+ (2016) -
- ISO/DIS 37122:2018 – Sustainable Cities and Communities –Indicators for smart cities.

- ISO 37120:2018 – Sustainable Cities and Communities – Indicators for city services and quality of life

Huovila et all performed, for the CITYKeys project (www.citykeys.eu) a comparative analysis of aforementioned standards and indicators and provided a framework for Smart Sustainable Cities assessment, designed to enable relevant actors co-work together, „speak the same language" and monitor each other's progress in a transparent and unified manner. The measurement dimensions identified are Energy, Green gas emissions, Transport, Digital infrastructures and electronic service, Resource management, Citizen participation, Competitiveness, Economy, Environment, Quality of Life, Research, and knowledge.

The CITYKeys framework is structured in 5 categories: People, Planet, Prosperity, Governance, and Replication, each of these having a set of measurable indicators.

Bosch et al propose the measurement of over 100 indicators evaluating the following aspects of Smart Sustainable Cities [8]:

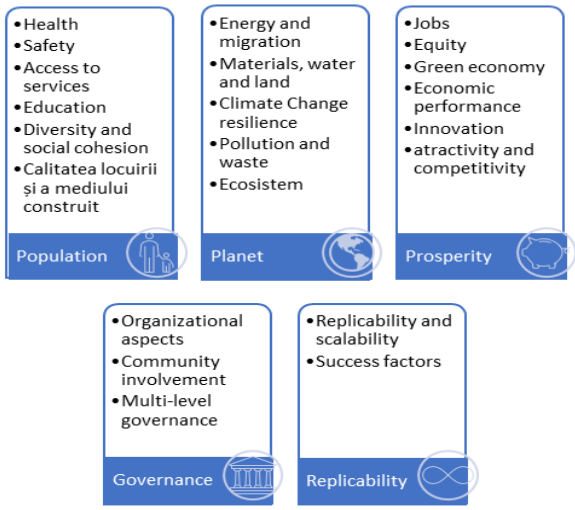

Fig. 1. Dimensions for Smart City indicators. The author's design based on a bibliography (Bosch et al., 2017)

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