Smart Cities, Sustainable Cities, or Both?
A Critical Review and Synthesis of Success and Failure Factors

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Abstract: As the majority of world population will be living in cities by 2050, it became a necessity for societies to build cities that are capable of meeting the needs of current and future generations in a smart way. There have been initiatives toward smart/sustainable cities that had succeeded, and others had failed. Being sustainable and smart had been used in a quite confusing way. In this paper, we attempt to understand related concepts, such as smart, sustainable, sustainable development, and sustainability. Then, we analyse five examples of existing initiatives of smart/sustainable cities to understand the factors behind their success or failure, by applying SMART criteria as a managerial perspective on those initiatives. Finally, we conclude the paper with key implications and possibilities for future research.

1 INTRODUCTION

It is speculated that 70% of the world's population will live in cities by 2050 (ITU, 2015). As cities have more opportunities for education and work to offer, populations in cities, especially in emerging economies, are speculated to reach 4 billion by 2030 (Deloitte, 2015). Consequently, the consumption of resources and services in cities will grow massively. To accommodate this growth, there is a need for innovation in managing cities' resources. Thus, sustainable urbanization became a key concern for societies in terms of environmental efficiency and intelligent employment of resources. Hence, the notion of "a technologically interconnected city" or Internet of Things (IoT) using Big Data is promoted to achieve the efficiency and intelligence in managing cities' resources (Bonomi et al., 2014; Deloitte, 2015).

Societies are becoming increasingly oriented toward achieving sustainability and improving the quality of life with the use of Information and Communication Technology (ICT). Then, the concept of "smart sustainable city" is put forward to ensure that "sustainability" is not overlooked at the expense of fancying ICT (ITU, 2015). In the literature, sustainability in societies is usually emphasized from the environmental aspect in terms of how ICT can reduce carbon emissions and support intelligent use of energy (Gholami et al., 2015; Watson et al., 2010; Brandt et al., 2013), while the other important aspects (i.e., economic, social, and cultural) were under-researched.

We argue that ICT is a means of achieving intelligent resource management in a city, but it does not necessarily presuppose that the city is successful in being smart and sustainable. Thus, the purpose of this article is to clarify key concepts (i.e., smart, sustainable development, sustainability and smart cities) that have been used conjointly and separately in some occasions. The objective is to understand "what are the key success and failure factors of smart sustainable cities?" by analysing examples of existing initiatives.

This paper is organized as follows: in Section 2, we introduce and discuss relevant concepts. In Section 3, we analyze and discuss real examples of smart/sustainable city initiatives. Section 4 concludes the key contributions and limitations of the paper and higlights opportunities for future research.

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2 BACKGROUND

2.1 Smart

The word "smart" has been treated as an adjective, instrumental concept, or a normative concept (Höjer and Wangel, 2015). As an adjective, smart had several meanings in Oxford and Merriam-Webster dictionaries, such as “mentally alert”, “very good at learning or thinking about things”, “showing intelligence”, “knowledgeable”, and “programmed so as to be capable of some independent action”. These meanings apply for persons, objects, or places. A smart person is interpreted as either a mentally intelligent and alert or using ICT.

As an instrumental concept, smart means creating “products, services and product-service systems in which ICT play a major role” (Höjer and Wangel, 2015), and this concept is more focused on the means, and not the final outcome. As ICT started to reshape our society and “the way we interact with our friends, communities, transportation modalities, homes, offices, and even our bodies” nowadays, smart word is often related to the use of ICT that provides a level of intelligence and coordination of information around us through sensor-based technology (Stimmel, 2015, p.6). However, using a smart phone without being connected to the Internet and interconnected with other mobile devices and/or computers does not mean any smartness; “the novelty is thus not so much the individual technologies, products or services but the interconnection and the synchronization of these and the systems they include, so that they work in concerted action.” (Höjer and Wangel, 2015).

Hence, a smart object (e.g., smart phone) is programmed to act autonomously and intelligently by being connected and interconnected with other objects. A smart place, either a city or a building, is often described as being capable of managing its resources intelligently, and it is often based on the notion of technologically-interconnectedness (i.e., IoT) (Bonomi et al., 2014; Deloitte, 2015).

Contrarily, smart as a normative concept is focused more on the desired outcome mirrored in the efforts to improve (Höjer and Wangel, 2015). Accordingly, smartness is determined by achieving an intended outcome as specified priori. Doran (1981) has set SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) criteria for writing management's goals. SMART criteria model suggests that a goal should be (1) Specific: precisely defined, (2) Measurable: progress towards the goal can be measured, (3) Achievable: realistic and attainable within constraints of available resources, knowledge, and timeframe, (4) Relevant: bring the desired social, economic, or environments outcomes, and (5) Time-bound: have clearly stated deadlines.

To conclude, the word smart is interpreted differently (i.e., intelligent, ICT-supported, outcome, or criteria) and at different levels (i.e., vocabulary, concept, and model). This has to do with the context (i.e., persons and their use of ICT, places managing their resources intelligently, and objects and their autonomy and interconnectedness).

2.2 Sustainability, Sustainable Development, and Sustainable Cities

The word “sustainable development” emerged in the 1980s to include various aspects (i.e., economic, urban, rural, industrial, agricultural, technological) (Hembd and Silberstein, 2011). Then, sustainable development was defined by the World Commission on Environment and Development as (Butlin, 1987): “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” There have been research efforts to identify indicators for sustainable development employed in Europe, which include socioeconomic development, social inclusion, demographic changes, public health, climate change and energy, sustainable consumption and production, natural resources, sustainable transport, good governance, and global partnership (Steurer and Hametner, 2013). Sustainable development goals are deemed to be interconnected (Le Blanc, 2015) and require an integration of thinking across all sectors of the city and providing incentives for collaboration between national and international organizations as well as citizens to participate in the sustainable development decision-making, policy-making, and governance (Dassen et al., 2013; Martin et al., 2014).

In dictionaries, the word “sustainability”, means the ability to be used without being completely used up or destroyed. Sustainability, as a concept, has been used at the corporate-level (Baumgartner and Ebner, 2010), industry-level (Erol et al., 2009), and community-level (Dempsey et al., 2011). Sustainable communities are defined as “places where people want to live and work, now and in the future. They meet the diverse needs of existing and future residents, are sensitive to their environment, and contribute to a high quality of life. They are safe and inclusive, well planned, built and run, and offer equality of opportunity and good services for all”

(UK Government Web Archive, 2010). Communities are striving to continuously achieve the goal of sustainability that refers to *"the ability of humans and human society to continue indefinitely within a finite natural world and its underlying natural cycles"* (Hembd and Silberstein, 2011). This definition of sustainability is focused more on the natural world (i.e., water, energy and food); however, the environmental view on sustainability of the community is no longer accepted (Dempsey et al., 2011). The United Nations Educational, Scientific and Cultural Organization (UNESCO) has defined sustainability as "a paradigm for thinking about the future in which environmental, societal and economic considerations are balanced in the pursuit of an improved quality of life" (UNESCO, 2016). The UNESCO's definition of sustainability emphasized the economic and societal dimensions of our world. While the social and economic dimensions of sustainability are recognized, less research attention has been given to these dimensions (Lam et al., 2014; Salahodjaev, 2016; Dempsey et al., 2011). The concepts "sustainable development" and "sustainability" can be easily confused with each other, but the UNESCO has solved this confusion by acknowledging sustainability as a "long-term goal", or a "desired end-state" that can be sustained over time (Weingaertner and Moberg, 2014; Höjer and Wangel, 2015), while sustainable development is the series of "processes to achieve that goal of sustainability".

The components of a community are represented as economy (physical built capital, such as machinery and buildings), society (human capital, such as knowledge and health), and environment (natural capital, such as water and energy) (Hembd and Silberstein, 2011). From a systems-based view, putting emphasizes on relationships among economy, society, and the environment is paramount to sustainability of a community, as the relationships between these three parts constitute the properties of systems (i.e., communities) (Hembd and Silberstein, 2011).

These relationships have been explained in three different views that evolved over time (Hembd and Silberstein, 2011): (1) unconnected view: in which the priority is given to the economic development, for instance, over the environmental and societal considerations. (2) interconnected view: in which all the economic, environmental, and societal considerations need to be taken into account for development decisions and sustainability lies in the overlap between the three components. This interconnected view better resembles the concept of sustainable development, as it has to consider economy, society, and environment in meeting the needs of current and future generations. (3) interdependent view: in which "economy exists and functions within society, and together they exist and function within a finite environment and depend on it" (Hembd and Silberstein, 2011); this view is said to hold true for the concept of sustainability that the more economy and society grow, the more important it becomes to preserve the finite natural environment.

To conclude, "sustainability" is a goal that can be achieved by the "sustainable development" processes with focus on economy, society, and environment components of a community and the relationships between these three. Additionally, strategies to achieve the goal of sustainability need to reflect the notion of "Think Globally, Act Locally" (Hembd and Silberstein, 2011). A sustainable city (or eco-city) must be built on social development, economic development, environmental management, and urban governance to ensure having "low ecological footprint" and eliminate transferring economic, social and environmental hazards to other locations and future generations (UN, 2013).

2.3 Smart Cities and Smart Sustainable Cities

Traditional cities are going through serious urban challenges, nowadays, ranging from environmental (i.e., climate change, energy, and pollution), economic (i.e., globalization), to social (i.e., urbanization) (Mosterman and Zander, 2013). These challenges make cities more consumers than preservers of the environmental resources, which threatens the sustainability of the cities for the years to come. The increasing density of population in cities may increase their economic significance; however, this may have unlikely social and environmental impacts (UN, 2015). According to figures from the United Nations (UN), 80% of the world's urban population will be in Asia and Africa and, particularly, in the developing countries in the becoming 15 years (UN, 2013). World's cities significantly contribute to 70% of global greenhouse gas emissions (UN-Habitat, 2011) as well as 60-80% of global energy consumption and 75% of carbon (CO2) emissions (UN, 2016).

To achieve sustainability, cities need to implement smart solutions enabled by smart technology. These smart technology solutions require "smart city initiatives" from the society (Albino et al., 2015). Smart city initiatives have to involve citizens, government, businesses, and non-government

institutions in collaboration and partnership efforts (Vanolo, 2014; Mosterman and Zander, 2013). This social involvement has to focus on organizing a team with a dedicated manager, diagnosing the current situation with regard to urban challenges specific to the city and current ICT infrastructure, identifying smart technological solutions, setting action plan (i.e., goals, schedules, costs, and performance indicators), financing the smart city action plan, implementing smart city project, and evaluating the smart city project (Bouskela et al., 2016). Several indicators have been proposed to measure the performance of a smart city project (ISO/IEC JTC 1, 2015; Albino et al., 2015). The widely cited indicators for the "smartness" of a city are mapped to six characteristics: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living (Giffinger et al., 2007).

Several definitions have been put forward for "smart city" concept; these definitions were generated from many different disciplines (i.e., ICT and urban planning) and communities (i.e., academic and industry) (Nam and Pardo, 2011; Chourabi et al., 2012; Albino et al., 2015). Additionally, various keyword terms have been used as synonymous to "smart city", which makes the concept of smart city quite blurry (Albino et al., 2015; Nam and Pardo, 2011). A smart, or smarter, city is a city that is characterized as an "instrumented, interconnected, and intelligent" (IBM, 2010; Kehoe et al., 2011; Albino et al., 2015). These characteristics are enabled by the use of ICT. The "instrumented" layer refers to sensor-based systems that provide real-time data through sensors, meters, cameras, and unstructured data. The inputs from the instrumented layer are integrated and transformed into event-related information at the "interconnected" layer to provide rich insights for decision-making. Business intelligence and analytics are applied to the information provided by the interconnected layer and other city-relevant data and, then, the analysed information is visualized to understand the city requirements and city policies at the "intelligent" layer to allow making informed decisions and taking actions. These three layers that build up the smartness in a smart city are constructed by smart technology solutions and ICT infrastructure, such as IoT, Big Data, and Internet. It is worthy to note that despite ICT is a key ingredient of a smart city initiative (Negre and Rosenthal-Sabroux, 2015), ICT in itself does not denote an "intelligent or smart" city (Kondepudi and Kondepudi, 2015). ICT should have a degree of autonomy and intelligent devices, and services have to be linked to the ICT infrastructure through IoT that is defined as (Botterman, 2009, p.12):

"A global network infrastructure, linking physical and virtual objects, through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability as the basis for the development of independent federated services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability."

Smart cities are not so smart without a reliable and superfast Internet that connects and integrates sensors, meters, cameras, other smart devices as well as data/information/knowledge systems throughout the city to communicate people with those devices, systems and other people promoting the concept of IoT (Atzori et al., 2010). The other key smart technology solution in a smart city is Big Data that maximizes computation power and algorithmic capability to analyse and identify patterns in large data sets, and provide a form of intelligence along with accurate and objective truth (De Mauro et al., 2015). Several definitions have been set for big data; however, it has been defined as *"the information assets characterized by such a high volume, velocity and variety to require specific technology and analytical methods for its transformation into value."* (De Mauro et al., 2015).

From an ICT perspective, the term "smart" in a smart city implies the use of Internet, ICT, IoT, and Big Data. However, from the perspective of urban planning and development, "smart" implies that a city has a key goal to achieve its economic, social, and environmental sustainability and, thus, improve the quality of life (Albino et al., 2015; Kondepudi and Kondepudi, 2015). A major critique to many smart city initiatives was that these cities had focused on using ICT to address environmental issues and ignored the social aspects (Albino et al., 2015), and the fact that smart cities are built for people to improve the quality of life, which is defined as "an individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" (WHO, 1997, p.1).

Hence, the concept of "smart sustainable cities" was suggested after analysing about 100+ definitions of smart cities by the International Telecommunication Union (ITU)'s focus group (ITU-T Focus Group on Smart Sustainable Cities, 2014; ITU, 2015). The analysis indicated some

attributes that have been claimed to characterize smart cities belong primarily to the concept of sustainability, such as quality of life and sustainable development (Vesco and Ferrero, 2015), which gave rise for the concept of "smart sustainable cities (SSC)s" that emphasizes the sustainability as a goal to be achieved after iterations of sustainable development efforts (i.e., economic, social, and environmental). It is worthy to note that: (1) cities are not necessarily made sustainable using smart ICT, (2) using ICT in cities does not necessarily contribute to sustainable development, (3) smart ICT can be used for sustainable development in other settings than cities, such as industries or buildings, and (4) SSCs exist only when smart ICT is used for making cities more sustainable (Höjer and Wangel, 2015).

An SSC is defined as "*an innovative city that uses information and communication technologies (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, environmental as well as cultural aspects*" (ITU, 2015). An SSC has three key characteristics: sustainability (i.e., governance, pollution, climate change, etc.), quality of life (i.e., financial and emotional well-being), and intelligence (i.e., improving economic, social, and environmental standards) (ITU, 2014).

3 ANALYSIS AND DISCUSSION

We selected five examples of smart/sustainable cities that we found providing insights into key criteria to consider when making decisions to build smart sustainable cities, especially that this is the common trend nowadays to be equipped for the needs of the future generation. The five examples include cities, such as Masdar, Dongtan, Sino-Singapore Tianjin Eco-city, Songdo, and Busan (see Table 2). We applied SMART criteria model to understand the success and failure factors of existing smart city example initiatives from a managerial perspective, which need to be considered by governments when investing in and implementing smart city projects in the future.

The examples introduced with regard to their location, area/capacity timeframe, goals, expected outcomes, challenges faced, and achievements done so far. From the descriptions in Table 1, it appears that the most struggling smart/sustainable cities are Masdar and Dongtan. Masdar had set a goal that is not possible to achieve that is "to be zero-carbon city" and it was not able to attract the exact population that was intended to inhabit it. According to Table 1, Masdar does not fulfill three important SMART criteria: the achievability of its unrealistic goal "zero-carbon", the relevance of its goal in bringing desired social outcomes that it could only attract 300 people out of intended population 50000 people, and thus, being unable to finish the project on the pre-set deadline 2016. However, the goal of Masdar has been rectified to reduce carbon emission by 50%.

For Dongtan, major challenges related to the corruption of local politicians and greedy consultancies who overlooked practicalities in designing the city. According to SMART criteria in Table 1, Dongtan made the same mistake as Masdar by setting an unrealistic goal of reducing the ecological footprint to 2.2 hectares per person, which is beyond the maximum of 1.9 hectares per person. The unrealistic goal of Dongtan has not been rectified, which creates blurriness around the measurability of the goal. Furthermore, due to corruption and greediness, the project had stopped for a long while, despite its valid timeframe, with only a wind turbines farm and the city ended up with zero inhabitants. Thus, Dongtan did not bring in relevance to desired economic development outcomes that the city was intended to achieve.

Sino-Singapore Tianjin Eco-city, Songdo, and Busan appeared to fulfill the SMART criteria and provide examples of successful smart/sustainable cities. The goals of the three cities considered the social development including culture and aimed at harmonizing it with the environmental and economic developments, along with employing ICT advancements. Despite this harmonization poses a challenge for the three cities, the goal is still achievable and the cities recorded a progress. This finding corroborates the claim in the literature that the success of smart/sustainable city initiatives has to do with the focus on the social development beside the environmental and economic developments, as this will pave the way to achieving sustainability (Albino et al., 2015). The key of building a successful smart/sustainable city is to have clear vision and well-

Table 1: Mapping the examples to SMART criteria.

Examples	Specific goal	Measurable	Achievable	Relevant	Time-Bound
Masdar, UAE	Yes	Yes	No	No	No
Dongtan, China	Yes	No	No	No	No
Tianjin, Singapore - China	Yes	Yes	Yes	Yes	Yes
Songdo, South Korea	Yes	Yes	Yes	Yes	Yes
Busan, South Korea	Yes	Yes	Yes	Yes	Yes

Table 2: Analysis of examples for smart/sustainable cities.

Examples	Description
Masdar City (Zero Carbon City)	**Location:** Abu Dhabi, UAE **Area/Capacity:** 6 Km2 / 50000 residents **Time frame:** started in 2006 and it is scheduled to be completed this year 2016, but the completion date has been further extended to 2030 **Goal:** to be a zero-carbon city **Expected outcomes:** -100% renewable energy (solar panels, wind turbines, etc.), 80% of water is recycled -It is a car free city provided with green transportation systems, such as rapid transit system, biking and walking **Challenges:** -Run out of the scheduled finishing time -The set goal will not be achieved "to be a zero carbon city", even after the project is finished, it will reduce it only 50% **Achievements:** -5% of the city is completed -The city is inhabited by only 300 people all of them are students at Masdar Institute of Science and technology
Dongtan City (Eco-City)	**Location:** Island of Chongming near Shanghai, China **Area/Capacity:** 84 Km2 / 600000 residents **Time frame:** started in 2005 and expected completion by 2040 on two phases **Goal:** -To make Dongtan low carbon and zero waste city as possible by reduce the ecological footprint to 2.2 hectares per person, while according the World Wide Fund for Nature WWF 1.9 hectares is the maximum for achieving sustainability -To develop a new paradigm of economic development **Actual outcomes:** self-sufficient city by using renewable energy (solar panels, wind turbines and bio-mass fuels) **Challenges:** corruption and greediness **Achievements:** The city remains as a ghost city with only 10 large wind turbines standing in the air with no buildings
Sino-Singapore Tianjin Eco-city	**Location:** between Singapore and China; the city located in China near to Beijing **Area/Capacity:** 30 Km2 / 350000 residents **Time frame:** started in 2007 and expected completion by 2020 **Goal:** to be socially harmonious, environmentally-friendly and resource-efficient **Expected outcomes:** -Use of non-motorized modes of transport such as light rail system and bicycles -Renewable energy, water conservation, and effective waste management **Challenges:** making balance between achieving three harmonies ([people-environment], [people-economy], and [people-people]) and three abilities (practicability, replicability, and scalability) **Achievements:** Only 3 Km2 of the city are completed so far, the city is inhabited by 6000 people in 2014 and is still growing but still no hospitals or shopping malls
Songdo Smart City	**Location:** 65 km southwest of Seoul, South Korea **Area/Capacity:** 86 Km2 / 75000 residents **Time frame:** started in 2005 and completed in 2015 **Goal:** -To be Aerotropolis (centrality of its airport infrastructure) -To be Ubiquitous City (U-City) (integration of information systems with social systems through wireless networks Actual outcomes: -Qualified for Leadership in Energy and Environmental Design (LEED) -Over 120 buildings intend to achieve LEED certification, making Songdo the largest private LEED development in the world -Co-generation and waste management systems relying on a network of tubes that suck in the garbage and transport it efficiently to treatment facilities **Challenges:** -Occupancy rate is lower than expected -Balancing its sustainable development goals with environmentalists' calls for preserving bird habitats **Achievements:** the city is finished since 2015
Busan Green U-City	**Location:** southeast of Korea, fifth busiest sea port in the world and first IoT-Based smart city in Korea **Area/Capacity:** 765.64 Km2 /3 540098 residents **Time frame:** started the shifting and retrofitting to next generation of technology program in 2005 and the project is done on 2 phases, Phase 1 (2006-2011) and phase 2 (2012-2016) build a city with a 'smart' economy, 'smart' lifestyle, 'smart' culture, and 'smart' green environment **Expected outcomes:** Improve the structure of local industries, boost the local economy and enhance the quality of life for Busan residents by integrating the latest next-generation ubiquitous technology into the city's major infrastructure (logistics, transportation, tourism, health, disaster prevention and safety and environment). Promote Busan City's status in the international community by creating the world's first-ever U-city **Challenges:** In developing business models to ensure that new city technologies and services are profitable **Achievements:** currently Busan U-city in its final phase and when it is finished, it will be a role model of U-City (Smart City) according to Young-Sik Kim, Director General, Planning and Financing of Busan Metropolitan City: *"When the implementation of the Busan U-City is complete, it will usher in a new era in urban mobility around the city, with education, medical service, and public welfare all benefiting from the creation of a smart community environment."* (Cisco, 2016)

defined and doable goal to achieve. The most important factor is to not only build many smart or sustainable cities, the most important is how to get them fully occupied. ICT and Big Data play a major role in coordinating the economy, environment and social and culture factors, and thus achieving sustainability in a smart manner.

To conclude, the success of a smart/sustainable city can be related to its goals being measurable, achievable, relevant to the desired outcomes (i.e., social, economic, and environmental), and accomplished within a certain timeframe.

4 CONCLUSIONS

In this paper, we clarified and discussed related concepts (i.e., smart, smart city, sustainability, sustainable development, and smart sustainable city), that have been used interchangeably and confused with each other, by highlighting the differentiating characteristics of each concept. We applied SMART criteria model by looking at success and failure factors of existing smart/sustainable city initiatives from a managerial perspective. Such a perspective offers important considerations to governments when investing in and implementing smart city projects in the future. As any research effort, this study has a limitation that it relies on a theoretical analysis of documented data from secondary sources. Thus, further empirical examinations can provide rich insights into the outcomes of this study.

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