RESEARCH ARTICLE

A smarter approach towards smarter cities

Jason W. P. Ng*
IEEE Senior Member and IET Fellow

Abstract: Smart cities have gained widespread interests in the recent years. However, the understanding of the subject can differ among different smart cities' communities, particularly across the academia, industry, and government sectors. Similarly, the approach towards the realization of smart cities can vary from one city to the other, depending on their standpoints and perspectives. These are largely due to the subject matter at hand which is not only inherently interdisciplinary but also all-encompassing in nature, hence resulting in the wide heterogeneity in the treatment of the subject. The purpose of this paper is thus aimed to summarize the basic pertinent understanding of smart cities (in terms of "why", "what", "who", "when", "where") as well as to put forward the various key approaches in smart cities (in terms of "how"). From there, a smarter approach towards smart cities is then delineated taking into account the considerations of the government, providers and consumers in order to attain an overall win-win benefit for all the stakeholders involved. It is meant to be a short and concise paper for both practitioners and researchers, (1) who are in the field to gain an additional insight into the subject or (2) who are new in the field to get an introductory overview of the subject, so as to obtain a better understanding in the approach towards smart cities that is relevant to their individual context.
Keywords: smart cities, innovation, partnership, ecosystem

*Correspondence to: Jason W. P. Ng, Institute of Electrical and Electronics Engineers. Email: jason_wp_ng@ieee.org

Received: May 1, 2017; **Accepted:** August 31, 2017; **Published Online:** September 15, 2017
Citation: Ng J W P, 2017, A smarter approach towards smarter cities. *Journal of Smart Cities*, vol.3(1):14-22. http://doi.org/10.26789/JSC.2017.01.002.

1. Introduction

Smart cities have drawn significant widespread interests, among the practitioners and researchers, in the recent years. It is a popular urban label that has caught the attention of many cities, including their government, industry and academia into action. Since its inception, a number of related initiatives and programmes have, as such, been launched, implemented and some completed, in the various cities across the different part of the continents. But when one starts posing the challenging question "Will the real smart city please stand up?"[1], many begin to wonder if this is after-all a (empty) hype or if this is really a (solid) reality.

The rationale for this is somewhat expected and its root cause can be traced to the use of the term "smart cities" itself. In fact, the term "smart cities" is not new. It first appeared during the early Nineties which was coined to signify urban development in the Technopolis Phenomenon - an innovative approach towards economic development, involving technology downstreaming in both the public and private sectors, in order to create new infrastructures for economic growth, diversification, and global competitiveness[2]. In the later years, the term was reinvigorated and gradually became a 'catchy' label, as well as a 'catch-all' label, in the urban context. Some have therefore criticized the term is about everything and therefore is about nothing. The reason for this is largely due to the subject matter of the term itself that can be rather vague and all-encompassing in nature. This has thus led to a wide heterogeneity in the treatment of the subject put forward by the different smart cities' communities (particularly across the government, industry, and academia), largely based on their perceived standpoints/perspectives or, more often, based on their own (core) capabilities. As a consequence, the term "smarter cities" was introduced as a substitution in some of the recent literatures instead, as an attempt to make a distinction from such "mislabeling" hype. Likewise, others have reworded the term in the guise of "intelligent cities", "information cities", "digital cities", "virtual cities", "cyber cities", and several others, depending on their intended emphasis or representation context.

This paper thus aimed to put forward, in a concise manner, the key elements in the basic understanding of smart cities; more importantly, to distil the fundamental foundation in the smart cities characterization as well as its methodologies (i.e. why smart cities, what are smart cities, who coined smart cities, when smart cities started, where are smart cities, and finally how to do smart cities). It is meant for practitioners and researchers, who are interested or involved in the domain, to gather an overall holistic understanding in the various aspects pertaining to the smarter approach towards smarter cities.

2. The Emergence of Smart Cities

Now, to put things into perspective, let's take a look back at a brief history of our city evolution to better understand where we span now at the onset of the smart city movement. To do this in an apparent way, an indicative illustration depicting the evolution of our city, marked by key stages of the different revolution eras, is as shown in Figure 1.

A smarter approach towards smarter cities © 2017 Jason W. P. Ng. This is an Open Access article distributed under the terms of the (Creative Commons Attribution-NonCommercial 4.0 International License), permitting all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

As seen in the figure, the city evolution has gone through several stages of revolution. It started from the Agricultural Revolution, also called the Neolithic Revolution, where the nomadic society of hunter-gatherers began to master the ability of food cultivation, hence resulting in a large-scale transition of human culture from a lifestyle of hunting-gathering to that of agricultural-settlement. With food surpluses brought about by refined production technique, specialized trades developed which hence gave rise to the extension of a city, largely driven by economic activities. This is then followed by a series of Industrial Revolution propelled by the introduction of new manufacturing processes in the first industrial revolution (i.e. Industrial Revolution), discovery of new technologies in the second industrial revolution (i.e. Technological Revolution), and the invention of digital technologies in the third industrial revolution (i.e. Digital Revolution). The Digital Revolution marked the beginning of the information age, resulting in the recent Information Revolution that triggers the onset of the present smart city movement (in which 'information' plays a central role in the lattice across the smart city functions).

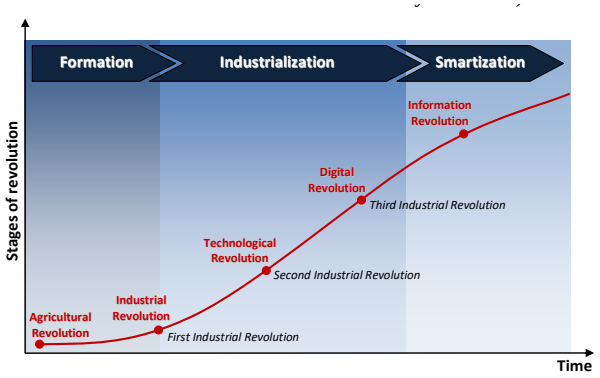

Figure 1. Phases of development in city evolution

In all, the evolution of city can be viewed to have gone through three broad phases of development: (City) Formation, (City) Industrialization, and (City) Smartization - that is, the pinnacle of self-actualization period where we are currently residing in. The smart city movement invokes a self-reflection of the city's past development and induces a rethink of its future development, so as to maximize its full potential through smart (evolution) growth of the city. In other words, a more efficient and effective growth of the city, constituting a single coherent drive towards smart city in a controlled and coordinated fashion; rather than letting the city grows and sprawls as it likes, and be pulled by forces from all directions in an uncontrolled and uncoordinated fashion. Examples of cities in pursuit of such smartization include Singapore[3], Milton Keynes[4], Barcelona[5], Seoul, San Francisco, Amsterdam[6], and Dubai[7].

3. The Key Drivers Behind Smart Cities

There are a number of factors that drives the mass-uptake of smart cities across the different continents. Generally, they can be classified into three broad perspectives based on the considerations from (1) a macro-level (i.e. country) viewpoint, to (2) a micro-level (i.e. city) viewpoint, and further down to (3) a nano-level (i.e. citizen) viewpoint. These viewpoints are predominantly influenced by Globalization, Urbanization, and Transformation respectively - the three spheres of influence that form the key force-drivers behind smart cities (see Figure 2).

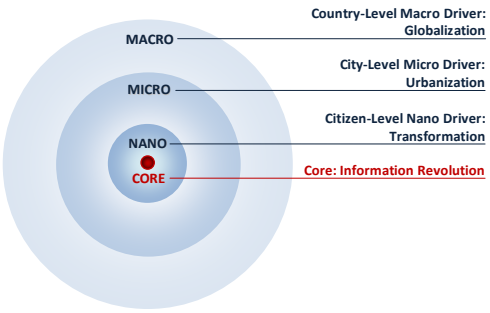

Figure 2. The three key drivers of smart cities

3.1. Country-Level Macro Driver (Globalization)

The macro driver behind smart city, which can be perceived from a country-level standpoint, is a set of external forces derived and imposed from outside the city. In sum, these forces are generally driven by globalization. Fundamental changes are taking place in the global landscape caused by, for instance, the restructuring of global economy, rising world population, and depleting natural resources, along with concerns relating to the environment and climate change. Cities, although only occupy about 2-3% of the Earth's land mass, are responsible for 75% of the global energy consumption and 80% of the world's greenhouse gas emission[8,9]. In addition, they consume 75% of the world's natural resources and produce 50% of global waste. Furthermore, up to 75% of global economic output emanates from the cities[10,11]. As such, cities are commonly regarded as the primary engine of the country's economy, but they are also accountable for much of the global consumption, pollution and wastage issues. This explains why countries around the world are often being called forth to engage their cities as the central focus in addressing these global issues, in order to ensure sustainability for the future generations. Besides the pursuit of global sustainability, cities in various countries also need to be globally competitive in view of economic globalization[12]. To do this, different civic measures such as drawing foreign investments, creating new-growth industries, attracting creative class[13], retaining local talents, and others were put in place in the cities. Essentially, cities are not only competing with their neighbors on a national stage, but also with their peers, on the other side of the world, in the international context.

3.2. City-Level Micro Driver (Urbanization)

Whereas, the micro driver behind smart city, which can be perceived from a city-level standpoint, is a set of internal forces derived and imposed from inside the city. These forces are largely driven by urbanization. According to the

United Nations report on World Urbanization Prospects[14], for the first time in history, since 2007, the global urban population has exceeded the global rural population. In other words, more people now live in urban areas than in rural areas globally. Over the past decades, cities around the world have gone through a process of rapid urbanization. In 1950, only less than 30% of people worldwide lived in the cities. But in 2014, this number has reached 54% of the world's population, and is projected to continue to grow to as much as 66% of the world's population by 2050. To put this into context, this is almost a complete reversal of the entire global rural-urban population distribution from the 1950 (ratio 70:30) to the 2050 (ratio 34:66). Such unprecedented urbanization can be traced to two main causes: (1) In-migration: a large-scale migration from rural areas to urban areas as a result of mechanization (caused predominately by push-based migration), and (2) Immigration: a large-scale migration from foreign rural areas to home urban areas motivated by economic reasons (caused predominately by pull-based migration). Although, due to economies of scale, a number of applications and services are better provided in populated urban areas, this rapid as well as massive influx of new citizens presents several overwhelming and hard-pressed challenges to the limited resources of the cities' internal urban systems - for instance, the delivery of basic services, the maintenance of urban infrastructures, the operation of education functions, the provision of healthcare facilities, the uphold of public safety, and many others. In addition, accompanying this continual influx is a growing shift in the population demographic. That is, a gradual increase in the proportion of aged people alongside a steady decline in the proportion of young people. In fact, the ratio of aged people (over the age of 60) to young people (under the age of 15) is expected to triple, from 33 per hundred in 2000 to 101 per hundred in 2050[15]. This general ageing of the population will therefore pose additional pressure on the existing cities' social and health care infrastructures, which can consequently compromise their abilities to serve and keep up with the needs of their elderly citizens.

3.3. Citizen-Level Nano Driver (Transformation)

Finally, the nano driver behind smart city, which can be perceived from a citizen-level standpoint, is a set of underlying forces derived and imposed from underneath the city. These forces are driven by the inherent transformation in the lifestyles of the citizens themselves, brought about by the core of Information Revolution. According to the International Telecommunication Union (ITU) report on "Measuring Information Society"[16], the past years have witnessed a persistent and almost universal growth in Information and Communication Technologies (ICT) uptake worldwide; so much so that there are, for instance, nearly as many mobile phone subscriptions as there are the number of people in the world at the end of 2011. This accelerated penetration of ICT diffusion internationally has, as a consequence, resulted in a fundamental change in the lifestyles of the people, particularly among the more digitally-literate citizens commonly residing in the cities. It effectuates a transformational change in their day-to-day interactions with the urban systems; in other words, the way they live, work, learn, and play within the city. The citizens hence become more accustomed in expecting the receipt of right information, at the right place and at the right time (i.e. information-push); or in demanding the delivery of required information through anytime, anywhere services via any devices (i.e. information-pull), within the urban settings. In the information age, such transformation is infectiously widespread, driven by information exchanges and connections through, for instance, social-based application and services (e.g. social medias/social networking sites). With the gradual shift in the people consumption from a tangible product orientation towards an equally-important intangible service orientation, more emphasis should thus be placed on the latter intangibles so that the urban systems can progress coherently with the needs of the citizens within the city landscape.

Overall, cities around the world are facing several multifaceted challenges in addressing the above emerging issues brought about by the three spheres of influence: Globalization, Urbanization and Transformation; each of which is of significance from a macro (country), micro (city), or nano (citizen) perspective, in driving the mass-uptake of smart cities across the continents. Their goal is to devise smarter solutions in the effective management of the cities so as to be able to cope with the massive tensions built-up in the three spheres simultaneously.

4. The Definitive Framework of Smart Cities

Note that although smart cites have been well studied and researched for quite some time now, there isn't yet a consensus in a formal definition of smart city among the researchers and practitioners. This is due to the inherent concept of smart city which is not only interdisciplinary but also broad and all-encompassing in nature. For instance, the IEEE Smart Cities has adopted the definition provided by Giffinger *et al.*, who has defined smart city in terms of its six smart characteristics:

> "A city well performing in a forward-looking way in economy, people, governance, mobility, environment and living, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens"[17].

Whereas, the ITU Focus Group on Smart Sustainable Cities has devised its own definition, following an analysis of a wide number of existing definitions, given as:

> "A smart sustainable city is 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 and environmental aspects"[18].

Other key definitions, commonly cited in the literatures,

are tabulated, according to its categorical sectors, as shown in Table 1.

Table 1. Some key definitions of smart city

Academic	"A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" * [19]. * *Note that the above definition by Caragliu et al. is essentially derived from that of Giffinger et al.*
Industry	"A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city" [20].
Government	"A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/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" [21].

Notice the definitions across the three categorical sectors differ from one another significantly, depending on their associated standpoints and perspectives. Additionally, there exist several other smart city's definitions and frameworks put forward by other proponents, which are established solely around their individual core competencies or understandings. These are largely attributed to the ambiguity of the smart city concept, causing its definition to be diversely heterogeneous. Nevertheless, many have followed the definitive frameworks of Giffinger *et al.*, as well as Caragliu *et al.*, which are deemed to be comparatively more objective and comprehensive in scope (with impact areas covering from education to healthcare and several other domains). To be in line with the majority of the reported research literatures, this paper has likewise adopted their works, with an operational definition of the construct delineated as follow:

> "A smart city is a city that uses technologies and other means to realize and incorporate smart economy (competitiveness), smart people (social and human capital), smart governance (participation), smart mobility (transport and ICT), smart environment (natural resources) and smart living (quality of life), in a holistic manner via participatory citizens".

For ease of reading, the exemplifying elemental-factors that made up the six smart characteristics of smart city, as stated in the definition, is as depicted in Figure 3. In fact, Cohen has also further developed these six smart characteristics into a Smart City Wheel (taken from the smart cities' ranking work by Giffinger *et al.*), which is basically an encapsulation of a set of Key Performance Indicators (KPIs) of the framework, as an overall measure of the city's Smart City Index [22].

However, take note that each of the above characteristics does not exist in isolation; instead, each aids to form an integral and synergetic part of the larger smart city system that is greater than the sum of its whole. For instance, "creativity"

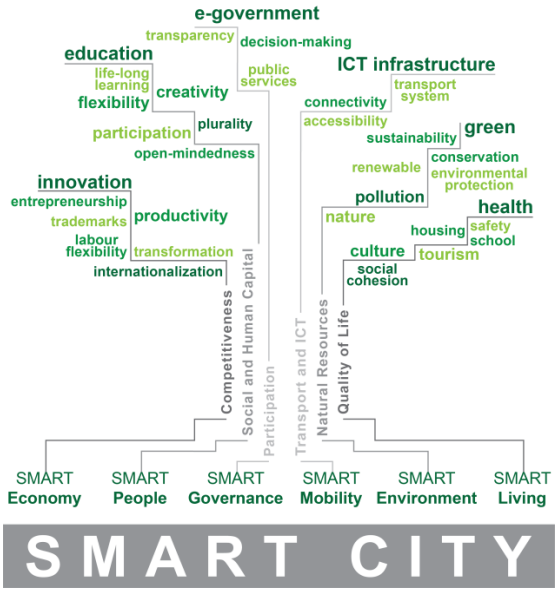

Figure 3. The smart city tree's six-pillar framework

in Smart People can drive great "innovation" in Smart Economy; likewise, "innovation" in Smart Economy can inspire further "creativity" in Smart People. The complex network of intra- and inter-relationships of each of the six characteristics, via multiple bi-directional interactions (i.e. "influenced by" and "influence to") among its different factors, helps to constitute the city as an integrated whole. None of which can be isolated or emphasized at the expense of the others, in the holistic roadmap towards smarter city. Note also that there are other definitive frameworks to understanding smart city as well. Some of the most commonly-cited include Chourabi *et al.*'s eight smart city dimensions that are made up of (1) Technology, (2) Management & Organization, (3) Policy, (4) Governance, (5) People & Communities, (6) Economy, (7) Built Infrastructure, and (8) Natural Environment [23]; as well as Nam and Pardo's three smart city dimensions that are made up of (1) Technology, (2) People, and (3) Institutions [24].

5. The Innovation Challenges in Smart Cities

Now, there are two key fronts that one can play in smart city innovation; in sum, they can be categorized as (a) Product Innovation and (b) Process Innovation. The former can be viewed as an internalized innovation that focuses more on smart goods or services in the uptake of smart cities; and the latter can be viewed as an externalized innovation that focuses more on smart implementation or deployment method in the uptake of smart cities. Both are equally important in order to realize and ensure an efficient and effective adoption of the intended smart city initiative in the city.

5.1. Product Innovation

A city can only be rightfully termed as smart if it is able to extract and exploit its underlying city's intelligence, for the provision of smart applications and services in the city; and such intelligence is in turn gathered from the flow of physi-

cal and virtual sensory information crisscrossing throughout the overall digital grid of the city. In fact, without this added 'intelligence' exploitation, its "smart city" labeling can only be pronounced as a hype, with the city taken to be functioning as per normal, as with the operation of other traditional cities. That is why a city that integrates its digital infrastructure with the physical one is often reckoned to be fundamental in the development of smart cities. The ubiquitous interweaving of its digital and physical fabric is as like seamlessly forming a digital skin over the physical city; it aids to enable the city to constantly harness the power of information within its grid, in order to collect, integrate, analyze, optimize and decide its corresponding actions intelligently. It also helps to provide an elucidation into how its city work, where its city has problems, and what types of solution can be applied in its city. The use of ICT is, as such, often regarded as the key enabler in smart city. Without it, the entry barrier towards the realization of smart city would be rather high; in other words, the ease of entry of smart city increases with respect to the availability and quality of the ICT infrastructure within the city. In fact, some have even termed ICT as the basic operating system of smart city. It introduces a new paradigm of interactions, anytime, anywhere, and anyhow, by anything or anyone in the city (whether it is people to people, people to things, things to things, or things to people). Unlike the past eras which demand the physical movement or presence of the relevant entities to bring about the necessary interactions, the information age has essentially expedited the process by capturing and accelerating the flow of information within the network. Now this is critical, as such information-flow is synonymous with the life-blood of the city that helps to supplement and accelerate the growth of the city. Hence, crippling the information network is no difference to blocking the transportation network of the city; it is analogous to clogging the main arteries, veins and capillaries of a human body, which is known to be detrimental to the advancement of city development in the information age.

In a similar essence, IBM has outlined three foundational concepts of smart city, namely Instrumented, Interconnected, and Intelligent[20]. Instrumented refers to the different sources of real-world data from both the physical and virtual sensors; Interconnected refers to the integration of those data into a computing platform and the communication of such information among the various city services; and Intelligent refers to the inclusion of analytics, modeling, optimization, and visualization in the urban processes to support better decision-making. From a macro-level perspective, a smart city can hence be treated as a 'system of systems'[25]. A system that is made up of a set of interdependent 'city-function' systems (from across the different domains of the smart city framework), connected synergistically together to improve the planning, management and operation of the city. Specifically, with reference to the above three foundational concepts, there are five main areas of technical challenges that can be derived in the field of smart city. In fact, the various technological works and advances in smart city can be broken-down and classified into at least one or more of the following aspects: (1) **S**ensing, (2) **M**anaging, (3) **A**nalyzing, (4) **R**esponding and (5) **T**o Sensing, termed herein as the SMART innovation challenges of smart city. For ease of understanding, Table 2 details a brief exemplification of the five aspectual challenges mapped across the three foundational concepts of smart city. Note that the SMART technological innovation model can be applied in applications and services, as big as, for instance, a smart healthcare syndromic-surveillance platform to guard against disease-outbreak invading into the city; or as small as, for instance, a smart street-lighting system to self-govern its daily operation and preventative maintenance automatically.

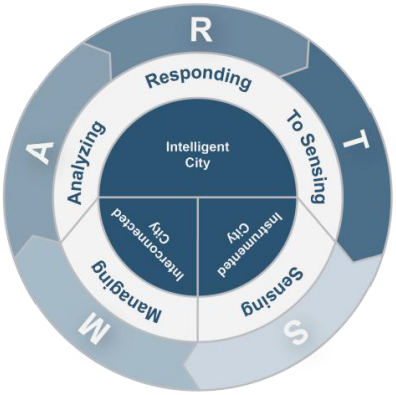

Figure 4. The SMART technological innovation model.

As a summary, Figure 4 illustrates the SMART innovation model in relation to the three smart city foundations. It first starts with the '**s**' (i.e. 'sensing') of an instrumented city which is concerned with the generation of data through the broad spectrum of sensory technologies overlaying the city, followed by the '**m**' (i.e. 'managing') of an interconnected city which is concerned with the collection and dissemination of data throughout the various city functionalities, and finally ends with the '**art**' (i.e. 'analyzing', 'responding' and 'to sensing') of an intelligent city which is concerned with the computation of data, via analysis or synthesis (in conjunction with different "what if" scenarios), so as to trigger smart action/intervention/decision, within a closed-loop or open-loop smart city system. Its purpose is to expose its base raw-data layer, extract its associated useful-information layer, and transform it into its corresponding insightful-knowledge layer, within the 'data → information → knowledge' progression in smart city. This is analogous to the function of a biological body via first (a) capturing all the relevant data sensed by the sensory organs of the body, such as the eyes, ears, nose, tongue, and skin; then (b) receiving and transmitting the data through the nerves of the central nervous system; and finally (c) processing the data by the neurons in the brain to govern the internal and external operation of the body. With that, the different micro-level data generated from each of the cellular functions can then be collated and aggregated to reveal its associated macro-level pattern and abstraction, so that the mind can prioritize and react in a coordinated manner in order to

Table 2. Exemplar of SMART innovation challenges

Instrumented	**S**	**Sensing** Data underpins all functionalities of smart city. How do we sense this vast quantity & variable quality of data generated by our daily activities remains a major challenge. The trade-off between cost and reliability is one of the key factors of consideration, whether the devices are infrastructure-based or infrastructure-less sensing technologies. As such, a series of research into virtual sensing has arisen as an economical alternative to physical sensing. In addition, people are the central focal point in the transformation into a smart city. In the human-city interaction, they are not only key consumers of data, but also important providers of data, both about themselves as well as their environments. As a result, the use of human as sensor has also been looked-into with the intention to achieve a relatively inexpensive but reasonably accurate large-scale fine-grained sensing. But take note that the employment of these physical/virtual-sensing and social/crowd-sensing are in fact complementary with one another. The former can help to provide the content of the sensed information (e.g. what, when, where), whereas the latter can aid to supplement the context of the sensed information (e.g. why, how), in order to ascertain a more complete picture and comprehensive understanding of the data. However, great care has to be taken in the exploitation of participatory sensing (i.e. sensing with prior-awareness of the users) vs. opportunistic sensing (i.e. sensing without prior-awareness of the users) as part of the integral sensor fabric of the city.
Interconnected	**M**	**Managing** The primal concern in managing smart city is in the inter-connection of the city nervous system, namely the collection of data from the variety of sensing technologies as well as the dissemination of data to the diversity of city functions. Its challenge lies in the need to harmonize the heterogeneity of sensors as homogeneous things in the smart city system, and the need to ensure a safe and secure delivery of information to the different smart city's applications and services. To do this, the requirement for common standards among the heterogeneous sensors, and interoperability across the various sectors are therefore essential. Apart from that, security measures and access-control mechanisms have to be put in place to prevent any privacy breaches in smart city; additionally, legislative policies have to be designed and implemented to protect the rights of the users in the system. Note that each of these safety and security steps is significant particularly with the availability of open public data, in conjunction with the gathering of closed private data, all inputted, amalgamated, and distributed within the smart city ecosystem. Without them, the basic trust and confidence among the different entities cannot be built, which will consequently lead to the gradual breakdown in the whole collection and dissemination of data throughout the entire interconnected system.
Intelligent	**A**	**Analyzing** The main core of smart city is in the 'intelligent' foundation. It is the only smart brain of the city in analyzing (as well as synthesizing/optimizing/simulating/etc) the city dynamics in order to draw in-depth insights in understanding the city. The smart city analytics can span across several fields, such as Data Science (e.g. to realize the value of the data), Big Data (e.g. to account for its volume, variety, velocity, and veracity), and Data Analytics (e.g. to analyze its content and context over the space, time, and/or frequency dimensions). All of which are set to process the data so as to elucidate its underlying intelligence to improve the city operation.
	R	**Responding** Following that, corresponding response has to be actioned in the smart city system, according to the given intelligence. There is no point carrying out the smart city analytics, if they are not going to be acted upon to produce the intended output-outcome based on the raw input-data. Such response can either be done manually by a human operator or automatically by a machine agent; it includes, for instance, the exploitation of the given insights to view and make well-informed decision (the current), to review and rectify the situation (the past), or to anticipate and take proactive action (the future), with the limited resources available in the city.
	T	**To Sensing** Upon responding to effectuate the desired outcome in the city, the whole cycle then reiterates itself and goes back to sensing. This constitutes a continual closed-loop setup, with any necessary adjustments made to adapt the behavior of the system automatically to suit the ever-changing environment. Unlike a one-off open-loop setup that is sometimes utilized for certain applications & services, a closed-loop smart city system has the ability to self-monitor/diagnose/govern itself continuously. However, several issues and concerns remain in the determination of the balance between the autonomy and dependency, as well as trust and control, of the system.

ensure the overall healthy growth and sustainability of the body.

5.2. Process Innovation

Note that every city is different, with its own past history, present consideration, and future development. As a result, each city is unique in its uptake of smart city, depending on its needs, challenges, and priorities faced, at that period of time. In other words, each and every city has to evaluate its own needs, assess its own challenges, determine its own objectives, prioritize its own activities, coordinate its own resources, and establish its own metrics, in accordance to its particular time-frame and positioning in its overall roadmap towards smart city. There are therefore no one-size-fits-all KPIs for all cities [26]. Instead, each city has its own specific set of quantitative and qualitative KPIs, specially laid out based on its priorities at that time, to measure, guide and drive the overall smartness of its city. Nonetheless, the methodology in setting the indicators for every city, in order to be effectual, have to fulfill the SMART criteria; that is, its formulated indicators need to be Specific, Measurable, Achievable, Relevant and Time-bound [27].

There are a various number of approaches in the uptake of smart city, even though all of them are aiming and working towards the same smartization target. Generally, there are four common classifications, often mentioned in the literatures, in the introduction and implementation of smart city initiatives, as depicted in Figure 5. First is the top-down approach driven by the government (where the city officials and government agencies decide and define the smart city vision), second is the bottom-up approach driven by the citizens (where the people participate in the co-creation of the smart city development), third is the technology-push approach driven by the providers (where the solution providers or vendors push smart city's systems and technologies in accordance to their core competencies), and fourth is the market-pull approach driven by the consumers (where the end-users pull smart city's applications and services in accordance to their needs). Notice that on one end of the 'top-down' spectrum, the government typically has more control over its smart city progression; but its high-level smart city vision, which is defined by a few top decision makers, might not be able to accurately address the complex interactions and priorities reflected at the bottom. Whereas, on the other end of the 'bottom-up' spectrum, the smart city progression, which is rooted and arisen from the bottom, is generally more relevant to the people; but its diverse smart city advancements might be too fragmented and could not be coordinated synergistically upwards. Similarly, on one end of the 'technology-push' spectrum, the solution providers would normally have more say and control over the input of smart city's systems and technologies, extracted or mod-

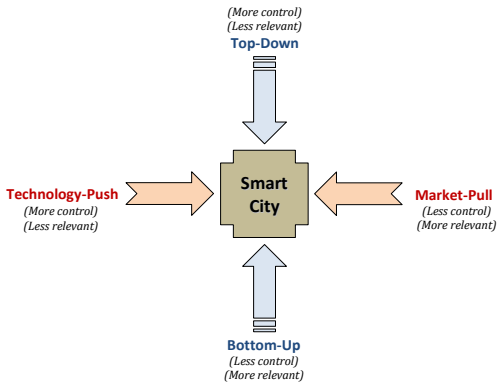

Figure 5. Classification in the approaches towards smart city

Figure 6. Public-Private-People Partnership (4P)

ified from their portfolios/capabilities; but their provisions might not be necessarily relevant to the consumers or essential to the market. Whereas, on the other end of the 'market-pull' spectrum, the smart city's applications and services are specifically demanded by the end-users to meet their various needs within the city; but their disparate requirements might appear quite scattered and incoherent to the providers. To avert these and to be successful in the uptake of smart cities, one should therefore adopt a middle-ground compromised approach by involving and integrating the government, businesses and users concurrently, which many have termed it as the public-private-people partnership (4P) [28,29], as illustrated in Figure 6.

Hence, in addition to the product innovation described in the previous section, creative ideas and novel solutions in the above process innovation are also critical in order to ensure the successful deployment of smart city in the city. Its key success factor is to include the various stakeholders as active agents in the process of change, rather than as passive subjects in the smart city progression. To facilitate this, the notion of an open and user-centered innovation approach for smart city has thus emerged. In here, open innovation [30] refers to the opening up of the innovation processes for the inflows and outflows of knowledge to facilitate the internal acceleration of innovation as well as the external exploitation of innovation; and user-centered innovation [31] basically refers to user-driven innovation that is set to fully engage the end-users across all phases of the innovation process, in a proactive and co-creative manner. The use of urban living labs [32–35] is one example of such open and user-centered innovation ecosystem that is founded on a public-private-people partnership, where Komninos *et al.* have summed it as "cities as living labs for open innovation" [36]. The initial concept of living labs was first originated in MIT, with the objective of turning the targeted users as not only observed subjects, as in a traditional testbed, but also as sources of creation in a living laboratory [37]. It helps to bring all the different relevant stakeholders together and stimulate a collaborative environment for co-creation right from an early stage of the research and innovation process. In other words, the use of the urban living labs can act as a compromise between the 'top-down' and 'bottom-up' approaches, as well as a bridge between the 'technology-push' and 'market-pull' counterparts, in order to harness its inherent collective intelligence within a real life environmental context.

As such, a successful smart city should be originated and co-created by a well-integrated partnership; and not by a small handful dictating and directing its course of direction. It is a tripod comprising of the government, industry and academia, with the participation of people forming the heart of the tripod partnership. In fact, as widely noted in the literatures, one of the important components of success in the deployment of smart cities is the inclusion of "people" in the public-private-people partnership. The integrative partnership framework embraces the participatory involvement of the users, which is a way to constantly tap into the extensive innovative potential of the general population. Its main idea here is to involve the citizens at every stages of the smart city development, so that the city can grow smart organically, according to their overall needs and requirements. After all, smart city is for the people; there will be no smart city without the support of its citizens. It is therefore efficacious to include the citizens as engaged actors in the end-to-end process of the smart city development. Otherwise, its smart city advancement would inadvertently cause unnecessary issues such as user-disengagement or digital-divide in the city - a clear contradictory disparity in its original set out towards a smart city. With the provision of the right platform and tools, the citizens can play an active role in the evolution of their city, whether it is to include the citizens in the decision-making process of their city, or to support the citizens in the co-creation of their city. However take note that it is simply impossible to involve everyone within the city, which will inevitably lead to the selective inclusion of some or unintentional exclusion of others. Nevertheless, its resulted outcome, innovated through a multitude of individuals and/or groups or communities, via a balance between cooperation and competition, is still envisaged to be synergistically better than the simple sum of its parts. In addition, a smart city is nothing without the people forming its basis. The complex interactions between the city and its inhabitants constitute the fundamental digital layer of the city. Hence, apart from the above, the people also play an important participatory role in the capturing, delivering, and generating of data within the digital grid; all of which are significant and can

be collected and gathered as crowd-sourced information for smart city. That is why, a smart city should always put the people first; in other words, a smart city is a citizen-centric city that always places the citizens at the center of the innovation ecosystem.

But no one can do it alone, not even the stakeholders. The broad challenges of smart city are just too great for any single organization or government to take up the initiative itself. Nonetheless, the government can act as a catalyst in stimulating an open and collaborative environment among the public-private-people partnership by, for instance, making available to them the access to open data. Such partnership can then help to alleviate the "information island" problem - a common and imminent problem in the breaking up of the digital-grid among the different smart city functions. This phenomenon normally surfaces and can be classified into three broad observations: (a) the data is available but it is not being tapped, (b) the data is tapped but it is not being processed, and (c) the data is processed but it is not being actioned. The occurrence of such phenomenon is due to the way the various city functions are inherently organized, causing the data-flows within each of the different sectors to be somewhat vertically heterogeneous and not associated with one another. That is, the different city functions typically tend to operate in silos based on what they specialize in, and normally insulate from one another in their provision of smart applications and services within the city. As like the biological-body analogy, the function of the hands will not consciously cooperate with the function of the legs synergistically, without the prior intermediation of the central brain constantly tapping, processing and actioning the entire coordination of the body. Hence for the entire city to function properly as an overall healthy system, clever and innovative partnerships among the various parties are therefore critical in order to ensure the holistic uptake of smart city.

5.3. Concluding Remarks

The new paradigm brought about by the 'city smartization' period has ushered in a wealth of opportunities ahead of us, only if we could think and act smartly. There are a number of strong external and internal drivers that are forcing smart cities to happen, which have consequently pushed many cities into taking action in order to be part of the 'smart' bandwagon. But the uptake of smart city is still rather immature and ill-defined. At the moment, the definitions of smart city, as well as its frameworks, are still evolving; and there are yet any formal methodologies and systematic metrics to assess the value or to measure the performance of smart city. In addition, the entry to smart city is also confronted with a number of hurdles, namely the political (e.g. the attribution of power and control among its stakeholders), technical (e.g. the interoperability of its heterogeneous systems and technologies), and financial (e.g. the justification of its return on investment) barriers. Many proponents have therefore taken a rather long term view in the overall roadmap towards smart city, with its immediate return value rationalized in terms of its public civic-value rather than its private economic-value. Nonetheless, looking at the point in time that we are residing in, in relation to the span of the 'city smartization' period, our route to smart city is still at its infancy phase of development, where much of its hidden potential has yet been unlocked and remains to be fully realized.

According to Forrester Research, "Smart city solutions must start with the 'city', not the 'smart'"[38]. This paper has delineated two forms of innovation that can be conducted in the field of smart city: (1) Product innovation based on the SMART technological framework, and (2) Process innovation based on the 4P partnership model. The former is pertaining to 'how to do smart city with emphasis placed more on creating its technological content'; and the latter is pertaining to 'how to do smart city with emphasis placed more on putting it into context'. Both innovation fronts are complementary to one another in order to ensure and put forward a more complete realization of smart city that actually meets all the particular needs of that particular city at that particular time. These can be applied whether it is for the development of new green cities (such as Masdar City[39] and Songdo IBD[40]) or the redevelopment of old brown ones (such as London[41] and Hong Kong[42]). The only main difference is that the new cities are created as smart where their essential infrastructures might be too undeveloped or unavailable; while the old cities are regenerated as smart where their existing infrastructures might be too rigid or restrictive.

Lastly, as a closing statement, bear in mind that the road towards smarter city is not a one-off process but an evolutionary one. First we shape our city, then our city shape us - it is a perpetual inter-looping cycle of innovation, with the city acting as real-world civic laboratory for continual development and transformation.

References

[1] Hollands R G, 2008, Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City: Anaysis of Urban Trends, Culture, Theory, Policy, Action*, vol.12(3): 303-320. http://dx.doi.org/10.1080/13604810802479126

[2] Gibson D V, Kozmetsky G and Smilor R W eds, 1992, *The technopolis phenomenon: Smart cities, fast systems, global networks*. Rowman & Littlefield, Lanham.

[3] Mahizhnan A, 1999, Smart cities: The Singapore case. *Cities*, vol.16(1):13-18. https://doi.org/10.1016/s0264-2751(98)00050-x

[4] Saint A, 2014, The rise and rise of the smart city [Smart cities urban Britain]. *Engineering & Technology*, vol.9(9):72-76. https://doi.org/10.1049/et.2014.0924

[5] Bakıcı T, Almirall E and Wareham J, 2013, A smart city initiative: The case of Barcelona. *Journal of the Knowledge Economy*, vol.4(2):135-148. https://doi.org/10.1007/s13132-012-0084-9

[6] Lee J H and Hancock M, 2012, Toward a framework for smart cities: A comparison of Seoul, San Francisco and Amsterdam. *Innovations for smart green cities: What's working, what's not, what's next*, 26-27. https://doi.org/10.1016/j.techfore.2013.08.033

[7] Al-Hader M , and Rodzi A, 2009, The smart city infrastructure development & monitoring. *Theoretical and Empirical Researches in Urban Management*, vol.2(11):87-94. http://www.jstor.org/stable/24872423

[8] Tibaijuka A K, 2007, The future in our hands: Addressing the leadership challenge of climate change. *Contribution of the United Nations human settlements programme*, UNHABITAT, New York.

[9] UN-Habitat, 2011, *Cities and climate change: Global report on human settlements 2011*. Earthscan, London.

[10] UNEP, 2012, *Global Initiative for Resource-Efficient Cities - Engine to Sustainability*. United Nations Environment Programme, Nairobi.

[11] UNEP, 2012, *Sustainable, Resource Efficient Cities - Making it Happen!* United Nations Environment Programme, Nairobi.

[12] Porter M E, 1990, The competitive advantage of nations. *Harvard Business Review*, vol.68(2):73-93. https://doi.org/10.1007/978-1-349-11336-1

[13] Florida R, 2002, *The rise of the creative class-and how it's transforming work, leisure, community and every day life*. Basic Books, New York.

[14] United Nations, 2014, *World Urbanization Prospects: The 2014 Revision, Highlights*. Department of Economic and Social Affairs-Population Division, United Nations, New York.

[15] United Nations, 2002, *World Population Ageing: 1950-2050*. Department of Economic and Social Affairs-Population Division, United Nations, New York.

[16] ITU, 2012, *Measuring the Information Society*. United Nations specialized agency for Information and Communication Technologies (ICT) - International Telecommunication Union, Geneva.

[17] Giffinger R, Fertner C and Kramar H, *et al.*, 2007, *Smart Cities - Ranking of European medium-sized cities*. Vienna University of Technology, Vienna, 1-12.

[18] ITU-T, 2014, *Smart Sustainable Cities: An Analysis of Definitions*. Telecommunication Standardization Sector of International Telecommunication Union, Geneva.

[19] Caragliu A, Del Bo C, and Nijkamp P, 2009, "Smart Cities in Europe", *Proceedings of the 3^{rd} Central European Conference in Regional Science*. https://doi.org/10.1080/10630732.2011.601117

[20] Harrison C, Eckman B and Hamilton R, *et al.*, 2010, Foundations for smarter cities. *IBM Journal of Research and Development*, vol.54(4):1-16. https://doi.org/10.1147/jrd.2010.2048257

[21] Hall R E, 2000, The vision of a smart city. *Proceedings of the 2^{nd} International Life Extension Technology Workshop*. Upton, New York.

[22] Cohen B, 2012, What exactly is a smart city. *Co. Exist, 19*.

[23] Chourabi H, Nam T and Walker S, *et al.*, 2012, Understanding smart cities: An integrative framework. In *System Science, 45^{th} Hawaii International Conference on, HICSS 2012*, 2289-2297. IEEE. https://doi.org/10.1109/hicss.2012.615

[24] Nam T and Pardo T A, 2011, Conceptualizing smart city with dimensions of technology, people, and institutions. *Proceedings of the 12^{th} Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*, 282-291. https://doi.org/10.1145/2037556.2037602

[25] Naphade M, Banavar G and Harrison C, *et al.*, 2011, Smarter cities and their innovation challenges. *Computer*, vol.44(6):32-39. https://doi.org/10.1109/mc.2011.187

[26] ITU-T, 2015, *"Key Performance Indicators Definitions for Smart Sustainable Cities"*. Telecommunication Standardization Sector of International Telecommunication Union, Geneva.

[27] Doran G T, 1981, There's a SMART way to write management's goals and objectives. *Management Review*, vol.70(11):35-36.

[28] Schaffers H, Komninos N and Pallot M, *et al.*, 2011, Smart cities and the future internet: Towards cooperation frameworks for open innovation. *Future Internet*, 431-446. https://doi.org/10.1007/978-3-642-20898-0_31

[29] Komninos N, Schaffers H and Pallot M, 2011, Developing a policy roadmap for smart cities and the future internet. In *eChallenges e-2011 Conference Proceedings*. IIMC International Information Management Corporation, Dublin.

[30] Chesbrough H W, 2006, *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press, Boston.

[31] Von Hippel E, 2005, Democratizing innovation: The evolving phenomenon of user innovation. *Journal für Betriebswirtschaft*, vol.55(1):63-78. https://doi.org/10.1007/s11301-004-0002-8

[32] Niitamo V P, Kulkki S and Eriksson M, *et al.*, 2006, State-of-the-art and good practice in the field of living labs. In *Technology Management Conference (ICE), 2006 IEEE International*, 1-8. IEEE. https://doi.org/10.1109/ice.2006.7477081

[33] Schumacher A J and Feurstein B K, 2007, Living labs - A new multi-stakeholder approach to user integration. *Enterprise Interoperability II: New Challenges and Approaches*, 281-285. https://doi.org/10.1007/978-1-84628-858-6_31

[34] Kusiak A, 2007, Innovation: The living laboratory perspective. *Computer-Aided Design and Applications*, vol.4(6):863-876. https://doi.org/10.1080/16864360.2007.10738518

[35] Cosgrave E, Arbuthnot K and Tryfonas T, 2013, Living labs, innovation districts and information marketplaces: A systems approach for smart cities. *Procedia Computer Science*, vol.16:668-677. https://doi.org/10.1016/j.procs.2013.01.070

[36] Komninos N, Pallot M and Schaffers H, 2013, Open innovation towards smarter cities. In *Open Innovation Yearbook 2013, Directorate-General for Communications Networks, Content and Technology.* Publications Office of the European Union, Luxembourg.

[37] Intille S S, Larson K and Beaudin J S, *et al.*, 2005, A living laboratory for the design and evaluation of ubiquitous computing technologies. In *CHI'05 extended abstracts on Human factors in computing systems*, 1941-1944. ACM. https://doi.org/10.1145/1056808.1057062

[38] Bélissent J, 2010, *Getting clever about smart cities: New opportunities require new business models*. Forrester, Cambridge.

[39] Cugurullo F, 2013, How to build a sandcastle: An analysis of the genesis and development of Masdar City. *Journal of Urban Technology*, vol.20(1):23-37. https://doi.org/10.1080/10630732.2012.735105

[40] Lindsay G, 2010, *Cisco's big bet on New Songdo: Creating cities from scratch*. Fast Company, New York.

[41] Willems J, Van den Bergh J and Viaene S, 2017, Smart city projects and citizen participation: The case of London. In *Public Sector Management in a Globalized World*, Springer Fachmedien, Wiesbaden, 249-266.

[42] Govada S S, Spruijt W and Rodgers T, 2017, Assessing Hong Kong as a smart city. *Smart Economy in Smart Cities*, Springer, Singapore, 199-228.