SMART CITY Smart City Global Journal 2023

TOP Agenda

Smart City Global Journal 2023

Urban Competitiveness through
Digital Transition and Climate Action

KAIA Korea Agency for Infrastructure Technology Advancement

SMART CITY TOP Agenda

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Recommend

Smart City Top Agenda Journal is an excellent publication bringing contemporary and state of the art insights into how different cities are shaping their futures to become more sustainable, connected and dynamic places to live, work and invest.

Smart City Top Agenda Journal은 서로 다른 도시들이 더 지속 가능하고 연결되며 역동적인 삶과 일 그리고 투자의 장소가 되기 위해 미래를 어떻게 형성하고 있는지에 대한 현대적이고도 최첨단의 통찰력을 제공하는 훌륭한 출판물이다.

Roz Hansen
Professor, Faculty of Architecture, Building and Planning, University of Melbourne

Smart City Top Agenda Journal will serve as a platform that presents potential technological solutions to our challenges, as well as discussions from humanities and social sciences. This book sets forth discussions of cities' enduring values and how we can build good cities for future generations - a culmination of civilizations and cultures where citizens live happy lives.

Smart City Top Agenda Journal은 우리가 직면하고 있는 문제의 해결책과 실현 방향에 대한 인문·사회학적 관점과 기술적 논의를 집약한 플랫폼의 역할을 하고 있다. 시민들이 행복한 삶의 장소이자 문명과 문화의 집적체로서 도시의 변함없는 가치를 이해할 수 있는 담론을 펼침으로써 다음 세대를 위한 좋은 도시를 만드는 방법을 우리에게 주지시켜 주고 있다.

Kim, Donyeon
Professor, Dept of Architecture and Global Smart City, Sungkyunkwan University

Generally speaking, cities are at the tipping point where 5G is going to take off paving the way for IoT and AI to empower communities and boost local sustainable development. It is a new dawn for Smart Cities, some would call it sustainable cities, and others are coining it as Cognitive Cities. Personally, I recommend staying ahead of the curve by reading the Smart City Top Agenda Journal's 2023 book, the lighthouse about the approaches that create a positive impact on urban living.

일반적으로 말하자면, 오늘날의 도시들은 5G가 보급되기 시작하면서 사물인터넷(IoT)과 인공지능(AI)을 통해 사회 공동체에 새로운 힘을 부여하고 지역의 지속가능한 개발을 촉진할 수 있는 환경이 조성되기 시작하는 티핑 포인트(전환점)에 있습니다. 이것은 스마트시티를 구현하기 위한 새로운 시작으로 어떤 사람들은 이를 지속가능한 도시(sustainable city)라고 부르며, 어떤 사람들은 이를 인지 도시(Cognitive City)라고 표현합니다. 개인적으로 제가 권장하고 싶은 것은 도시 생활에 긍정적인 영향을 미치는 방법에 관한 지침서로서 'Smart City Top Agenda Journal'의 2023년도 책자를 읽음으로써 남들보다 앞서 나가는 것입니다.

Jorge Saraiva
Chief of European Network of City Policy Labs

I find the latest technical information and visionary wisdom to create a city where people are happy, sustainable. New technologies and policies that are introduced every year contribute to extending the life of the Earth a little longer, making our dreams and imaginations a reality.

사람이 행복한 도시, 지속 가능한 도시를 조성하기 위한 가장 최신의 기술 정보와 선각자들의 지혜를 발견하게 된다. 매년 새롭게 선보이는 기술과 정책은 우리의 꿈과 상상을 현실로, 지구의 수명을 조금 더 연장하는 데 기여한다.

Kim, Kabsung
Professor, Urban Planning and Engineering, Yonsei University

Smart City Top Agenda Journal is an excellent resource for global city policymakers, offering the most current thinking on reimagining the city for the 21st century. It has been a real privilege to participate.

Smart City Top Agenda Journal은 세계적인 도시 정책 입안자들을 위한 훌륭한 자료로 21세기를 위한 도시의 이미지를 재구상하는 것에 대한 가장 최신의 사고를 제공한다. 참여하는 것은 정말 특권이었다.

Mark Watts
Executive Director of C40 Cities Climate Leadership Group

Smart City Top Agenda Journal compiles cutting-edge worldwide on-going smart city related initiatives making it a singular inspiration source for those professionals active in this and other related fields.

Smart City Top Agenda Journal은 전 세계적으로 진행 중인 스마트시티 관련 이니셔티브를 편집하여 이 분야 및 기타 관련 분야에서 활동하는 전문가들에게 영감을 주는 유일한 원천으로 만든다.

Luis Muñoz
Professor, Telecommunications Engineering,University of Cantabria

With an impressive range of contributors and rich, engaging content, I can recommend this journal to anyone interested in the transformative potential of connected place technologies.

인상적인 범위의 기고가와 풍부하고 매력적인 콘텐츠를 통해, 나는 이 저널을 연결된 장소 기술의 변형 가능성에 관심이 있는 사람이라면 누구에게나 추천할 수 있다.

Nicola Yates
CEO of Connected Places Catapult

KAIA assembles a rich and explorative range of thought leaders' ideas in each year's Smart City Top Agenda Journal. It was equally thrilling and humbling to join fellow authors in reimagining the principles cities ought to embody in their pathways to sustainability.

국토교통과학기술진흥원(KAIA)은 매년 Smart City Top Agenda Journal에 풍부하고 탐구적인 사고를 하는 소위 '생각하는 리더'들의 아이디어를 담는다. 도시가 지속되어 나아갈 수 있는 가능성을 위해 구현되어야 하는 원칙들을 다시 구상할 목적으로 같은 스마트시티 전문가들과 함께하게 되어 무척 기쁘고 스스로도 부족한 부분을 채울 수 있는 경험이 되었다.

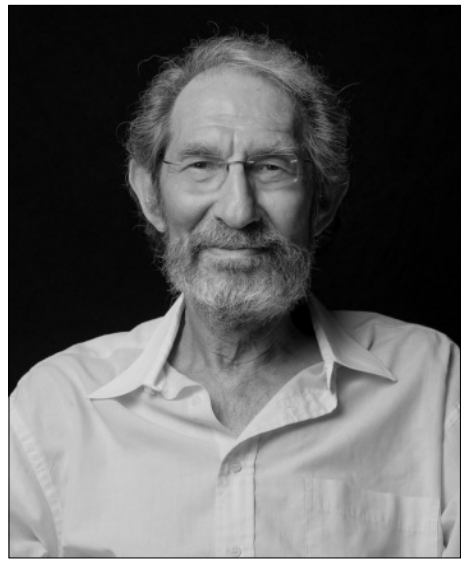
Gino Van Begin & Tim Lazaroff
Secretary General of ICLEI, Local Governments for Sustainability

Developing a Science of Cities:

Growth, Innovation and Sustainability

도시과학 개발:
성장과 혁신, 지속가능성

Geoffrey B. West



Geoffrey West is Shannan Distinguished Professor and former President of the Santa Fe Institute and Associate Senior Fellow of Oxford University's Green-Templeton College. West is a theoretical physicist whose primary interests have been in fundamental questions across physics, biology and the social sciences. His research includes metabolism, growth, aging & death, sleep, cancer, and ecosystems. Recently he has been developing a science of cities and companies, innovation, and long-term global sustainability. West has lectured at many high profile events including TED and Davos. He has received many awards and was featured in numerous publications, podcasts and TV productions. He authored the best-selling book Scale; The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies and was named to Time magazine's "100 Most Influential People in the World" in 2007.

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ABSTRACT

In this paper we review progress towards developing a Science of Cities from the perspective of scaling and network theory. Since cities are the primary source of innovation, wealth creation and power, but also the prime source of crime, pollution, disease, climate change, and the consumption of energy and resources, there is an urgent need for a unifying systemic, quantitative, predictive theory of cities that spans scales from the local to the global. Despite their extraordinary complexity and diversity, cities exhibit a surprising simplicity in how their infrastructural and socio-economic metrics scale with size: wages, patents, crime, disease, social connectivity, transport and utilities all scale similarly across the globe. The mechanistic origin of these "universal" scaling laws, which transcend history, geography and culture, is explained, and related to the underlying principles of urban infrastructural and social networks. The theory predicts that socio-economic metrics, such as wages, patents and crime, scale super-linearly (the bigger the city, the more per capita), whereas infrastructural metrics, such as roads and electrical lines, scale sub-linearly (the bigger the city, the less per capita, expressing a systematic economy of scale). Consequently, the super-linearity of a city's social metabolic rate, driven by positive feedback dynamics of urban social networks, leads to the increasing pace of life and to open-ended, faster than exponential, growth. Left unchecked this leads to a singularity beyond which a city will stagnate, contract, and eventually collapse. To circumvent this requires a continually accelerating systematic succession of interventions, re-inventions or innovations. The advent of big data, machine learning and artificial intelligence is an exciting development in addressing these major challenges. We argue, however, that we will only have truly Smart Cities if they are integrated into and informed by traditional approaches and the bigger conceptual framework of a Science of Cities.

KEYWORDS

Perspective of scaling, Network theory, science of cities, Socio–economic metrics, Growth of cities

초록

이 글은 규모 확장 및 네트워크 이론의 관점으로부터 도시과학을 개발하는 활동의 진전을 되돌아본다. 도시는 혁신과 부의 창출, 권력의 주요 원천인 동시에 범죄와 오염, 질병, 기후변화, 에너지·자원 소비의 주요 원천이기 때문에 체계적이고 계량적이고 예측 가능하며 범위가 지방에서 지구로 확장될 수 있는 도시 이론이 시급하게 요구되고 있다. 도시는 극도로 복합적이고 다양하지만, 놀라울 정도로 단순한 특징이 있다. 바로 도시의 기반시설과 사회경제적 매트릭스, 즉 임금과 특허, 범죄, 질병, 사회적 연결성, 교통, 전력·수도 시설이 전 세계적으로 규모에 따라 확장되는 추세가 비슷하다는 점이다. 역사와 지리, 문화를 초월하여 통하는 이 '보편적인' 확장 법칙의 기계적인 기원은 도시의 기반시설과 소셜 네트워크라는 기본적인 원리로 설명된다. 이 이론이 예측하는 바는 임금과 특허, 범죄 같은 사회경제적 매트릭스가 초선형적으로super-linearly(도시 규모가 더 클수록 1인당 지표가 더 높게) 확장된다는 것이다. 그에 비하여 도로나 전선 같은 기반시설 매트릭스는 저선형적으로sub-linearly(도시 규모가 더 클수록 1인당 지표는 더 낮게) 확장된다. 이는 체계적인 규모의 경제가 발생한 결과이다. 도시의 사회적 신진대사 비율의 초선형성은 도시의 사회적 네트워크의 긍정적인 피드백 동학에 의해 구동되고, 생활 속도의 가속화와 기하급수적인 비율보다 더 빠르고 끝없는 성장으로 이어진다. 제어되지 않을 경우 이런 추세는 특이점을 넘게 되고, 그 이후 도시는 정체되고 수출되며 결국 붕괴될 것이다. 이런 파국을 피하려면 개입과 재발명, 혁신을 계속 가속화하면서 체계적으로 잇따라 실행해야 한다. 빅데이터와 기계학습, 인공지능의 등장은 이런 주요 도전을 해결하는 작업에 있어서 흥미로운 발전이다. 그러나 진정한 스마트시티의 구현은 이들 기술을 전통적인 접근 및 도시과학이라는 더 큰 개념적인 틀과 융합할 때에만 가능하다고 우리는 주장한다.

키워드

규모 확장, 네트워크 이론, 도시과학, 사회경제적 매트릭스, 도시의 성장

Well before the end of this century the overwhelming majority of human beings will be living in urban environments, many in megacities of unprecedented size. When averaged over the next 30-40 years, the continued exponential increase in the world's population will result in about a million and a half people being urbanised every week. This is equivalent to adding a metropolitan area the size of Seoul every two months, a country the size of Denmark every month, or a Germany every year! China, a country that until recently was slow to urbanise, has gone into ultra-high gear on its way to building 200-300 new cities over the next 25 years, each in excess of a million people. At the present rate they will be urbanising the equivalent of the entire US urban population over the next 20–25 years. In addition to this extraordinary migration of people in China, there will be a similar process occurring in Africa and India. The resulting challenge of the ever-increasing needs for energy, materials, food and water, and the inevitable stress on the social fabric will likely dwarf the huge changes wrought by the Industrial Revolution during the 19th century, potentially leading to an existential threat to socio-economic life on our planet.

Furthermore, the time scales for addressing these problems are very short, probably only a few decades. It is in the very nature of the super-exponential growth we are witnessing that the immediate future comes upon us increasingly more rapidly, confronting us with new challenges we typically only recognize after it's too late. It is no accident, for instance, that problems such as global climate change, the availability of clean water, and the degradation of the environment, are now recognized as truly major concerns, if not existential, whereas less than 50 years ago they were barely acknowledged.

Given this, it is no exaggeration to state that the future of humanity and the long-term continuance of the extraordinary socio-economic life we have developed on the planet are inseparable from the fate of our cities. Consequently, it is becoming increasingly urgent that we develop a deeper understanding of the process of urbanization and the dynamics, growth and evolution of cities

in order to provide a principled, credible framework for policy-makers and practitioners who are addressing the challenge of a sustainable planet, where all citizens can have a high quality and standard of living and lead meaningful lives.

Needless to say, understanding cities is a very old subject going back to ancient Greek and Chinese writings, and many others besides. Consequently, a wide variety of perspectives and frameworks have been developed for trying to understand what cities are, how they arose, how they function, and what their future is. Almost all extant theories of the city are largely qualitative, developed primarily from focused studies on specific cities or groups of cities supplemented by narratives, anecdotes and intuition. They are rarely systemic and typically do not integrate issues of their physical infrastructure with those of the socio-economic dynamics of their citizens. The situation, however, is rapidly changing as new developments are being initiated, many stimulated by the advent of Big Data and the vision of Smart Cities, both, perhaps naively, touted as panaceas for solving all of our urban problems. These are extremely important and potentially very powerful techniques, but we need more. We also need to develop a quantitatively computable, predictable and integrated holistic framework for understanding cities at all scales in order to complement both these new developments as well as traditional methodologies. Such a big picture, coarse-grained framework is needed to provide conceptual support for having confidence in using big data, machine learning and artificial intelligence, whose pitfalls are well-known. They alone are not sufficient: big data needs big theory (West, 2013). In a word, we need to develop a Science of Cities (Bettencourt & West, 2010; Batty 2013; West, 2017: Lobo et al., 2020; Bettencourt, 2021).

We tend to think of cities primarily in terms of their physical infrastructure. Indeed, it is typically the buildings, facilities, roads and transport systems that are conjured up when we say the word “city” and these are the prime focus of attention of architects, developers, urban economists, etc. This stands in contrast to the view of the city as a stage, a background set, a catalyst or an engine

for facilitating social interactions. The creation, enhancement and evolution of social networks are what has made cities the most marvellous machine invented by human beings (Glaeser, 2012). It is why cities are the centers of innovation and entrepreneurship, the hubs of wealth creation, and the magnets that attract creative individuals whose interactions lead to new ideas, innovation, growth, and change.

However, despite all of these positive attributes, enhancing the social dynamic is also why cities are the prime centers of negative attributes such as crime, pollution, poverty, disease, the consumption of energy and resources, and consequently the origin of the major challenges discussed above. This dark side of cities can be viewed as an inevitable consequence of the generalisation of the Second Law of Thermodynamics to social systems: loosely speaking, this states that whenever energy is used to create order, as manifested in the positive attributes of a city, then a certain degree of disorder (entropy) is necessarily also created. This production of social entropy cannot be avoided; indeed, a major motivation for developing a Science of Cities is to help administrators, practitioners and planners to quantitatively understand the inevitable inter-relationship among and between the positive and the negative, and to minimize its adverse consequences.

The multitude of issues facing cities, ranging from health, well-being and crime to pollution, finance, development, and business, are often dealt with as if they were autonomous and disconnected from each other, even if their totality is necessarily constrained by overall budgets. For many problems this has worked well but for many others this has led to unfortunate unintended consequences (Jacobs, 1961). Although not always obvious, all aspects of city life are interconnected and inter-related. The study of complex adaptive systems, of which cities are a quintessential example, has taught us to be wary of naively breaking down a system into independently acting component parts and that a small perturbation in one part of the system may have untold consequences elsewhere (Mitchell, 2009; Kempes & West, 2020). An extreme example of this was, and still is, manifested by the Covid

Figure 1. Examples of both physical and social urban networks:
(A) Road transport system; (B) Subway system; (C) Electrical grid; (D) Social network

pandemic: a random fluctuation in a virus in a city in China led, among many other things, to no football in Spain, a shortage of flour in the United States, street demonstrations in France, and the bankruptcy of Hertz rental car, all happening within just a few months! Prior to the pandemic these were considered as independent of each other, but the pandemic made it clear that, despite appearances, even in "normal" times they are actually interconnected, if only very weakly (Kempes & West, 2021).

Given the extraordinary complexity, diversity and apparent individuality of cities, and their need to continually adapt and grow, developing a science of cities is a daunting, if not impossible, task. Nevertheless, some progress has been made. The remainder of this paper is devoted to summarizing some of the results that have emerged from viewing cities through the lens of how they scale with size. Implicitly, this reflects the organization and dynamics of the multiple urban network structures, whether physical or social, through which energy, resources and information are exchanged (Fig. 1).

Much of the scaling/network perspective is inspired by its success in understanding living systems, such as organisms and ecosystems. These have much in common with cities in that they are highly complex and self-sustaining, requiring the close integration of enormous numbers of constituent units that need efficient servicing at all scales. In living systems this is accomplished through branching networks, such as our cardiovascular, respiratory and neural systems (Fig. 2). These networks are typically hierarchical and fractal-like and are presumed to be optimised by the continuous

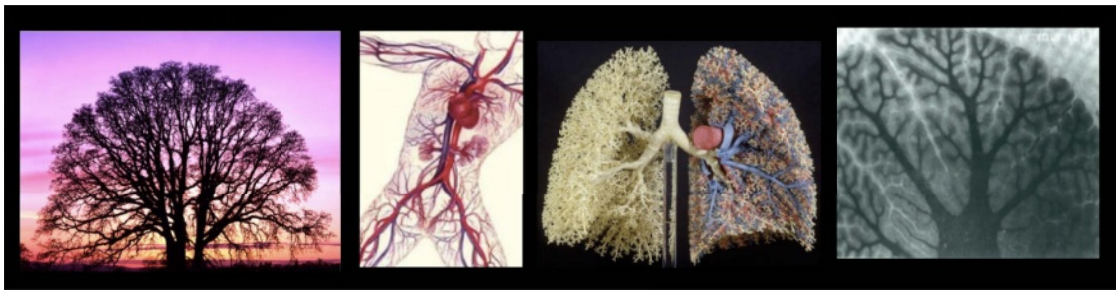

Figure 2. Examples of biological networks; in order:
a tree, the human cardiovascular system, the mammalian respiratory system (lungs), and the mammalian brain

"competitive" feed-back mechanisms implicit in natural selection (West, Brown & Enquist, 1987; Brown et al., 2004; West & Brown, 2005).

The generic mathematical, physical and geometric properties of these networks lead to surprisingly simple and general scaling laws for almost all physiological and life-history characteristics of organisms regardless of their body plan, whether mammals, fish, birds or plants. The most famous and most fundamental of these laws is Kleiber's law for metabolic rate; (this is the amount of energy or food needed per day to sustain an organism). Mathematically, this is predicted to scale as a simple power law with an exponent of ¾: in simpler terms this means that if metabolic rate is plotted logarithmically against mass, then the data should lie on a simple straight line whose slope is ¾. As can be seen from Fig. 3, this is in excellent agreement with data.

Equally important is that similar scaling relationships hold true for almost any organismic characteristic from growth rates and lifespans to lengths of aortas and heights of trees (Calder, 1984; Schmidt-Nielsen, 1984). The corresponding exponents have a "universal" character in that they are all predicted to be simple multiples of 1/4, in agreement with observation; (for example, for heart rates, the exponent is -1/4, and for tree heights it is +1/4). So, despite appearances, all mammals from mice and cats to human beings, giraffes and whales are, to a large degree, scaled versions of one

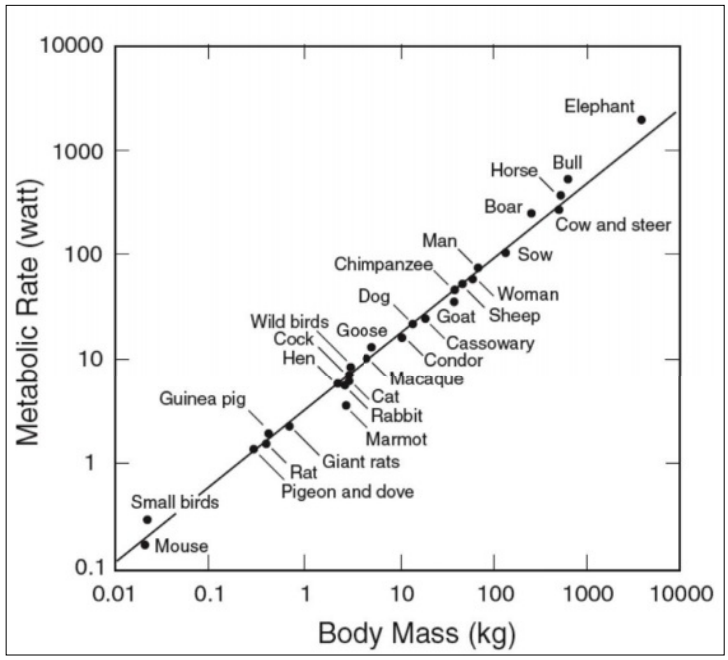

Figure 3. Metabolic rate (in watts) plotted logarithmically against mass (in kg) for a variety of animals; the slope of the line is very close to ¾, as predicted by theory

another, following the non-linear ¼ power scaling laws. It is worth noting that these scaling laws imply a systematic economy of scale: an animal that is twice the size of another, and therefore composed of about twice as many cells, requires only about 75% more food and energy each day, rather than twice as much, as might naïvely have been expected from a linear extrapolation: thus, with every doubling of size, there is a reduction of about 25% in the energy requirements.

The remarkable regularity manifested by these results is extremely surprising from the perspective of natural selection in which each organism evolved in its own unique environmental niche subject to “random, capricious and chaotic” forces. One would have expected the data points to be much more randomly distributed and much less correlated across the graph, reflecting the individuality and historical contingency of the evolutionary process. Clearly, the dynamics of evolution are constrained by the laws of physics.

Do cities obey similar hidden scaling laws? What are the hidden constraints on cities and what, if anything, is being optimized? Like organisms, cities have evolved by some variant of natural selection driven by competitive forces; but also like organisms, they function as network systems. So are New York, Los Angeles, Chicago, New Orleans and Santa Fe, approximately scaled up versions of each other despite looking quite different and with different histories, geographies and cultures?

A comprehensive analysis of data representing a broad spectrum of urban characteristics reveals that this is indeed the case (Kühnert, Helbing, & West, 2006; Bettencourt et al., 2007). Underlying the extraordinary complexity of cities lies a hidden simplicity: regardless of the metric, cities are to a large degree scaled versions of one another. Socio-economic metrics such as wages, patents, assets, sales, diversity, crime, police, and disease, as well as infrastructural ones such as roads, gas stations, electrical and water lines, volumes of buildings scale systematically and predictably with population size suggesting that universal principles that transcend history, geography and culture underlie their dynamics, organisation and structure. Some examples are shown in Figs. 4 and 5, where both infrastructural and socio-economic metrics are plotted logarithmically versus city size, as measured by their population. As can clearly be seen all of these are straight lines indicative of power law scaling, regardless of the metric or location across the globe.

The infrastructural networks of cities mimic the resource and energy networks that support biological organisms and ecosystems, which minimize the energy needed to sustain them. Likewise, the various physical networks in cities, such as their electrical, gas and water systems, have evolved towards being approximately optimal in order to minimize the loss of energy and resources. Similarly, transportation networks have to be space-filling, meaning that they need to service every citizen, building and facility in the city. Together with optimisation principles this leads to scaling laws with sublinear exponents (i.e., values less than 1) and therefore to economies of scale, similar to what

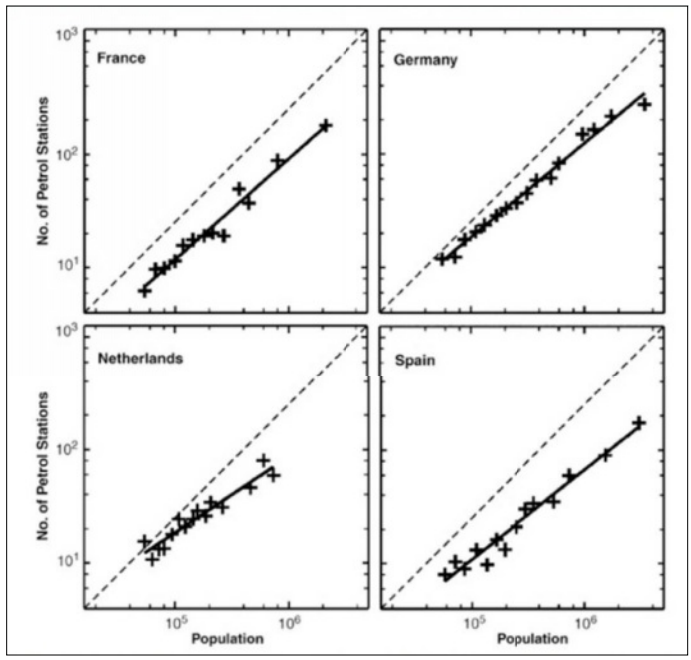

Figure 4. The number of gasoline (or petrol) stations plotted logarithmically as a function of city size for four European urban systems. All the exponents cluster around 0.85, manifesting a systematic economy of scale. This scaling law is valid for almost all infrastructure across the globe.

is seen in biology. The major difference is that instead of 0.75, the exponent in cities is approximately 0.85. This is illustrated in Fig. 4 where the number of gasoline (or petrol) stations is plotted logarithmically against city size for four European urban systems; the slopes of all four are close to 0.85. This scaling law is valid not only for gasoline stations across Europe, but for almost all infrastructure across the globe, including roads, electrical cables, and water lines, whether in Europe, Asia or the Americas (to the extent where data is available). Thus, the infrastructure of cities manifests a surprisingly systematic economy of scale: within a given urban system cities need about 15% less infrastructure per capita with every doubling of size.

As already emphasised, infrastructure provides the physical scaffolding for facilitating and enhancing the social interactions which underlie the creation of wealth, ideas, innovation and growth, as well as of crime, disease and pollution. The essential feature of human social networks is the exchange

of information which, in cities, underlies the metropolitan buzz of increasing productivity, speed, ingenuity and opportunity. As such, cities have evolved towards optimizing this dynamic. Each interaction builds on, and multiplicatively reinforces, previous ones: the more you have, the more you get; the rich get richer, and the poor get relatively poorer even as the overall level of activity may increase. Optimising this positive feedback mechanism in social networks leads to *superlinear* scaling, namely, that socio-economic characteristics of cities should scale as power laws whose exponents are larger than one (Bettencourt, 2013). Since the behaviour of all of these socio-economic characteristics originate in the dynamics and structure of social networks, their exponents are expected to have similar values, as is confirmed by the data and illustrated in Fig. 5 (Schlapfer et al., 2014).

Despite cultural and ethnic differences, the structure of social networks and the form of social relationships, including the modular clustering of human interactions in families, communities, work and businesses, is pretty much the same the world over. Consequently, there is an approximate

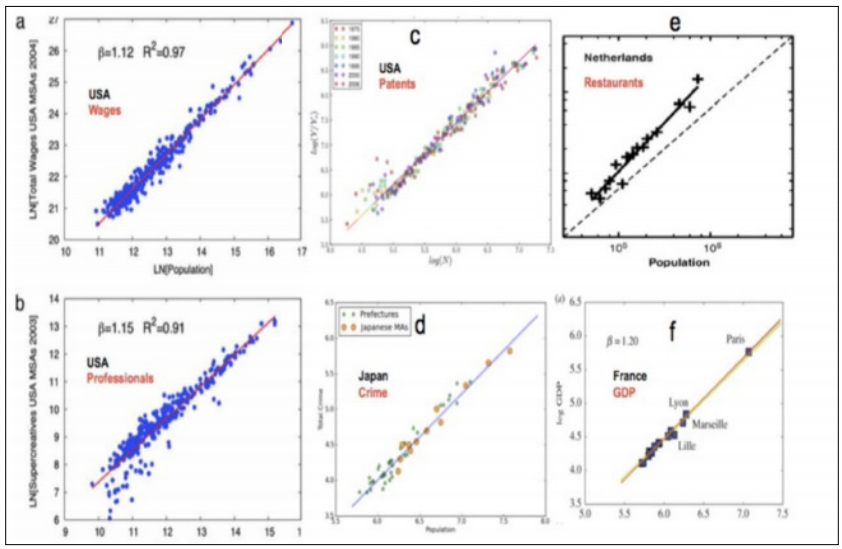

Figure 5. Various socio-economic metrics plotted logarithmically versus population for urban systems across the globe. All the exponents cluster around 1.15, manifesting a universal increasing return to scale (superlinear scaling).

universality in how urban metrics scale with city size: regardless of history geography and culture socio-economic metrics scale with city population as simple power laws with a common exponent of about 1.15. Systematically across the globe and regardless of the indicator, the larger the city the more innovative “social capital” is produced. In simple quantitative terms, the scaling law states that, if city size doubles, then all socio-economic indicators such as wages, wealth, patents, GDP, the number of social interactions and educational and research institutions increase by approximately the same degree, namely, by about 15% per capita. This surprisingly systematic and universal phenomenon is the major reason why cities have been, and still are, so attractive and seductive.

And they will probably remain so despite the fact that, to approximately the same degree, doubling city size also increases crime, pollution and disease by the same 15% per capita, since they too are derivative of social interactions. The good, the bad and the ugly come together as an integrated, predictable, package. People are attracted to larger cities by the expectation of more innovation, opportunity, culture, higher wages, and a greater sense of “action” but they will also experience an equivalent increase in pollution, crime, and disease. As a recent highly relevant example consider a city of 10 million people: it will have double the number of covid cases in half the time a city of 100,000 would, and integrated over a month or year’s time would have about 200 times as many cases, despite being only 100 times larger. Consequently, it is much wiser to be in a small town during a pandemic rather than in a large city, but during “normal” times it would be much better to be in a large city if you want a greater buzz, more social interactions, more opportunity, greater access to culture and increased wealth.

The physics and mathematics of networks constrain the pace of biological life to be systematically slower as size increases: times are longer and rates are slower following sublinear quarter power scaling laws. Consequently, large mammals live longer, take longer to mature, have slower heart rates, and cells that work less hard than small mammals, all to the same degree. In contrast,

the positive feedback mechanisms in social networks which give rise to superlinear scaling lead to the speeding up of socio-economic life with increasing size. The bigger the city, the faster the pace of life: diseases spread more quickly, business is transacted more rapidly and people walk faster···all approximately to the same predictable degree, following the 15% rule.

In general, metabolic rate, whether of organisms, cities or companies, is apportioned between maintenance (which includes repair and replacement) and new growth. During the growth of organisms, the sublinear ¾ power scaling of metabolic rate cannot keep pace with the maintenance demands of the additional new cells so growth eventually stops, leading to a stable size at maturity (Fig. 6). This stability, coupled with the slowing of the pace of life as size increases, plays an important role in the long-term sustainability of life on the planet (West, Brown & Enquist, 2001).

In contrast, the superlinear scaling of the metabolic rate of cities (which, in addition to energy, includes the supply of materials, assets, and money) leads to open-ended super-exponential growth, which is

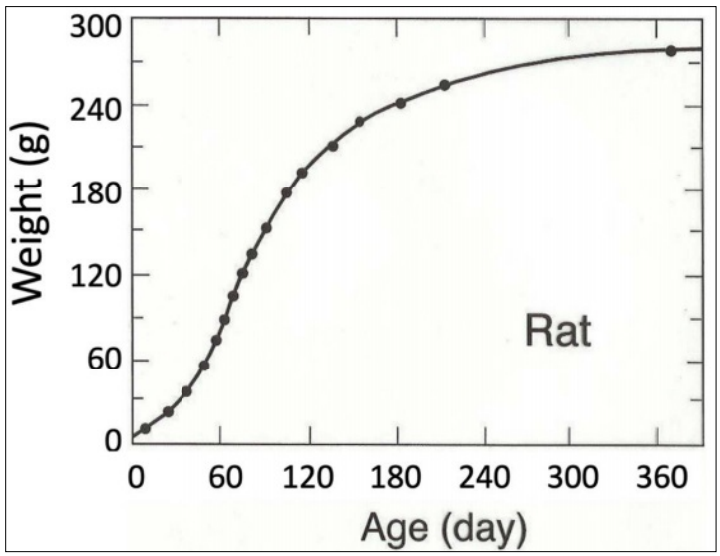

Figure 6. Growth curve of a rat illustrating the general sigmoidal behaviour, characteristic of the bounded growth of animals

what is generally observed (Fig. 7). The superlinearity of social metabolic rate, driven by social network dynamics, outpaces the maintenance demands of the new entities being added to the city – the people, buildings, roads, etc - the excess fueling further growth and the increase of standards of living. This multiplicative process has dominated our socio-economic lives since the Industrial Revolution, building on the discovery and exploitation of fossil fuels and the development of capitalism, free markets and entrepreneurship. This is the good news.

However, there is also some potentially bad news. Mathematically, the theory also predicts that super-exponential growth, left unchecked, leads to what is known as a finite time singularity. This simply means that socio-economic metrics, such as the GDP, the number of patents, or the amount

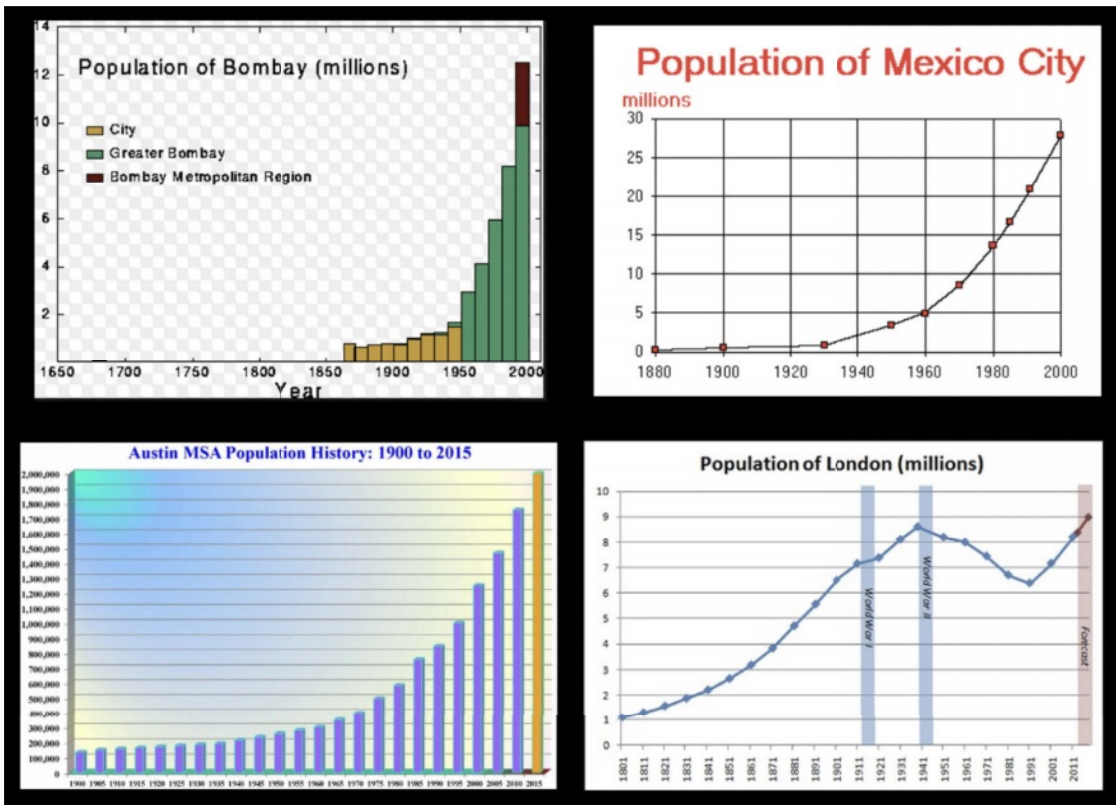

Figure 7. Growth curve of various cities illustrating their characteristic open-ended growth

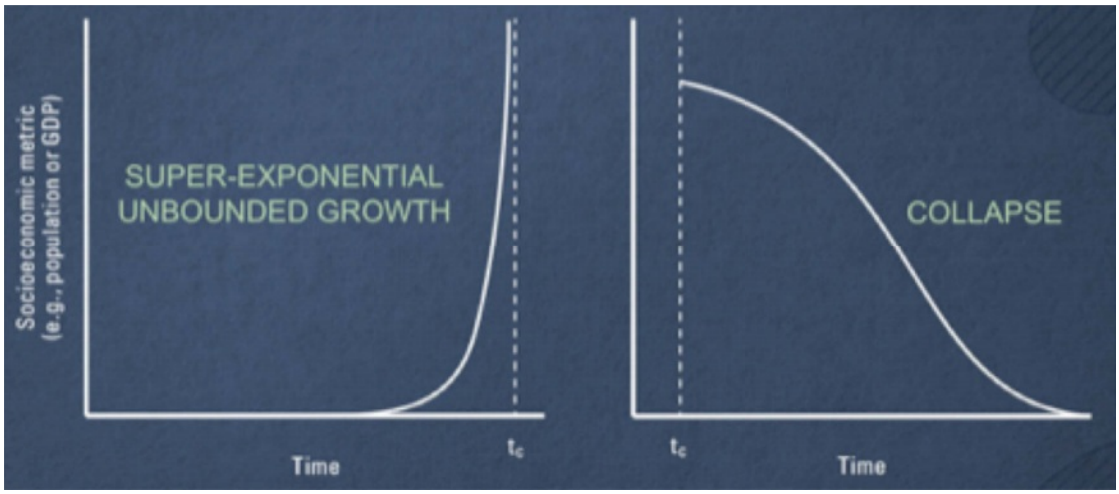

Figure 8.

Left panel: Illustration of the super-exponential growth of a socio-economic metric driven by the super-linear scaling of social metabolic rate; this approaches an infinite value at the finite time singularity, tc,, denoted by the dotted vertical line. Right panel: without some change or intervention, this leads to the system collapsing beyond the singularity.

of crime, will eventually become infinitely large at some finite time, tc, as illustrated in the left panel of Fig. 8. This is obviously impossible, and signals that something has to change before reaching the singularity. If not, the system will collapse, or at least contract (right panel of Fig. 8).

To avoid such a collapse and ensure continued open-ended growth requires a major systemic intervention, innovation or paradigm shift that “re-sets” the clock so that one can effectively start all over again. Having made the transition to a new phase and having “reset the clock” to avoid stagnation, contraction and ultimately collapse by circumnavigating the impending singularity, the positive feedback process begins again ensuring the continuation of super-exponential growth. However, as before, this eventually leads to a new finite time singularity which likewise has to be circumvented by a new intervention or innovation. This entire sequence is continually repeated thereby pushing potential collapse as far into the future as the creativity, inventiveness and resourcefulness of human beings allow. Thus, to sustain open-ended growth requires continuous cycles of paradigm-shifting innovations, interventions or re-invention, as illustrated in Fig. 9.

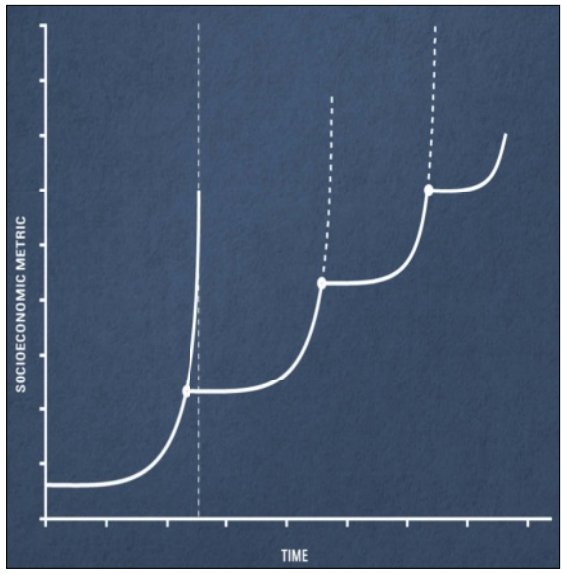

Figure 9. An idealized representation of successive super-exponential growth trajectories, each of which could potentially lead to a singularity (denoted by the vertical dotted line) and subsequent collapse unless an innovation, or paradigm shift, is made at a time prior to the singularity (denoted by the white dots). This effectively resets the clock to start the entire cycle over again.

Thus far, cities have been remarkably successful in accomplishing this. On the grand scale of human history the discoveries of iron, steam, coal, computation and, most recently digital information technology, are among the major innovations that have fueled their continued growth and expansion. On a more modest scale the inventions of concrete, the telephone, the automobile, the fax machine and cellular phone have enabled unrelenting urban expansion. The concepts of continued business and economic cycles, and of implied cycles of innovation, are taken for granted, despite scant quantitative mechanistic theory to support them. It is generally assumed that as long as human beings remain sufficiently inventive we will stay ahead of any impending threat by continuous and evermore ingenious innovations.

Unfortunately, however, there is another potential issue. Theory dictates that to sustain continuous growth such discoveries or interventions must be made at an increasingly accelerating pace; the

time between successive innovations must systematically get shorter and shorter. For instance, the time between the most recent major shift from the “Computer Age” to the “Information and Digital Age” was perhaps 20 years, to be compared to the thousands of years between the Stone, Bronze and Iron Ages. More generally, data on past innovations quantitatively supports the predictions of the theory. The time to the next significant innovation, whatever it is - driverless cars or smart cities - is destined to be even shorter. We are all too familiar with the increasingly faster pace that new gadgets and models appear and of the increasingly faster pace of urban life. Socio-economic time is speeding up driven by the very dynamic that has led to our success. Yet we are the same human beings with basically the same brains that we had when we were hunter-gatherers and the pace and complexity of life were so much more modest than they are now in our highly complex urban communities and mega-cities. The resulting stress, tension and anxiety are palpable and inevitable.

To address this challenge and the long-term sustainability of cities, and indeed the entire planet, we need to understand how we got here and incorporate these ideas into our thinking and planning about the future. A new paradigm is needed, a more holistic conceptual framework which spans scales from the local to the global and which integrates the incipient science of cities with more traditional approaches and includes architects, urban planners, developers, economists, practitioners, politicians, etc as well as scientists. In a word, we need a credible unifying, systemic, quantitative, predictive theory of cities and urbanization. The advent of big data, machine learning and artificial intelligence is an enormously exciting development in this regard, but only when it is incorporated into, and informed by, a bigger conceptual framework – such as a science of cities – will we have truly Smart Cities.

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Smart Cities are the Future:

Futurist Perspectives and Scenarios

스마트시티가 미래다:
미래학자의 관점과 시나리오

Jason Schenker

Jason Schenker is a Futurist, Economist, Speaker, and Author who prepares leaders for the future. Mr. Schenker has given over 1,000 keynote speeches, including multiple in-person and virtual speeches for events in the Republic of Korea. He is the author of 36 books on emerging technologies, finance, and the economy. Mr. Schenker is the Chairman of The Futurist Institute, an occasional columnist for Bloomberg Opinion, and an instructor of 20 courses for LinkedIn Learning on business, leadership, economics, risk management, finance, and audit. As President of Prestige Economics, Bloomberg News has ranked Jason Schenker the #1 forecaster in the world in 26 different categories since 2011, including for his forecasts of industrial metals prices, oil prices, the euro, and U.S. jobs. Mr. Schenker has given over 1,000 TV interviews. He has been a guest host on Bloomberg Television and a guest on CNBC, CNN, BNN, and the BBC. Mr. Schenker holds Master's degrees in Negotiation, Applied Economics, and German.

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ABSTRACT

In this article, Chairman of The Futurist Institute Jason Schenker lays out the most important fundamentals driving the case for smart cities. He discussed the goals and opportunities for smart cities, including the top priority of fostering perceived abundance to ensure social order and economic stability. Mr. Schenker describes how successful smart city development will require a futurist approach, tenacity, and flexibility of mind. He also evaluates the accelerated adoption of remote life technologies during COVID-19 as a critical precursor of smart cities as well as the most crucial technological pillars of success for smart cities. He also evaluated emerging technologies that will be critical for future smart cities. Mr. Schenker presents four futurist scenarios to reveal key levers of opportunity and support that can accelerate future smart city development. The four scenarios include stagnation, continuation, reversal, and parabolic shift. Mr. Schenker defines these scenarios, shares the beliefs required for each of them, and assesses their plausibility. Using these analyses, Mr. Schenker reveals levers that could accelerate smart city development. Finally, Mr. Schenker includes a discussion of how the Republic of Korea can accelerate its smart city development and how Korea can benefit from developing and exporting winning smart city technologies.

KEYWORDS

Smart cities, Technology, Korea, Energy, Strategy

초록

이 글은 스마트시티를 주도하는 가장 중요한 기초를 제시한다. 또한 스마트시티의 목적과 기회를 논의하는데, 여기에는 사회 질서와 경제 안정을 보장하기 위한 풍요를 형성하는 일이 무엇보다 급선무라는 논의가 포함된다. 스마트시티 개발의 성공에 필요한 요소는 미래적인 접근과 끈기, 마음의 유연성이다. 코로나19 팬데믹 기간 동안 원격 기술의 채택이 빨라졌는데, 이는 스마트시티의 결정적인 전 단계이자 스마트시티가 성공하기 위한 가장 중요한 기술적 기둥이다. 이 글은 아울러 미래 스마트시티에 결정적인 기술이 될 만한 신기술들을 평가한다. 이어 미래 스마트시티 개발을 가속화할 주요 기회와 지원을 드러내기 위해 네 가지 미래 시나리오를 제시한다. 네 가지 시나리오는 정체와 지속, 반동, 포물선 변화이다. 이 글은 이들 시나리오를 각각 정의하고 그에 필요한 믿음을 공유하며 각각의 가능성을 진단한다. 이 분석을 통해 스마트시티 개발을 가속화할 수단을 드러낸다. 마지막으로 한국이 어떻게 스마트시티 개발을 가속화할지, 어떻게 앞선 스마트시티 기술을 개발하여 수출함으로써 혜택을 볼 수 있을지 논의한다.

키워드

스마트시티, 기술, 한국, 에너지, 전략

Introduction

Smart cities are the cities of the future. They incorporate and integrate technologies to make life, especially urban life, more livable in a world of increased constraints and challenges. But while the opportunities and benefits of smart cities will be tremendous, the requirements to get there are not insignificant. The speed of advancement and adoption will depend on the magnitude of stakeholder investment, support, and urgency.

The Case for Smart Cities

The global population is set to grow by around two billion by 2050, with urban populations to increase by that much – or more. The future of cities will be comprised of smart cities that leverage data and technology to ensure convenience, livability, workability, safety, and, most importantly, perceived resource abundance. Rousseauian economic realities of limited resources, distributive behavior engendered by Cold War Two, and the critical nature of sustainability imperatives will all have tremendous roles to play in how we approach the future of urban life.

The big question of the decades ahead is whether we can cross the digital divide quickly enough to ensure that a preferred future of abundance and convenience comes to fruition before dystopian risks become insurmountable. We can get there, but a futurist approach, tenacity, and flexibility of mind will be required.

The Goals of Smart Cities

If demographics are destiny, then the challenges ahead for urban life are clear. Simply put, resource constraints risk becoming more significant challenges as the global population rises further and population centers see greater density levels than ever before. Resource limitations and strain are likely to accompany future increased risks to economic and business continuity, as well as associated risks to social stability. The goal of smart cities should be to effectively mitigate those risks and threats.

We see several imperatives and priorities when considering smart cities. Most planners and observers of smart city technologies tend to focus on a few key underlying imperatives for the future of smart cities. They usually include convenience, livability, workability, and safety. In short, smart cities should fulfill these critical human desires because the hallmarks of modern society are convenience, places that are pleasant and safe to live, and where working is as easy and convenient as possible. But while these are smart city advocates' most often stated objectives, perceived abundance should be at the top of the list.

As energy, food, and water resources experience ever-increasing global demand, it will be essential to use technology to remove risks associated with a lack of supply. The social order often operates on a thinner razor's edge than most people would readily admit, which is why it is imperative to keep fear of shortages at bay. This is why smart cities can be a critical lever to help maintain social order and stability by using technology to foster a sense of perceived abundance regardless of the global realities of any potential imbalances in natural resource supply and demand.

Most people may need help understanding the engineering, physics, chemistry, or supply chain complexities that provide them with water, food, power, or fuel. In truth, they need not understand

these systems in all their various parts. But they must have faith in the systems, infrastructure, and institutions that foster stability and continuity. By being the technological bridge that crosses the divide of growing demand against a future tightening of supply, smart cities can be critical technological loci that maintain the social order and ensure prosperity by fostering stability and preventing the populace of increasingly-large urban centers from slipping into the bottom level of Maslow's hierarchy of needs en masse.

Opportunities for Smart Cities

There are many opportunities for technology to improve urban living today, and there will be even more technologies that improve urban living and usher in smart cities in the future. The recent mass accelerated adoption of remote life technologies during COVID-19 represents the opening salvo in the push toward more expansive smart cities. While faced with quarantines, people turned to online and remote apps and technologies to augment the level of normalcy in their lives. The most important technologies to gain increased prominence during COVID-19 were remote work, online education, e-commerce, and telehealth. These had all existed for many years, experiencing a persistent upward trajectory in adoption that went parabolic during the pressure-cooker years of COVID. Looking further into the future, integrating existing, emerging, and future technologies will reduce pressure on urban infrastructure and natural resources.

Remote work has been one of the most impactful remote life adaptations during COVID. Long before COVID-19, remote work had been the working style de rigueur of salespeople, consultants, and executives. While remote was a commonplace way of working for these road warriors, adopting remote work to allow a wide range of non-traveling white-collar workers to work remotely seemed incomprehensible before the pandemic. With the outbreak of COVID, remote work became a

requirement for a broad swathe of workers, resulting in improved quality of life for many workers. It reduces commuting, allows for more lifestyle flexibility, and reduces fuel consumption and transport expenses. While the percentage of remote workers may vacillate in the post-COVID period, the potential to reduce infrastructure congestion, hydrocarbon consumption, and costs is likely to provide significant incentives for many workers to remain remote – or to become remote in the future. With a longer-term perspective of future smart city development, remote work becomes conditio sine qua non for most white-collar workers. The economic, social, and sustainability impacts are too great to ignore.

Online education will likely become a less optional fixture of urban life and smart cities. While some learners have much better outcomes from in-person courses, online education creates new opportunities for many people who otherwise lack the time, flexibility, or funds to commute to school in person. Moreover, online education is much less likely to require workers to give up paid full-time jobs, which lowers the opportunity costs of more education, making greater educational attainment less financially burdensome than in-person education. The economic benefits of a more educated populace are significant for cities that will be increasingly typified as intellectual capital economies.

Along with remote work and online education, e-commerce and telehealth are remote life technologies that experienced parabolic adoption during the COVID-19 pandemic. These technologies of convenience also have significant economic, sustainability, and social benefits. E-commerce efficiency is likely to increase over time, reducing friction in the last mile of supply chains by making retail consumption more accessible and efficient. Meanwhile, telehealth is likely to remain an essential tool to improve public health outcomes in a way that reduces stress on urban healthcare systems that are likely to face increased demand in the years ahead. While demographic stressors will increase the demand for healthcare, anticipated shortages of healthcare workers also threaten to reduce the supply of medical professionals available for in-person treatment. As we look to cities of the future,

remote life is not likely to be a passing fad but rather the first signs of this imminent transition to technology-enabled and technology-improved urban living.

Sustainability and Relief of Resource Pressures

United Nations Sustainability Development Goals (SDGs) can only be met with an increased commitment to sustainability. This is where remote life and other smart city technologies offer the potential to be a boon for sustainability targets. With fewer workers commuting to offices and fewer students commuting to schools, there is likely to be reduced consumption of resources at those structures, including reduced consumption of water, natural gas, paper products, and trash removal services. The sustainability impact of reduced consumption is clear, and the implication from a stability standpoint is that if we want the world to be one of real or at least perceived abundance, current and future increased adoption of remote technologies will be critical. But more than remote life technologies will be needed for smart cities to achieve their full potential.

The integration of technologies and the use of data will be key levers of resource utilization and optimization. Smart city technological integration will be critical to reduce urban carbon and other environmental footprints. The most important priorities for smart city planners leveraging current sustainability-improving strategies include a focus on reduced resource consumption, energy efficiency and renewables, increased recycling, and a higher level of infrastructure utilization.

The opportunity to simultaneously improve urban life and make sustainability gains is significant. But it can only happen with the right technologies, mindset, and support.

Tech Pillars of Success

Although technological advancements have accelerated in recent years, the transition to technologically-seamless smart cities includes significant requirements and challenges. When thinking of the city of the future, four key technological pillars will help support and fulfill the promise of smart cities. These include data collection, widespread use of sensors, advanced analytics, and increased cybersecurity.

You cannot improve what you cannot measure, which is why smart cities will require data collection everywhere. This will include integrated and seamless data collected across assets in transport infrastructure, power, energy, water, and more. This data collection will be enabled through expansive and myriad sensors across assets. In effect, smart cities of the future can only come into existence with the collection and analysis of valuable data in high volumes, with persistent and ubiquitous data collection.

Data alone cannot usher in an era of smart cities. Sensors and data collection need to be accompanied by ongoing data integration and sophisticated, effective analysis. Advanced artificial intelligence and quantum computing are likely to be critical tools in measuring and monitoring massive real-time data sets to maximize and optimize asset and resource use.

Cities brimming with technology that makes urban life both better and more sustainable sound amazing. But they will also have much greater vulnerabilities to cyberattacks than cities of the past or the present. In the cybersecurity world, experts speak of the attack surface of various technologies and assets. An attack surface represents the multiple points of vulnerability that could be attacked. A smart city's data and tech infrastructure will be massive, putting pressure on smart city planners to secure technological assets with an advanced, expansive, and resilient cybersecurity tech stack.

Without a way to effectively protect all of the data and technology of future smart cities, a futurist vision of great promise could become a hellscape of malintent criminals, state-sponsored actors, and other entities that would seek to undermine and disrupt the social order.

Smart cities will overflow with data and technology, which is why effective cybersecurity will become a critical bulwark of smart city data, tech, and asset security. Only if these needs are met will sufficient conditions be met to achieve smart city greatness.

Emerging Technologies for Smart Cities

Abundant technology can help ensure a perceived abundance of resources, even in the face of increased scarcity. A wide range of emerging technologies will be vital for developing smart cities. Aside from the technologies mentioned above are a number of other emerging technologies that will be critical for smart cities, including autonomous transportation, data collection and analytics, the metaverse, and smart utilities. Most of these technologies have yet to reach maturity, and it may take years or even decades before we see them reach their full fruition. But they will all play a critical part in the development of smart cities.

As noted above, data collection and analysis technologies will be critical parts of the future of smart cities. The impact of AI is likely to be significant, with still unknown potential benefits to be derived from quantum computing. Yet one thing seems inevitable, the ongoing real-time collection of data in cities will require significant analytical power. There is also likely to be a substantial energy requirement in collecting, managing, and analyzing such a massive amount of data.

Data collected across cities will also likely be paired with and integrated to include transport vehicle data. This will likely include drones and self-driving vehicles with various levels of autonomy. As with other technologies, self-driving vehicle technologies are still emerging and evolving. While some vehicles on the road currently have self-driving capabilities, it may be a long time before stop signs and traffic lights are no longer needed. There are likely to be intermediate stages of development in which vehicles are both self-driven and driven by humans. The duration of this stage will be impacted by larger systems, as regulatory, liability, and technological issues present legal, social, and administrative challenges that may take some time to adjudicate.

While the complete and total dominance of self-driving vehicles on the roads of future smart cities will take time, metaverse technologies present opportunities now. To effectively structure data collection in aspiring smart cities, those cities need to be mapped. This is where virtual reality and augmented reality technologies could prove valuable. The use of metaverse tech could also prove invaluable for helping self-driving vehicle systems bootstrap on-road mileage to increase the number of scenarios that can be tested to accelerate the rollout of self-driving fleets and augment the data collection necessary to make the legal and regulatory case for full vehicle autonomy.

Smart utilities will also be critical for smart city development. At the top of this list are smart meters for power and water, as well as smart grids in larger regions and countries. The good news is that this kind of technology has the greatest chance of adoption and implementation, as it has been rolled out in many cities and countries. The use of smart technologies is essential for maintaining perceived abundance. Keeping urban dwellers happy and confident depends on water and power at the basest level.

Smart utilities are a win all around. They help manage demand and supply while offering sustainability benefits and supporting the stability of the urban social order. These technologies will

become increasingly important as electric vehicles become more ubiquitous in the years ahead. In a push for sustainability, electric vehicles have been earmarked as critical parts of the solution to reduce CO_2 emissions. But more electric vehicles require more power, which comes from the grid. This could stress power grids across urban areas, regions, and nations. The use of smart meters will be critical for demand management and managing load serving, especially during peak periods of power demand to ensure that there is sufficient power to keep the lights on and the grid operating.

Most of these technologies have yet to reach maturity, and it may take years or even decades before we see them reach their full fruition. Some technologies may take longer to come to fruition, especially self-driving vehicles in the hoped-for time when stop signs and traffic lights are no longer needed.

Mindset Requirement – Become a Futurist

Technology alone will not be enough to make smart cities a reality. Mindset requirements will be equally important. While technology and data will be ubiquitous in cities of the future, it is vital that those looking to implement smart cities are approaching a populace that is prepared to embrace technology – or could become willing. If the public is somehow opposed to technology or has Luddite tendencies, the potential for smart city failure is high. Similarly, it is important for would-be brilliant city designers and developers to ensure that they foster a culture of data among those working on smart cities and the future smart city populace at large. Data is not a one-time ingredient or building block of smart cities but an ongoing requirement.

The greatest potential to ensure that a smart city populace will embrace technology and data is to foster a culture of education. An educated populace is likely to better understand the imperative

of perceived abundance and the value of data. An educated populace is also likely to have a larger white-collar population that would more readily embrace remote life technologies that enhance convenience, reduce cost, and foster income-advancing education opportunities.

Sustainability is also a critical part of smart cities, where the focus and mindset of the populace need to be aligned. From a sustainability standpoint, a communal focus can be a tremendous advantage. While prioritization of energy-efficient and eco-efficient institutions offers the greatest chance to foster perceived abundance, there will still be some sacrifices to be made. With stakeholders having a shared vision of prioritized sustainability, more effective buy-in for smart city utility management can be secured.

Above all, smart city planners need to take a long-term strategic approach to smart city development, as these projects will take many years or decades to bring to full fruition. Futurist thinking should be part of that approach as well, which means that smart city planners will need significant flexibility of mind when it comes to their plans. Planning the future based on new and emerging technologies is not something to approach with a rigid plan or unmovable timetable. Smart city plans rely on new and emerging technologies, which is why the future could be very different than urban planners currently imagine. The emerging technologies of today could fail, succeed more rapidly than planned or even be supplanted and surpassed by entirely different technologies. There are many variables that will shape the future. Identifying precisely what technologies will be most critical – and at what pace they will be impactful – requires a particular strategic approach.

Four Scenarios of the Future of Smart Cities

As a futurist looking at a strategic question, it is important to analyze trends of the past and data of the present to craft a vision of the future. Futurists often assess potential future outcomes in a four futures framework. This strategic planning framework was initially pioneered by Jim Dator, a professor at the University of Hawaii at Mānoa. This framework goes well beyond the typical management consultant's preferred but rather uninspired use of three potential scenarios: mid-case, high-case, and low-case.

In a four futures framework, past trends play a significant role. The first future scenario shows a "stagnation" compared to past trends. It is a future where the trends and technologies of the past essentially stop changing, so things remain unchanged and stagnate in the future. The second future scenario shows a "continuation," where future trends continue at the same pace as recent past trends. The third scenario is a "reversal," where the trends of the past completely reverse in the future. Finally, there is the fourth future, which shows a "parabolic shift." In this scenario, the trends of the past accelerate rapidly in the future and reflect an upward parabolic shift. In the section below are four future scenarios for smart cities. The value of describing these future scenarios lies in identifying beliefs about them and assessing each scenario's plausibility. This can help identify what key changes to watch for and what actions to take to adapt future long-term plans for a desired outcome.

Future Scenario 1 – "Stagnation"

Description: In this scenario, the technologies we have today stop evolving and do not improve. Demographic, population, and urban density neither rise nor fall. In this scenario, smart cities

would be very difficult to achieve, as technological improvements are required to have more comprehensive smart cities. Cities would essentially remain very much unchanged as they are today.

Beliefs: To believe that technology will cease to advance and demographics will cease to shift. We would also need to believe that sustainability ceases to be a priority and that natural resources do not face supply constraints.

Plausibility: This future scenario seems less likely, as technology and demographics are shifting rapidly. Moreover, sustainability also does not appear likely to fade as a critical topic, and natural resources are not limitless. Plus, human nature has consistently driven technological advancements, and a complete stagnation in technological developments would represent a major shift against human nature.

Future Scenario 2 – "Continuation"

Description: In this scenario, the trends of the recent past continue at a similar ongoing pace. Technological advancements continue, demographic changes persist, sustainability commitments increase, and resource constraints become of greater concern. These trends foster a greater interest in and need for smart cities.

Beliefs: To believe that this is the most probable scenario, we would need to believe that there is a commitment, potential, and willingness to finance more technological research and development at a pace similar to the past. We would also need to believe that demographics continue to drive up population growth and urbanization. We must also believe that natural resource constraints will become increasingly prioritized.

Plausibility: This is a very likely scenario and may well be definable as the base case, as it aligns with widely held expectations and forecasts about demographics, the global focus on sustainability, and natural resource concerns.

Future Scenario 3 – "Collapse"

Description: In this scenario, the technologies we have today fail or are abandoned. There is a significant pushback against data, technology, remote life, and sustainability. We would also likely see a major population reversal, removing any concern about emissions or natural resource constraints. Limited and congested infrastructure would no longer be a concern.

Beliefs: To believe that this is the most probable scenario, we would need to believe something genuinely catastrophic has happened. Some of the key technological hallmarks of modern society would be abandoned, along with any future drive to advance technology. We would need to believe that the ubiquitous technologies on the precipice of converging to help foster comprehensive smart city technologies are abandoned wholesale. We would also need to believe that sustainability is abandoned and that natural resource abundance is no longer a concern. We may also need to believe that global and urban populations are falling.

Plausibility: This seems like an unlikely scenario. Humans enjoy the conveniences of technology, and they have consistently demonstrated a propensity to improve their lives with technology. As such, a wholesale abandonment of current technologies and a cessation of the elemental human drive to improve life with technology seems unlikely. Moreover, although things could cause global and urban populations to fall, something catastrophic would be required. Finally, concerns about natural resource limitations and sustainability seem unlikely to vanish.

Future Scenario 4 – "Parabolic Adoption"

Description: In this scenario, technologies develop much more rapidly than they have in recent years. The effort to advance and integrate smart city technologies secures tremendous new financial, institutional, and governmental support. Sustainability and natural resource

imperatives gain more significant traction as demographic shifts accelerate, driving the smart city imperative to become an outright mandate. Heightened regulatory support for self-driving and autonomous vehicles could lead to self-driving fleets without stop signs and traffic lights.

Beliefs: To believe that this is the most probable scenario, we would need to believe that support for smart cities increases significantly. We would also need to believe that the underlying imperatives for smart cities become much more critical to the point where natural resource constraints, infrastructure congestion, and sustainability goals experience significantly more attention and support across countries and cities. We must believe that autonomous vehicles will find regulatory and governmental support.

Plausibility: This scenario seems highly plausible. For this to be the most likely scenario, it would require greater concern, support, and action on the part of technology-focused stakeholders to support and integrate smart cities technologies and bring a comprehensive vision of smart cities to full fruition.

In light of the four futures for smart cities above, reversal and stagnation seem less likely. But a continuation of trends or a parabolic adoption seems more likely. Key levers differentiating the scenarios are technological development and potential, demographics, sustainability commitment, and resource constraints. As is often common in futurist scenarios, when we describe the scenarios and identify key levers and beliefs, we can begin to determine what can be done to arrive at what futurists often call the preferred future.

Of these different futures, the preferred future might be either continuation, parabolic adoption, or somewhere in between. Since the key differentiating factors between continuation and parabolic adoption hinge on the level of support for smart city technologies and the focus on sustainability and natural resource concerns, this framework has helped reveal a blueprint for action. For policymakers

wishing to see a more rapid implementation of smart city technologies, various levels of support from stakeholders can mean a great deal of difference between a continuation and a parabolic shift in the path to implementing comprehensive smart city technology.

Support Requirements and the Case for Korea

In the Republic of Korea, many supportive factors enhance the potential for a more parabolic adoption of smart city technologies. As noted in our four futures scenarios above, stakeholder support is critical for smart city adoption. Public-private partnerships, government support, and a willingness to make infrastructure investments will be vital levers that could accelerate Korean smart city implementation. Beyond these factors, business and economic support are also in place, with Korean ICT industries among the best in the world with significant experience in exporting winning solutions. This presents the opportunity for Korea to become a critical global leader in integrating smart city technologies and guiding other cities along a path of development.

Even the rising geopolitical tensions we call Cold War Two present opportunities for the Republic of Korea. Korea has a chance to gain global ICT market share from China as global high-tech and dual-use supply chains further bifurcate. There is also a tremendous opportunity for Korea to leverage its smart city technologies to extend Korean soft power diplomacy and become an even more critical technological player in the global economy. By establishing city partnerships in countries that share Korean values, Korea can solidify itself as a more valuable player for good on the global stage. This could take the form of providing technological assistance or pilot programs in cities at less advanced stages of development or that face more significant resource abundance challenges. The United States and other countries have long used sharing technological advances to advance their

global standing. Plus, sister city programs have existed in Korea and many countries for decades. If the Republic of Korea were to adopt and build on these kinds of relationships, it might have a tremendous humanitarian impact, add to global stability, and open new markets for Korean ICT and smart city technology exports.

Conclusion

Smart cities are the future of cities. The idea of cities brimming with technology and data to ensure a perceived sense of resource abundance, foster greater convenience, and reduce infrastructure congestion may sound utopian today. But many of the key technological building blocks are in place and improving, with a potential for more parabolic technological advancements and smart city support. With more significant R&D investments, sustainability focus, and governmental support, the move to smart cities can accelerate from the recent trend. So, do we need smart cities? Yes, yet the pace of technological advancement will depend on the tenacity, support, and commitment of critical stakeholders.

Towards a New Digital Urbanity:

a Future for Smart Cities in the Century of Sustainability and Big Data

새로운 디지털 도시성을 향해:
지속가능성과 빅데이터의 세기에서
스마트시티의 미래

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ABSTRACT

Since the beginning of the information technology revolution in the last quarter of the 20th century, cities have interpreted the change in the economic and productive model as an opportunity to improve their competitiveness, attract investments and new jobs, and improve their public services through the use of digital technologies. From technology parks to new innovation ecosystems, cities have been adopting different profiles as smart cities. It has been one of the most important trends in strategic urban planning in recent decades. However, the successful smart city model seems to have reached a turning point due to new urban priorities and social sensitivities in times of climate emergency, economic and energy crisis. The smart city ideal seems to have lost the appeal it had for years for mayors around the world. There is even open talk of the death of this urban model due to the uncontrolled risks in the use of big data and artificial intelligence. In any case, technology is here to stay in urban management, but its role needs to be reconsidered and adapted to new citizen priorities. We need to cultivate a new urban culture for the digital era that protects the rights and freedoms of citizens and addresses real social concerns. A true digital urbanity is needed for the time of sustainability and the return to greener and more humane cities.

KEYWORDS

Smart cities, Big data, Digital rights, New urbanity, Sustainability

초록

20세기의 마지막 4반세기에 진행된 정보기술 혁명이 시작된 이래, 도시는 경제 및 생산 영역에서 진행된 변화를 기회로 응용하여 도시 경쟁력을 향상시키고 투자와 새로운 일자리를 창출하며 디지털 기술을 통해 공공서비스를 개선하는 데 활용해 왔다. 기술단지부터 새로운 혁신의 생태계에 이르기까지 도시는 스마트시티로서의 다른 외양을 채택해 왔다. 스마트시티는 최근 수십 년간 전략적 도시계획에서 매우 중요한 추세 중 하나였다. 하지만 기후위기와 경제·에너지 위기 시대를 맞이하여 도시의 우선순위와 사회적 민감성이 새롭게 변화하면서 스마트시티의 성공적인 모델은 전환점에 이른 듯하다. 한동안 세계 주요 도시의 시장들Mayors에게 매력적으로 여겨졌던 스마트시티의 이상은 이제 그 매력을 상실한 듯하다. 심지어 빅데이터와 인공지능AI을 활용하는 데 있어 내포된 통제 불가능한 위험으로 인하여 이 같은 도시 모델이 사망 선고를 받았다는 논의까지 공공연하게 들린다. 여하간 도시를 운영하는 데 활용할 기술은 이쯤 머물러 있고, 다만 그 역할은 새로운 시민의 우선순위에서 재고되고 조정할 필요가 있다. 디지털 시대를 맞아 우리는 시민의 권리와 자유를 보호하고 실질적인 사회적 관심사를 다루는 새로운 도시 문화를 함양해야 할 것이다. 지속가능성의 시대와 더 생태적이고 더 사람적인 도시로 회귀하는 시대에는 그에 걸맞은 진정한 디지털 도시성Digital Urbanity이 요구된다.

키워드

스마트시티, 빅데이터, 디지털 권리, 새로운 도시성, 지속가능

Introduction

The concept of smart city as a new paradigm of urban development and city management has gained relevance since the beginning of the 21st century, although it is not easy to determine precisely when the name was coined or who were its first promoters. Perhaps it is more important to understand that the idea of the smart city as a desirable model of city was not born in a vacuum. It is not an invention of someone fascinated by technology and who believed that digitalisation could solve all urban problems. In fact, the enormous influence and acceptance that the smart city model has had globally cannot be understood without exploring the roots and background of the digital age. Because the digital and Internet revolution began as a real revolution, not only technological and economic, but also social. It constituted a formidable hope for change in many areas and for many people. A wind of transformation that connected with some of the concerns of the counterculture and the hippy movement of thirty years earlier. We are talking about the free software revolution that began with the open source operating system developed by Linus Torvalds, which proposed software outside the commercial circuits, capable of reaching the highest levels of complexity and quality thanks to the collaborative work of thousands of programmers around the world. A movement that even made it possible to codify a new work ethic: the hacker ethic, theorised by the Finnish philosopher Pekka Himanen (2002), which allowed a glimpse of a new way of working that recovered dignity and appreciation for work well done, cooperation based on exchange and the common good, and the recognition of colleagues as the only hierarchy. Almost a new religion that did not lack its prophet: Richard Stallman.[1]

It was also a business revolution, more precisely against the business establishment, since a few young anti-establishment people were going to create the companies of the future thanks to their disruptive innovations and a new type of networked, scalable and tie-less company. Many believed

1 https://en.wikipedia.org/wiki/Free_Software_Foundation

that the adventure of the garage boys was just a Silicon Valley legend, but today three of the top ten companies in the world by market capitalization are Internet companies born in those years as small startups. And four more companies - including the number one, Apple - are technology companies that are essential to the new model of the digital economy that has taken hold in the world.[2]

The emergence of the Internet -especially since the World Wide Web- was also a social and cultural revolution by making available to people a lightweight technology through which it was possible to communicate, connect and collaborate with people around the world at very low cost outside of commercial circuits and political supervision. Today we are already accustomed to a multitude of free internet services - in exchange for our valuable personal data - and an infinity of applications that offer us an overwhelming degree of interpersonal and collective communication, never dreamed of by anyone. But thirty years ago, just a glimpse of this possibility triggered the imagination and the desire for personal freedom of many people. People who could communicate with others through a primitive wifi activated with Pringles cans as antennas. People who even believed that the Internet created a space outside - and safe from - governments and traditional political powers. A dream given form by Grateful Dead lyricist John Perry Barlow in his Declaration of the Independence of Cyberspace.[3]

Today we know that there has indeed been a digital revolution that has changed our lives, our economy, our work and the way we learn, relate to each other and entertain ourselves. We have also learned by now that some of its great advantages have been neutralized by other great disadvantages that were not foreseen at the time.

That veritable earthquake of hope that the Internet revolution generated in the 1990s had a particular

2 https://www.investopedia.com/biggest-companies-in-the-world-by-market-cap-5212784

3 https://www.eff.org/cyberspace-independence

impact on the field of territorial and city management. The network promised to make us less dependent on the specific place where we were and to give us more possibilities depending on the number and intensity of our active connections. And what was valid for people could also be valid for cities, no longer limited exclusively by their location and proximity to natural and energy resources, but with new possibilities for development if they were able to house many talented people and connect them with other places in the world to which they could sell their knowledge.

This had a major impact on all regional development and territorial management strategies. Digital innovation was the new raw material to cultivate. Everyone wanted to be the new Silicon Valley. And that produced a first generation of cities that wanted to be poles of the new technology that was conquering the world. These were times of low interest rates, large inflows of capital and overwhelming social optimism about what technology could bring.

In a short time, thinking shifted from how to accumulate knowledge and technological wealth to turning the city into a showcase of efficient management through the intensive application of information technologies, sensorization and data collection. The smart city was born. It was so credible and successful as a model from its inception because it still benefited from that techno-optimism that came from several decades ago, when the internet was a promise for the initiated, transmitted by the enervating sound of modems.After two decades of great development, the smart city model seems to have entered an existential crisis. The successive evidence of social manipulation that allows the accumulation -legal or illegal- of big data (the main asset of our cities today); the suspicion that excessive dependence on large technology companies reduces the room for manoeuvre of local governments and compromises the defence of public interest and public space; and theprogressive distrust of citizens towards political power at a time of growing social inequality around the world have created an adverse breeding ground for smart cities.

In the book I published in 2021 with my former colleague Daniel Sarasa under the title Open City, Digital City (2021), we set out precisely the objective of analysing this long journey of the smart city model to better understand the challenges it faces and to point out some of the paths that can lead to a new future for cities in the digital era. In this article I follow this thread to talk about the evolution of urban thinking within the framework of the new technological paradigm. And I will explain in the final part how it is necessary to move towards what we can call a new digital urbanity, a way of thinking about the city that integrates the potential of new technologies with social and civic priorities.

Recent international events have further highlighted the need to reflect on the priorities of smart cities. The energy crisis aggravated by the war in Ukraine, the high inflation resulting from this crisis and the succession of extreme weather phenomena in different parts of the world as a warning sign of climate change have led the concerns of citizens and local governments to scenarios very different from those contemplated in smart city projects. It is undoubtedly the time to put their valuable technological tools at the service of the social emergency of the moment.

Everyone wanted to be Silicon Valley

The relationship of cities to changes in the dominant production model has often been one of simple management of inconveniences and negative externalities: an effort to adapt their infrastructure and functioning to accommodate the new socio-economic reality. This was particularly evident during the first and second industrial revolutions, which attracted large numbers of rural immigrants to the city suburbs, forcing hasty urbanization and housing strategies to accommodate this new urban proletariat. Intense demographic growth forced a reconsideration of mobility systems

and health infrastructures. Always behind the needs and always coexisting with factories and chimneys that seriously polluted the air breathed by all.

The change towards the informational technological paradigm from the 70s and 80s of the 20th century, according to the concept developed by Professor Manuel Castells (1997), presented urban managers with a theoretically very different situation to the previous ones. For the first time, the key production factor for success in the new model was not traditional resources or raw materials necessarily close to the urban environment, but scientific-technological knowledge. An intangible that by its very nature was easier to delocalise and cultivate in different places. In addition, the irruption of the Internet represented the possibility of being able to access, share and develop that talent that would be the fuel of the new digital economy. As a result, the competition between cities and regions to attract the most innovative companies, people and ideas became more intense and global than ever.

It is possible that part of the social disappointment regarding smart cities that we perceive today can be explained by the exaggerated expectations that were generated in the 1990s and the beginning of the current century. Trying to be the new Silicon Valley has been one of the most robust trends in urban management since then, and this has marked the strategy of many cities (Rosenberg, 2002). It was possible to be one of the new factories of technological talent anywhere in the world.

One of the most interesting expressions of that push was the so-called New Century Cities. This is a name created by a joint research group ofthe Department of Urban Studies and Planning and the Media Lab of the Massachusetts Institute of Technology (MIT) to designate a group of large urban projects launched in different cities around the world at the turn of the century with a series of notable common characteristics.All of them proposed an intensive use of new information technologies in both the public and private spheres and aimed to be the cradle of innovative companies capable of

creating new skilled jobs and raising the international relevance of the city. These characteristics were visible in many other projects, but the NCC were different because they wanted to make a great effort of urban design for full integration into the city as a whole (not to make a technology park within the city) and also sought integration into the surrounding social fabric. In addition, from the beginning they raised the problem of governance of such ambitious projects in which public-private collaboration and the maintenance of long-term strategies were essential.

Digital Media City in Seoul, Arabianranta in Helsinki or MediaCityUK in Salford/Manchester are three magnificent examples of those great projects successfully executed. At the same time, they are the best exponent of the limitations that these projects encounter in terms of their strategic mission. They have often been successful within the perimeter of the project itself (job creation, new housing, attracting universities), but their transformative impact on the city as a whole is more debatable. In any case, they are the best possible witness to the enormous faith that urban thinkers and designers had at the time in the opportunity that the information technology revolution represented for cities.

The international financial crisis of 2008 changed the context of economic bonanza of the previous years and made other social priorities appear on the table of the mayors: social aid, the right to decent housing at a time of massive evictions, growing unemployment, budget crisis of local gorvernments… All this cooled the real estate investment associated with these large transformative urban projects and made the innovation strategies of the cities turn towards more measured interventions and more aligned with the new needs. On the one hand, the development of systems and devices applied to the management of urban services seemed an appropriate response at a time of budgetary crisis: technology was going to make the use of public resources more efficient and - very importantly - would turn the most advanced cities in this line of work into a showroom of urban innovation, which would attract technology companies and entrepreneurs to learn and test their solutions. The smart city, theorized since the early nineties, found its great opportunity with the popularization of the use of

wifi, the miniaturization and cheapening of electronic devices and the emergence of the smartphone, which gave citizens the possibility of having a powerful computer in their pocket to access urban services.

On the other hand, the difficulties encountered for urban design alone to become a facilitator of innovative activities generated an alternative line of thought, which focused not on physical proximity and neighbourhood in the same urban district of innovation agents (companies, startups, universities, laboratories, etc.), but on the development of an intense level of cross-relationships and collaboration between all of them through intermediate bodies and events. The idea was to create urban innovation ecosystems - which could be distributed throughout the city - rather than to create a smart district or an urban technology park.

More than twenty years later, it must be said that these new territorial strategies for promoting innovation have served to boost the adaptation of cities to the demands of the digital economy and to encourage support for entrepreneurs as an essential ferment of the new economy. But in most cases they have not led to the emergence of new champions of the digital economy, nor have they obscured the power of large cities.

On the contrary, the digital revolution has exacerbated the attractiveness of large capitals. According to recent studies, 9 out of 10 high-tech jobs created in the United States in the last decade are concentrated in just 5 places: Boston, Seattle, San Francisco, San Diego and Silicon Valley. At the same time, half of the cities in that country are losing jobs in these high-tech sectors (Atkinson, Muro & Whiton, 2019).

This is bad news for medium and small cities in many countries. In Spain, for example, youth emigration has doubled since the 1990s and has also become more selective: the percentage of

young emigrants with university degrees has tripled. Many intermediate Spanish cities - even major cities such as Valencia and Zaragoza - are now experiencing negative emigration rates and loss of intellectual capital: they receive foreign immigration or low-skilled nationals, but lose more young graduates to Barcelona and, above all, Madrid (González-Leonardo & López-Gay, 2021).

Despite this disappointing evidence, smart city projects have continued to spread around the world and have shown some resilience in the face of changing trends in urban management and in the attention of local governments. As the number of cases and experiences has increased, the effectiveness and reliability of technological solutions has had an easier time reaching the level of security demanded by public administrations.

The new urban landscape after the pandemic

The COVID-19 pandemic that started at the end of 2019 and spread worldwide in the spring of 2020 represented a terrible shock for all cities. The strict lockdown established in many countries radically changed the urban landscape and life in a way never seen before. Closed businesses, empty streets, emergency and security services on permanent alert··· According to the International Labour Organization up to 81% of employees worldwide were affected by the total or partial closure of their workplaces.

The coronavirus gave information technologies an exacerbated social protagonism. Millions of workers switched from one day to the next to remote working. What a few years ago was only a kind of luxury for digital nomads, became mandatory for a significant part of the working population, emptying the streets, highways and corporate districts in the center of big cities. In addition, social

networks definitely became indispensable for maintaining family and social relationships, as interpersonal contact was highly restricted and dangerous. In the same way, local governments and the rest of the public administrations had to close their citizen service windows and activate all possible channels of information and contact through digital systems.

The shock of the pandemic, from which we are still recovering in the autumn of 2022, had an ambivalent effect on smart cities. On the one hand, it became clearer than ever that digital technology was absolutely essential for urban management. From COVID-19 onwards, the smart city model was no longer an option but a strategic necessity for reasons of security and resilience. In a way, it was the definitive triumph of digital technology as the new nervous system of cities.

But, at the same time, the unprecedented urban landscapes created by the coronavirus activated new citizen sensibilities in another direction: the need for greener streets, with more space to rest, talk and coexist; the incalculable value of having basic services close to home (food, education, health, culture…); the benefit for everyone's well-being of having silent streets with very little traffic; the feeling of individual and collective vulnerability; the convenience of having a home in which there is simultaneous space for work, study, care, cooking or play….

Actually, this new civic sensitivity is not against technology; in fact, it takes its necessity and its indispensable value for granted. However, it is no longer a social priority, it is not the city's main objective. Technology can no longer use the adjective smart exclusively; cities must now be smart not because of their intense digitalisation but because of their social cohesion, their sustainability and their resilience in the face of a turbulent world.

The smart city, therefore, is facing a certain existential crisis, perhaps a turning point in its development. Of course, to paraphrase Mark Twain, it would be an exaggeration to say that the smart city is

dead. But it is also impossible to ignore the negative signs, the growing critical comments, the loss of the glamour that the initial idea of the smart city had for all the mayors of the world. The cover of the prestigious MIT Technology Review magazine was dedicated last summer to "the death of the smart city". Considering the outstanding contribution of many researchers from that university to the theorization and development of the smart city model, the meaning of the message cannot be trivialized.

It is true that in order to reach this moment of disaffection there have been other very important contributions. Leaving aside the excessive expectations created in the citizenship about the improvement that technology would bring to the management of public services and about the economic development that cities would benefit from their commitment to the technology sector, probably the main cause of the erosion of the smart city brand has been the problem of managing Big Data.

The risks of Big Data

Three concrete examples may suffice to explain what happened. The first of these was the discovery in 2018 of the illegal use of millions of personal Facebook profiles to generate a parallel electoral campaign in the United States by manipulating the political preferences of many voters in favour of extreme right-wing options. It was not the successful social network created by Mark Zukerberg who did it but a consulting firm - Cambridge Analytica - linked to the new international reactionary populism. But the problem was exposed with maximum crudeness: the weakness of control and security of personal data, whose malicious use can have serious individual and collective consequences. It is also suspected that similar techniques were used in the Brexit campaign for the UK's exit from the European Union. We all knew by now that there was no such thing as free services on the internet: the price was ourselves, the data that

define the way we live and think. But at that moment we discovered that the risk was not the flood of advertising but the adulteration of our democracies.

A second example. In this case, the social scandal was much smaller despite being equally toxic. Or perhaps more so, because it was covered up by the shield of philanthropy. As discussed above, the near-universal lockdown forced by the explosion of the pandemic in March 2020 moved much of human activity to digital networks. This was the case with education when it was decided to close classrooms in much of the world. In reality, no country was sufficiently prepared for this great experiment: neither in online teaching methodologies, nor in teacher training, nor in the preparation of students and their families in terms of networks, devices and knowledge of platforms for interaction with teachers and classmates. Nevertheless, most of the educational systems made a meritorious effort and managed to maintain the activity until the end of the course, although in general with significant learning losses. To sustain that sudden and unplanned immersion in online education, many governments turned to online platforms powerful enough to host all the activity of their education systems. To put it in perspective, up to 87% of the world's students (over 1.5 billion) were confined.

It was recently, through a study carried out by the NGO Human Rights Wacht , that we learned that a large part of the technological platforms and services used in at least 49 countries put at risk - or directly infringed - the privacy rights of all students, since their data were transferred without their consent for commercial or advertising purposes. Up to 290 technology companies were collecting data from students during their participation in online classes, but also outside of those times they were tracked in their leisure activity on the internet and in their relationship with family and friends, all without the knowledge of their parents. These platforms had offered their services to governments for free. But the hidden cost was overwhelming and malicious.

The third and final example in this series is almost a dystopia: a window into the future, which had an unexpected (and positive) ending. There is probably no better way to understand the crossroads that the different models of digital cities have reached than to pay attention to the great political, business and citizen battle that has been waged in recent years in the Canadian city of Toronto over what is probably the most ambitious and visionary digital urban project ever proposed so far (not in vain it was promoted by a subsidiary of Alphabet / Google).

In a space of just five hectares of former industrial facilities now in disuse owned by a public company on the shores of Lake Ontario, Sidewalk Labs proposed the construction of an integral prototype of a sustainable, hyper-connected and economically advanced city. Wooden buildings, a high percentage of social housing, quality public space, preferably pedestrian, autonomous cars, alternative mobility, public transport, self-production of clean energy, comprehensive recycling systems, incubator of companies specializing in smart cities with secured funding, urban innovation laboratory··· Considering the economic and technological power of the entity that promoted it, it was a spectacular and credible project as an avant-garde showcase of a city model for the 21st century.

However, Toronto Tomorrow - as Sidewalk Labs called its project - faced significant citizen contestation from the moment the first details began to emerge in early 2018. In the face of the dazzling promise of a pilot district with the world's most advanced urban technologies, a deep mistrust about the use and ownership of the data captured by the ubiquitous sensor network that the project envisioned increasingly emerged. It should be noted that since the battle of activists for the digital rights of Toronto's citizens began, scandals have erupted over the massive manipulation of personal data, such as Cambridge Analytica, among others.

Toronto authorities placed limitations and demands on the project as the public controversy

intensified. Finally, in May 2020, Sidewalk Labs abandoned the project on the grounds that the uncertainties of the pandemic did not make it viable at that time.

Two years later, the city of Toronto presented the new project for the Quayside: affordable housing, an urban forest, rooftop gardens, clean energy to make a zero-emissions district and an arts centre dedicated to indigenous cultures. The character of the new project explains better than any theoretical dissertation the turning point it represents for smart cities of the future; in some ways, the Toronto case has already changed the scale of urban priorities when it comes to assessing digital transformation projects. In a recent report on this case, MIT Technology Review titled: "Toronto wants to kill the smart city forever" .

The objections voiced by citizen digital rights activists in Ontario's capital city are fundamental issues that have not yet been well resolved in many of the digital city projects that have been implemented in recent years in other parts of the world. We are talking about essential issues such as the right to privacy and anonymity as one of the indispensable features of life in the contemporary city, today threatened by ubiquitous video surveillance, big data and artificial intelligence; the confusion of roles between public and private when it comes to managing urban space; the need for a more robust and participatory governance to face these new challenges; and the deep distrust towards the possibility that large technological corporations that already control much of our personal and professional information will also become masters in the immediate future of what happens in our cities by capturing their "digital dividends". In short, what the case of Toronto shows us is how the promise - however credible it may be - of wealth and skilled jobs is not enough to compensate for a certain feeling of expropriation of the citizens of their own city and an open rejection, today more justified than ever, of cities becoming a Big Brother much more powerful than the one imagined by Orwell.

A citizens' deal for the digital city

None of the above means that the intensive adoption of digital technology by cities to improve their public services and their relationship with citizens is going to stop. But it is possible that the real success of smart cities will not come until they put all their technological capabilities at the service of social and political priorities, leaving technology in the back office.

Technological solutionism has damaged the reputation of smart cities once the technological revolution has left behind part of its libertarian ideals of three decades ago to become a machine of great potential but no lesser dangers. The antibodies generated in society by smart technologies require a change in the approach to smart cities in order to make further progress in the positive use of the enormous potential of digital technology. But this new approach cannot again be something established from above, from power, be it political or technological.

Cities need a social covenant, a new deal, that determines what, how and for what purpose technology is used and, above all, how to generate robust mechanisms of citizen trust in the face of possible abuses or misuses of technology. To this end, it is essential to adopt a less arrogant position on the presumed capacity of technology to solve all urban problems. It has already been demonstrated that this is not true and, moreover, it imposes a technocratic language that generates distrust and rejection. It also seems advisable to avoid universal proposals, to bring technological solutions closer to the specific political priorities of each city and to show more empathy with the social problems of the present. And, of course, the smart city discourse must be committed to the goal of strengthening democracy - rather than being an instrument capable of eroding it - and protecting the public domain and the collective interest in all areas of urban life.

For some time now, many cities that have stood out for the deployment of advanced strategies such as smart cities have been actively working to incorporate this new, more holistic, more social and more political vision. Among them, those that belong -such as Amsterdam, Barcelona, New York, Berlin or Zaragoza- to the Cities Coalition for Digital Rights, whose declaration of principles states: “We strongly believe that human rights principles such as privacy, freedom of expression, and democracy must be incorporated by design into digital platforms starting with locally- controlled digital infrastructures and services” .

Advancing towards these objectives -indispensable today- requires building a new urban culture for the digital era. Reflecting, proposing and developing new ideas on how to hybridize the traditional knowledge of the management and design of cities with the opportunities opened up by digital technologies that have quickly become part of everyone’s life, from interpersonal relationships to work, leisure, education or the relationship with public administrations.

We should think about the classic concept of civility or urbanity. In many languages, civility refers to good manners, to the polite and courteous way of behaving in the social relations that are part of being in the city. From that primordial meaning, there has been an extension of the concept of urbanity to those qualities essential to good urban life. That is, ultimately urbanity is the art of making cities, good cities for a decent, safe and prosperous life.

The Barcelona architect and urbanist Manuel de Solà-Morales understood urbanity as something always linked to the tangible, to the material, to the physical form: “urbanity made of touch and vision, of sensations and suggestions”. He said that it is things that contain relationships, because he believed that urbanity is not built by singular architectural projects but by the enormous diversity of objects and spaces that make up the skin of the city and that are what give it the value of use, the flow of relationships,exchanges and experiences. In short, he saw urbanity as “that combination

of mixture and density that allows the residents of the city to participate and be part of urban society through the possibility of meeting one another" (De Solà-Morales, 2008).

If we consider the city, the urban, as that which encourages participation, encounter and exchange, today it would be impossible to dissociate it from the devices and networks that maximize these interactions; in the same way that we can no longer imagine the city without a significant number of people in a situation of remote working or digital nomadism, or public services that are only accessible online. The new urbanity must imagine how to integrate in its knowledge and practices the use of the digital and its consequences in the design and use of the city, its infrastructures and its public and private spaces. We must imagine a city that defends and preserves the virtues that have made it attractive for many centuries - and which always refer to the flow and wellbeing of people rather than to whether or not it has large unique buildings - while adapting to the new habits and needs of the connected citizen.

That is an effort that is largely still to be made, since we are still learning to recognize ourselves in our new urban behaviors as people permanently connected to a smartphone and, therefore, empowered by augmented reality, communicative ubiquity and, soon, the virtual reality of the metaverse.

But it is clear that we will need a new digital civility that, in addition and above all, establishes codes of ethics and conduct that protect our rights, our freedoms and our data, and inspire us with guidelines of conduct with which to continue being good and trusting citizens.

We need to reactivate the concern to ensure that all citizens have a real possibility to access digital services (the pandemic has shown us that they do not: most people have a smartphone, even in social sectors with low purchasing power, but there are many older people who do not have the necessary knowledge and skills to access online services). It is necessary to advance in open innovation processes that take

citizen participation to new levels of depth, giving the opportunity to contribute from the beginning in the design of public services. And it is necessary to review and strengthen the entire digital infrastructure to ensure the resilience of cities in the face of new environmental, energy, health and food challenges. It is essential to make decisive progress to guarantee urban sustainability, to renaturalize our cities and to make possible a socially inclusive model of life in an environment of great restrictions.

A complex and difficult task, which will only succeed if we actively seek a broad social consensus to support it.

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Putting People at the Centre of Smart Cities

사람 중심의 스마트시티

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ABSTRACT

Digital transformation has become an unavoidable requisite in sustainable urban development. During the past decade, having a safe viable access to internet and technology has become a specification for people to be able to fully participate in society changes, including access to e-administration, academia, affordable housing, healthcare appointments or online services. This social trend increases the digital divide for people who do not have access to internet. Furthermore, in recent years, digital innovations like civic technology, open data, digital platforms have changed how people understand, manage and participate in cities.

Recognizing the importance of digitalization through current major urban development trends, many smart cities and urban digital projects currently lack a strong and efficient human-centered approach. Many local governements face issues in termes of resources, staff-training and capacities to even start their people-centered digital transformation within their own territories. Furthermore, various concerns towards smart cities are frequently raised by civil societies, citizens and communities within cities, targeting transparency, data surveillance, private ownership of digital public goods or a lack of inclusion that directly impacts the most marginalized groups such as women, migrants or the youth.

Taking into account the necessity of building more sustainable, inclusive and community-based cities, many municipalities recognize that a multi-stakeholder cooperation is needed to build a better global smart city vision. This overall view shall center the human approach in its foundations as it is crucial to build a solid global outline that will benefit all cities all over the world.

UN-Habitat has already taken clear steps towards the implementation of a human-

centered smart city approach by launching a new flagship programme in 2020 called "People-Centered Smart Cities", which focuses on respecting human rights, ensuring that the benefits of digital technologies serve all populations and that smart cities align investments in technology and data with urban development priorities.

Following the launch of this flagship programme, UN-Habitat has published a serie of six playbooks dedicated to the People-Centered Smart Cities vision. These six playbooks present the five founding pillars of the People-Centered Smart Cities programme which are empowering people, making access to technology equitable, responsibly managing data & digital infrastructure, building trusty by securing digital assets and building multi-stakeholder capacity. All playbooks have different topics such as centering people in smart cities, assessing the digital divide, adressing the digital divide, shaping co-creation & collaboration in smart cities, building & securing digital public infrastructure and building capacity for people-centered smart cities. These playbooks are meant to be tools for local representatives and staff to be able to understand UN-Habitat's vision on more human-centered smart cities and how to implement this model in their own territories.

Furthermore, UN-Habitat is working directly with Member States by supporting them to develop more sustainable, inclusive and human centered visions in their urban development programmes through National Urban Policies, as a national urban policy tool is considered to be one of the greatest instrument to developp safe, sustainable and inclusive urban changes.

Regarding these perspectives, this paper sheds a light on the specificities related to a human-centered approach within the smart city, through a brief history of smart cities, a

presentation of the people-centered smart cities vision, a case study and the presentation of the five pillars of the People-Centered Smart Cities flagship programme developped by UN-Habitat. Finally, it opens the dialogue about creating an international guideline towards a people-centered smart cities vision that would be shared between all UN Member States and create an overall standard for better, more sustainable and inclusive cities within the current digital transformation our society is going through.

KEYWORDS

Digital, Sustainability, Smart cities, Inclusion, National urban policy

초록

디지털 전환은 지속가능한 도시 개발에서 피하지 못할 필요조건이 되었다. 지난 10년간 인터넷과 기술에 대한 안전하고 실행 가능한 접근은 사회 변화에 충분히 참여할 수 있는 전제가 되었다. 예컨대 전자정부와 교육기관, 알맞은 비용의 주거, 의료 약속, 온라인 서비스 등을 포함한 활동의 전제가 되었다. 이 같은 사회적 흐름은 그러나 디지털 격차를 심화하여 인터넷에 연결하지 못하는 사람들을 소외시키고 있다. 게다가 지난 수년 동안 도시 기술과 오픈 데이터, 디지털 플랫폼 같은 디지털 혁신이 사람들이 도시에 대해 이해하고 도시를 운영하고 도시에 참여하는 방식을 바꿔놓았다.

많은 스마트시티와 도시 디지털 프로젝트들은 현재의 주요 도시 개발 추세를 통한 디지털화의 중요성을 인식하면서도 아직 강하고 효율적인 사람 중심 접근을 하지 못하고 있다. 사람 중심 디지털 전환을 시도하는 단계에서조차 자원과 직원 교육, 시설의 수용 능력 측면에서 문제에 직면한 지방자치단체가 많다. 나아가 시민사회와 시민, 도시 내 공동체가 스마트시티로의 이행을 둘러싸고 우려를 제기하고 있는데, 그 대상은 투명성과 데이터 감독, 디지털 공공재의 사적인 소유, 여성·이민자·젊은 층 등 가장 주변화된 계층에 직접 타격을 주는 포용 결여와 같은 이슈이다.

많은 시 정부가 더 지속가능하고 포용적이며 공동체에 기반을 둔 도시를 건설할 필요성을 받아들이는 가운데, 더 나은 글로벌 스마트시티 비전을 이루려면 여러 이해관계자의 협력이 필요함을 인식하고 있다. 이런 전반적인 인식은 전 세계 모든 도시에 도움을 줄 탄탄한 글로벌 설계도를 그리는 데 중요하며, 사람 중심 접근을 바탕으로 할 것이다.

유엔해비타트는 2020년에 '사람 중심 스마트시티People-Centered Smart Cities'라는 주력 프로그램을 출범시킴으로써 이미 사람 중심 스마트시티 접근을 실행하기 위한 뚜렷한 발걸음을 내디뎠다. 이 프로그램은 디지털 기술의 혜택이 모든 참여자에게 돌아가고 스마트시티가 기술과 데이터 투자를 도시 개발 우선순위에 일치시키는 것을 확실히 함으로써 사람 권리 존중에 초점을 맞춘다.

주력 프로그램의 출범에 이어 유엔해비타트는 스마트시티 비전을 위한 여섯 개의 실행계획을 발표하였다. 이들 실행계획은 사람 중심 스마트시티 프로그램이 기초로 삼을 다섯 기둥, 즉 시민에게 권한 부여와 기술

접근성의 균등화, 데이터와 디지털 기반시설 운영의 책임성, 디지털 자산의 안전한 관리를 통한 신뢰 형성, 여러 이해관계자의 역량 형성을 제시한다. 6개 실행계획의 주제는 "각각 스마트시티에서 사람을 중심에 놓기와 디지털 격차 평가, 디지털 격차 해소, 스마트시티에서 공동 창조와 협력의 형성, 디지털 공공 기반시설의 건설과 안전한 운영, 사람 중심 스마트시티를 위한 수용 능력 형성"이다. 이들 실행계획은 지자체 간부들과 실무진이 유엔해비타트의 더 사람 중심적인 스마트시티 비전을 이해하고, 이 모델을 자기네 지역에서 실행하는 데 있어 도구가 되고자 하는 취지에서 작성되었다.

유엔해비타트는 나아가 '국가 도시정책 프로그램National Urban Policy Program, NUPP'을 통해 회원국이 더욱 지속가능하고 포괄적이고 사람 중심적인 도시 개발 프로그램을 개발하도록 지원하고 있다. 이 프로그램은 안전하고 지속가능하며 포용적인 도시 변화를 위해 매우 중요한 수단으로 여겨지고 있다.

이 논문은 이런 관점을 고려하여 스마트시티의 역사를 간략하게 훑어보고, 사람 중심 스마트시티 비전을 제시하며 사례를 분석한 뒤 유엔해비타트가 개발한 사람 중심 스마트시티를 위한 주력 프로그램의 다섯 기둥을 제시함으로써 스마트시티 내의 사람 중심 접근과 관련한 특별함을 살펴보고자 한다. 그럼으로써 사람 중심 스마트시티 비전과 관련하여 국제적인 지침을 만들어내는 작업에 대한 대화를 열고자 한다. 그 지침이 유엔 회원국 사이에 공유되어 우리 사회가 경험하고 있는 현재의 디지털 전환 속에서 더 낫고, 더 지속가능하며, 더 포용적인 도시를 위한 표준이 되기를 희망한다.

키워드

디지털, 지속가능성, 스마트시티, 포용, 국가도시정책

Introduction

Nowadays, digital transformation is key to fill up the needs of sustainable urban development. In the past decades, internet connectivity has been a requisite to gather full citizens' participation in society, including access to education, affordable housing, and critical government services – yet 3.7 billion people were offline in 2019. Recently, digital innovations as civic technology, open data, and digital platforms have given much impact on changing the way of people's understanding, management and participation within cities. The Covid-19 pandemic highlighted the urgent need for local and national governments to tackle and reduce the digital divide, especially regarding their marginalized groups. Thus, the New Urban Agenda(2016) requests the adoptions of a 'smart city approach that utilizes the digitalization, clean energy and technologies' and for 'citizen-centric digital governance' as the foundation for inclusive and resilient smart cities.

But, if one looks at the smart cities' field, there are many projects where technology is applied without considering the real demands coming cities and their citizens, especially regarding sustainable goals. Simultaneously, many cities and local governments don't have enough capacities, resources and strategic visions to get appropriate technologies that meet their actual demands. Indeed, there's a clear rise of trends towards surveillance, private ownership of digital public goods, infrastructure and discrimination through the automated decision-making generated by artificial intelligence. Since cities have become testbeds for these new technologies, there are global growing concerns about the lack of oversight, transparency and potential human rights violations within smart city frameworks.

Recognizing this, for the past recent years, several actors have argued that 'smart cities' need to be more aligned with broader public sector digital transformation efforts and a broader digital development agenda which includes 'gov tech', 'civic tech' and 'open government' initiatives.

Smart cities frameworks also need to take seriously in consideration people's concerns about surveillance and use of private data and recognize that despite our efforts, the digital divide – between countries, within countries and within cities – is still very much a reality. Clearly, the smart city needs an injection of fresh thinking.

There is still some progress that has bene made. We are indeed seeing a movement towards a more impactful, inclusive, sustainable and human-centric smart city gathering ground. National smart city charters, such as those from Germany and Brazil, make the case that digital transformation needs to be closely aligned with urban development goals and that this requires focus on open and transparent governance, strategic leadership, digital participation, inclusion and integration, securing access to digital infrastructure and managing data responsibly.

A review on smart cities

Since technology has been integrated into more aspects of public and private life settings, there are more chances to optimize some key components of human settlement planning such as mobility, energy, healthcare or physical infrastructure. These new life settings are improved with the use of these new technologies, which are aimed to develop optimization, efficiency and convenience within 'smart cities.' Those smart city technologies can generate new streams of data, which provide smart platforms running analytics to gain greater behavior and performance insights. The estimation of global sending to the smart cities market should rise between USD 820.7 billion to USD 2.5 trillion by 2026.[1]

Where are the smart cities originated from? There are several models within the smart city evolution,

1 UN-Habitat People-Centered Smart City programme, Playbook 3, PP15

that use various terms and different timelines. UN Habitat identifies 4 “phases” of smart city development : the “researcher’s smart city”, the “marketer’s smart city”, the “citizen’s smart city” and the “consumer’s smart city”.

The “researcher’s smart city, which has been identified as the first phase, emerged in the 1980s. Technology played a major role in how people envisioned cities after World War II. The appearance of Internet in the 1960s, and growing usage of computers in the 1970s led to a rise in the use of computing technology to measure and quantify urban parameters. Researchers then started to explore the use of computation as tools for urban planning from the 1980s, from which emerged the “researcher’s smart city.”

A new generation of urban planners started to focus on the optimization of urban processes based on digital technology during the 1990s and early 2000s, since the availability of using data in cities was highly increased. It was at this time that the first private sector on smart cities emerged, while the market opportunities in the smart city field became wider. Even the term “smart city” started to appear more in literature. At the beginning of the 1990s, it even became a mainstream consciousness term, which was confirmed when IBM initiated the “Smarter Cities Challenges” in 2010. This challenge targeted technology used by local governments and urban infrastructure developers. Several companies followed the stream, marking the second phase of smart cities, “the marketer’s smart city.”

The third phase, the “citizen’s smart city”, originated from criticism of the second phase. In the early 2010s, residents, academics and public authorities started to feel and recognize that the use of technology in smart cities lacked clear objectives and was actually driven by private sector concerns. These groups began to re-orient smart city project aims towards more public control. By doing so, the definition of the “smart city” had to be re-defined to include themes such as public participation,

education, public health, data governance and digital inclusion. Those concepts focused more on government services than infrastructure and had an emphasis on the role of technology in enhancing citizen engagement through crowdsourcing, open data, citizen science, civic technology and social media.

On the other hand, along with the simultaneous global growth of the technology sector, tech companies started to leverage cities as platforms to create their own markets. This stream was developed at the same time as the inclusion of hubs in the Silicon Valley in California, or Shenzhen in China, which increased the importance of start-up culture in the late 2000s. Old business models, regulatory structures and systems were disregarded from many tech companies by cutting out traditional institutions and leveraging digital platforms to deliver services directly to consumer. As an example, digital applications started to be used to provide consumers services such as taxis or other accommodations. The fourth phase, the "Consumer's smart city", considerably challenged the norms and especially the way local governments operated it. It then initiated a global re-consideration about regulations on the public human rights, hyperlocal data gathering and taxation.

More recently, there is a growing realization that the first smart cities waves have not resulted in the kind of deep and meaningful impact on urban development as originally hoped. Many smart city projects have been business as usual with technology added on top, often through efforts by technology vendors to sell digital infrastructure to local governments. Others have resulted in greenfield development projects which used the 'smart' moniker mainly as a brand, without proper consideration of good urbanism principles. There are also examples of smart city projects using data, artificial intelligence, CCTV and other technologies as a way to control the city without respect for human rights.

These concerns have brought out new debates about the value of technology in urban development. A better, inclusive and equitable approach to smart city development centering on public participation

and co-creation has been highly requested, by building local government capacity and achieving tangible outcomes. According to these interpretations, the role of technology should be re-centered, on transforming residents from being passive consumers to active contributors, and on the use and development of technology in urban environments.

Specifically, critics are targeting more public control and ownership of data in smart cities understanding the power that comes with the ability to access and control information. This debate reached a critical turning point in 2019 when Sidewalk Labs, a subsidiary of Alphabet(the parent company of Google), was widely criticized for co-opting the public participation process from the City of Toronto for a master-planned redevelopment of an industrial waterfront property into a "smart" community. Concerns over data ownership and privacy were central to the public outcry that resulted in the closing down of the project.[2] Emerging public awareness of surveillance technology and bias in algorithmic decision-making, particularly in the wake of COVID-19 has also challenged the traditional smart city framework as large technology companies have failed to address ethics in artificial intelligence and surveillance technologies, which was then discovered.

Towards people-centered smart cities

Voices are increasingly being raised – by countries, cities, civil society, the UN system as well as some companies – that there is a need for a new approach to smart cities built on good urbanist principles, sustainability objectives and real urban challenges and then thinking about appropriate technology to use.

2 UN-Habitat People-Centered Smart City programme, Playbook 1, PP14

At the United Nations High-Level Meeting on the New Urban Agenda in April 2022, several Member States called for a human-centric approach to digital transformation and highlighted the need to use digital transformation benefits while pointing out its risks and challenges. They spoke about the need to improve digital connectivity, equip communities and individuals with the necessary skills and digital literacy, in order to improve digital financial inclusion, and to reinforce international cooperation. For example, the Group of African States highlighted the need to tackle inequalities in informal settlement through provision of affordable housing and addressing the digital divide. The Republic of Korea highlighted how its national plans set out principles for Korean cities to pursue human-centered smart green cities for the 21st century.

It is clear that we are entering a new phase of smart city development, one that builds on the previous phases but focuses on putting people at the centre. People-centered smart cities leverage data, technology and services for common good, offering the inclusive and sustainable cities model that is needed in the 21st century. They use technology to advance human rights and they put in measures to overcome the digital divide. They also think strategically about the goals that they want to achieve and the challenges they want to overcome, and then think carefully about the kinds of data, digital technologies and innovations are needed to achieve those goals. This requires a new approach where governments engage in strategic smart city planning, build digital capacity, establish smart city governance frameworks and ensure that all technology projects are assessed based on the impact that they deliver in terms of quality of life and environmental outcomes.

This is not easy. Today's smart city framework is deeply complex for many national and local governments. Many cities have become testbeds for new, untested, and sometimes unregulated technologies, forcing local authorities to respond to disruptive trends instead of proactively shaping life in cities. As a result, many cities are constantly keeping up with today's technology industries. Massive amounts of data created by smart city technologies have brought out a global dialogue

about cybersecurity, privacy and surveillance, requiring local governments to upgrade their digital infrastructure and assess their ability to secure data and guarantee human rights in the digital era. The Internet of Things(IoT) has created new opportunities for digitizing infrastructure, such as streetlights and energy meters, but has also introduced new cybersecurity vulnerabilities that cities must build capacity to deal with. As a result of these large investments, new layers of digital infrastructure can put additional burden on municipal budgets, where unplanned expenditures can result in under-used or misallocated digital services.

However, there are good examples of cities and communities moving towards implementing a people-centered smart cities approach. Through an experiment to lead more democratic applications of technology for cities and citizens, the city of Barcelona's Digital City Plan sets out how the city can offer agile digital services, accomplish technological sovereignty and process to migrate towards free and open software and open standards, using data in a responsible and ethical way. The plan is connected with designing public services as 'digital services by default' driven by citizens' needs and experiences, and focuses on open standards and interoperability structures that minimize the demand to rely on vendors and providers, while promoting innovation.

UN-Habitat launched a new flagship programme titled "People-Centered Smart Cities" in 2020. The name "People-Centered Smart Cities" was chosen carefully with the will to highlight 3 key points, the first one being the importance of human rights. People-centered smart cities use technology and data responsibly, putting in place norms and standards around the use of private data, ethical frameworks to guide the use technologies and apply strong cost-benefit principles to ensure clear public benefit when choosing to invest in surveillance technologies. Secondly, people-centered smart cities ensure that the benefits of digital technologies benefit the whole population and that everyone has access to what ITU calls 'meaningful connectivity'. They work actively to assess and address the digital divide, ensuring that all communities have access to affordable internet connections,

putting in place programmes to build the digital literacy of the population and implementing digital public participation and co-creation processes. Finally, the people-centered smart cities align investments in technology and data with urban development priorities such as affordable housing, inclusive urban planning and green and affordable transport. This requires effective leadership, a clear digitalization plan, appropriate governance frameworks and building the digital capacity of all city staff, not just those working with ICT.

Case study:
People-centered smart city approaches in National Urban Policies

One of the ways that UN-Habitat is supporting Member States to put in place sustainable, inclusive

Figure 1. UN Sustainable Development Goals

Figure 2. Demonstration Projet: Smart-Metered Solar Borehole in Niger State (Nigeria)

and people-centered approaches in urban development is through National Urban Policies.

The importance of a national urban policy as a tool for governments to guide and manage urbanization is recognized by articles 80 of the National Urban AgendaNUA, which states;

> *"We will take measures to build legal and policy frameworks based on the principles of equality and non-discrimination, to enhance governments' ability to effectively implement national urban policies appropriately, and to empower them as policy makers / decision makers, ensuring appropriate fiscal, political and administrative decentralization based on the principle of subsidiarity."*[3]

Over the last six years, in collaboration with a wide range of partners, UN-Habitat has developed tools to support countries with the process of producing a national urban policy. At the Habitat III in 2016, UN-Habitat, OECD, and Cities Alliance launched the National Urban Policy Programme NUPP. This programme, which is funded by the Republic of Korea, provides support to countries as they develop a national urban policy.

3 Omoyele Williams, Remy Sietchping, National Urban Feasibility Guide, 2018, PP8

- The Purpose of the National Urban Policy Programme was to develop National Urban Polices and Smart City Strategies in the three countries, I.R. Iran, Myanmar and Niger State (Nigeria). The project aims to: (i) enhance capacity of subnational and national governments in the three pilot countries by developing, implementing, monitoring and evaluating national and sub-national urban policy (NUP and SUP) as well as developing smart city strategies; (ii) increase centralization of knowledge and tools on the development, implementation, and monitoring and evaluation of urban policy (NUP and SUP) and smart city strategies; and (iii) provide opportunities for knowledge sharing and peer leaning activities on urban policy (NUP and SUP) and smart city strategies. Since launching the project in 2017, significant progress was made, both at the global level of the programme, and at the country level. By Korea NUP phase 1, three countries drafted NUP reports and SCS reports and implemented demonstration project.

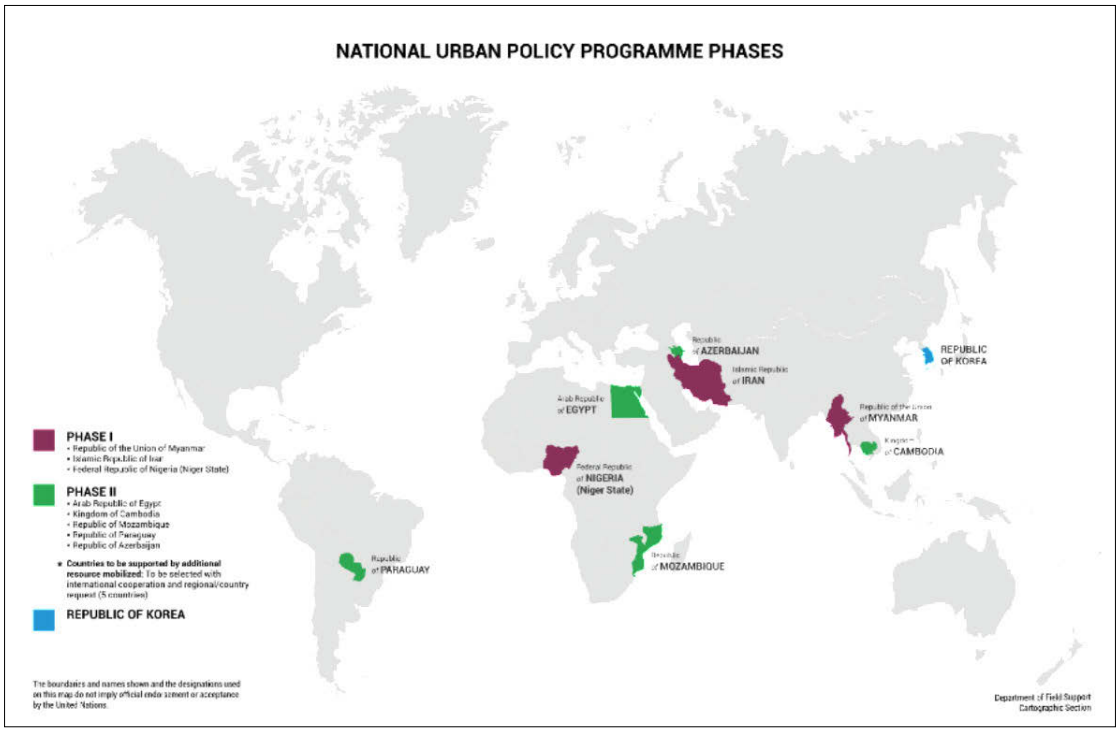

Figure 3. National Urban Policy Programme Phase

UN-Habitat is currently preparing to launch Phase 2 of this programme, focused on Scaling up People-centered Smart Cities through NUP. It focuses on transformation projects that demonstrate how to mainstream sustainable and inclusive digital transition in urban policy processes and people-centered smart cities in selected countries. NUP Phase 2 is expanding the programme to five additional countries: Mozambique, Egypt, Azerbaijan, Cambodia and Paraguay.

The five pillars of people-centered smart cities

Central to the people-centered smart city vision is ensuring that digital technologies improve urban environments and quality of life, while minimizing the negative and unintended effects of technology. UN-Habitat has set out this vision in a series of people-centered smart cities playbooks. The people-centered smart cities vision is centered around five pillars, first outlined in the report Centering People in Smart Cities.

Pillar 1: Empowering people

In order to build people-centered smart cities, local governments must reshape their decision-making process about the creation and use of technology. Smart cities should provide open, transparent, accessible and interoperable digital public goods. Cities will be able to focus more heavily on digital governance regarding the implementation of these criterium. In smart cities, a strong digital governance frameworks results in the improved ability of a local government and its citizens to control how data and technology is developed, evaluated, purchased and used in public services.

Smart cities rely mainly on technology and data, but few cities publish useful information about

Figure 4. People-centered smart cities playbooks

how these technologies work, or make the data they create publicly accessible. Open standards attempt to bridge that gap by providing technical information about a digital system to the public. For example, Digital Public Trust for Places and RoutinesDTPR is an open source project developed by a coalition including Boston's Office of New Urban Mechanics that is working towards developing a set of open communication standards for digital transparency in public spaces. Many cities have then adopted open standards. For example, the EU's bIoTope project is working to create an open standard for Internet of ThingsIoT technology, and the city of Montevideo adopted the Red Hat OpenShift Container platform to unlock data transmission between city departments and third parties.

Interoperability is crucial for local governments to consider when they should procure new technology or when different departments should provide services which can be overlapped and

relevant for many digital service aspects. Indeed, digital services can easily enhance frustration when people have to create multiple accounts with different services across local governments, or repeatedly provide the same data. As an example, Open & Agile Smart Cities offers a set of ten Minimal Interoperability MechanismsMIMs adopted by the network's partners and the European Commission. These mechanisms include standards for content management, artificial intelligence, security and data management among several others.

People-centered smart cities simultaneously build public commitments to transparency, privacy and inclusion across digital services and digital infrastructure administered by the local government, and can also create open, participatory and transparent opportunities for residents to shape the development and smart city technology usage. Such commitments invite the public to hold local governments accountable, to establish trust with residents, and to encourage the private sector to develop relevant solutions. But how can local governments accomplish these goals? This topic is related with addressing three key areas:

- How can cities make public commitments to transparency, privacy and inclusion that are actionable and that they can be held accountable to? Co-working with residents in order to build and prioritize principles that guide the city's use of data and technology.
- How can cities be better at involving residents in their technology projects? Use both non-digital as well as digital means to inform and involve people in procurements and strategic planning of technology initiatives.
- How can cities use digital platforms and tools to enhance public participation in general? This requires rethinking how digital technologies are used to unlock planning and participation.

People-centered smart cities should launch guiding principles for transparency, privacy and inclusion as they are related with smart city technologies. These principles should be constructed from community

consensus through a participatory process. The process of development of these principles will be perceived differently for each community, and should be tailored to and facilitated by the local culture and urban realities.

Residents must be engaged when it comes to decision-making and must define the role technology will play in their community. Residents can be engaged in four major ways:

- As drivers - Where residents join the decision-making process by actively setting budgets, setting strategic goals and defining the use of smart city technologies. Local governments must support a decision-making process by achieving this role with an institutional means of execution (such as financing, procurement, policy, and deployment or delivery).
- As democratic participants - Where residents participate in the decision-making process, influence project goals and desired outcomes and provide feedback on the use of smart city technologies.
- As co-creators - Where residents help local governments to build technology or infrastructure, create new uses for data and ICTs or co-develop policies and strategy.
- As ICT users - Where residents take part in online platform processes and digital infrastructure including open data, 311 platforms, augmented realityAR applications as well as sensor data collection primarily for the purpose of obtaining information, conducting analysis or providing feedback to local government.

Pillar 2: Making access to technology equitable

People-centered smart cities are built on the foundation of universal access to affordable internet, digital skills and digital devices. The digital divide is the gap between those who have access to and use ICTs including internet connectivity, internet-enabled devices and digital literacy skills

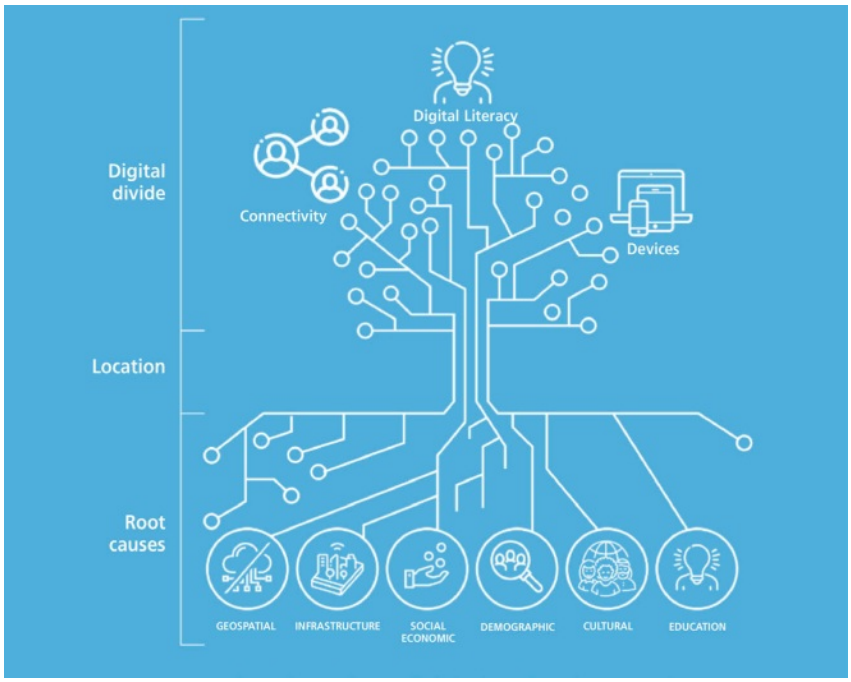

Figure 5. The impact of digital divide

and those who do not. Access to all three is fundamental for communities to establish a robust and sustainable connection to the digital world. Internet connectivity is widely regarded as the foundation for participation in a digital society - without robust, affordable, sustainable and inclusive internet connectivity as well as participation in digital society and access to digital service offerings remain systemically exclusive.

The UN has recognized the fact that internet connectivity can directly impact education, equity, innovation and economic development. The New Urban Agenda(2016), The Connect 2030 Agenda(2018) and the UN Secretary General's Roadmap for Digital Cooperation(2020) considers digital connectivity and digital inclusion as crucial factors to achieve sustainable development.

The impact of digital divide is key across many sectors including education, workforce development

and financial inclusion. During the global COVID-19 pandemic, schools had to use internet remote classes, leaving behind an estimated 4 in 5 children without internet access in developing countries. While every community is different, the digital divide consistently reflects and amplifies existing social, economic and cultural inequalities such as race, age, gender, income and ability.

UN-Habitat recommends cities to carry out an assessment to understand the digital divide and then develop a digital inclusion plan. The first step towards establishing a plan to reduce or eliminate the digital divide is to study the contours of local problems. Ways to do a digital divide assessment and a digital inclusion plan are outlined in UN-Habitat guides: Assessing the Digital Divide – Understanding internet connectivity and digital literacy in cities and communities and Addressing the Digital Divide – Taking steps towards digital inclusion.

However, increasing connectivity is not enough to solve the digital divide. Digital connectivity is a tool to increase access to public services and enhance opportunities for residents to become more active citizens, but digital inclusion is fundamentally about opening doors, increasing knowledge, and broadening horizons to help communities become more proactive. The main challenge around implementing these activities is the resident evolutions, which changes them from passive consumers to active contributors of technologies and urban environments.

Pillar 3: Responsibly managing data & digital infrastructure

Traditionally, infrastructure has referred to physical systems like sidewalks, roads, and power grids that support daily life in cities. Local and national governments are currently facing a new layer of public infrastructure that is taking precedence over cities control, manage, and understand the systems they operate: digital infrastructure. In the context of this playbook, digital infrastructure (as a public service) refers to the tools and systems which are required to make digital life function in cities.

The process of using technology to establish digital infrastructure in order to improve operational performance is called digital transformation. Digital transformation is new and as a result, it presents tremendous opportunities and risks to local and national governments, as well as the people they serve. Recent case studies have shown that the use of technology in smart cities can also weaken social protections, deepen inequalities and exacerbate existing discrimination, especially for marginalized groups such as the use of facial recognition or artificial intelligence in automated decision-making. Consequently, establishing digital infrastructure must be treated as a socio-cultural challenge, just as much as a technical one.

For local and national governments, digital transformation refers to how organizations leverage technology to build public services that are convenient, more efficient, accessible, and secure for everyone. In order to effectively use technology and to improve public services, local governments need to target their limited resources to the most impactful areas of digital transformation, to focus on the design of those services on the end-users, and to prioritize privacy, transparency and security throughout the process.

Digitization presents fascinating opportunities for cities, but can also introduce privacy, ethics, security challenges and create more confusion if there is a lack of buy-in from leadership or employees, or coordination issues regarding contracts, staff and data accessibility. When digitizing public services, governments should ensure that these efforts are aligned with the SDGs, and respond to the actual needs and living experiences of residents. This can be gained by taking a multi-stakeholder governance approach.

Digital government is increasingly popular, and makes particular sense in our post-pandemic reality that has increased the demand for remotely accessible services. Some governments use their digital transformation as an opportunity to stimulate collaboration with communities of practice

such as the Taiwan Digital Ministry's Public Digital Innovation Space and the City of Recife's Open Innovation and Government Programme. Some governments focus on safe data sharing across stakeholders to enhance service delivery, for example Germany's construction of shared digital infrastructure to standardized electronic medical records.

Transforming government culture and reforming legacy systems while keeping up with the pace of innovation in the technology sector can result on extreme challenges for governments. However, we have set out several steps that local governments can undertake when initiating digital transformation in their organization that are outlined in the guide Building and Securing Digital Infrastructure:

- Bulding digital service standards - Digital service standards provide united commitments across all digital services provided by your organization covering privacy, equity, security, and interoperability among other things.
- Establishing a civic technology stack - The civic technology stocks refers to key areas of digital transformation for local governments, namely digital identity, digital payments and data exchanges. Each of these areas forms a layer of digital transformation that comprises the "stocks."
- Establishing capacity and governance for government digital transformation - Any digital service previously established must be maintained and supported by a management structure that ensures the longevity of the service. All digital transformation models should centre on transparency and collaboration.

Pillar 4: Building trust by securing digital assets

A key step for developing robust digital public infrastructure is to ensure that both digital public

infrastructure, and the data that supports it are secured. Cybersecurity threats on local and national governments have become increasingly prevalent in recent years, which increases the need for cities to take actions. However, cybersecurity laws and policies have a direct impact on human rights, such as the right to privacy, freedom of expression, and the free flow of information. City governments should focus on educating residents on cybersecurity issues, being transparent on adopted cybersecurity policies or laws, and take human-rights approach to cybersecurity strategy. They must also acknowledge that cybersecurity risks are not experienced evenly by everyone, and that minorities and marginalized groups may experience disproportionate risks when using digital public services.

Local government's reliance on computer systems means that critical infrastructure such as transportation systems and energy grids can be more exposed to cyberattacks, which can result in large-scale service disruptions. Smart city technologies that transmit data from devices and infrastructure across the internet also introduce new security vulnerabilities for cities, because if it is unsecured, these systems can potentially be intercepted and exploited. Likewise, unprotected data used to deliver digital services can be accessed by hackers to obtain sensitive or personally identifiable information, which may expose local governments to the danger of fraud, ransom, and theft. Even further, unproven and untested smart city technologies can tackle human rights, as they have the potential to be misused. Especially, these risks increase when governments outsource services and software development to third party developers. A report endorsed by the Africa Cyber Security Conference estimated that the African continent lost about $3.7 billion dollars to cybercrime in 2017. Threatening cybersecurity attacks has become crucial for municipalities, which results in cities' putting cyber security prevention within their budget.

Nevertheless, city governments can actually take significant steps towards cybersecurity prevention without spending significant money on digital infrastructure. Indeed, for many cities cybersecurity isn't just a issue related to IT and is thus treated within a global approach that is being tackled globally.

This type of approach combines people, processes and technology through legal, political, educational, and technical means as part of a global model for all cities.

A successful preparation and prevention framework in municipalities for cybersecurity threats requires support and awareness across all levels of governance, including appointed staff and elected officials. Local officials should seize the responsibility they have on securing sensitive data and information within their departments and also understand the importance of the influence they may have on their own staff. Cities stand a greater chance of addressing security issues generated by emerging smart city technologies by adopting comprehensive regulations, implementing solid cybersecurity policies and protocols, developing organizational risk-awareness, and leveraging the appropriate tools.

On building a baseline for cybersecurity readiness as a first step, the UN-Habitat guide Building and Securing Digital Public Infrastructure recommend three steps:

1. Identifying any existing cybersecurity policies at a State, regional, or national level that is related to your municipality
2. Building a people-centered cybersecurity policy that is responsive to the unique needs of your community and which respects human rights
3. Identifying areas of security risk within your municipality and take steps to manage those risks

Pillar 5: Building multi-stakeholder capacity: takes root by collaborating with diverse stakeholders to establish smart city projects, infrastructure and services, by expanding the capacity of city staff for digital transformation and by evaluating the need for technology and addressing equity, environmental justice and social justice in smart city initiatives.

Digital transformation is as much important as human- centered digital process, as cities today are challenged to adapt new ways of working, designing and delivering services. In order to achieve modern expectations of fast, convenient and accessible public services, city and regional governments must transform their current ways of operating. Expectations for convenient digital service delivery were enhanced by the COVID-19 pandemic, which emphasized both the need for digital services, and policies that address security and privacy risks.

While there are many opportunities for using technology through the improvement of city services, the unprecedented pace of technological change introduces new risks to city leaders in the digital era, which requires them to build new infrastructure to accommodate modern demands. Municipalities increasingly need to build better ICT capabilities, while strengthening digital leadership, widening their knowledge base as well as promoting new forms of work that support digital transformation.

There are several ways to build digital capacity within an organization. The UN-Habitat guide Shaping Co-creation and Collaboration in Smart Cities outlines three key activities that governments can follow to maximize outputs and to reduce inefficiencies and cost:

- Co-working with diverse stakeholders to build smart city projects, infrastructure and services.
- Increasing the capacity of city staff for digital transformation.
- Evaluating the demand for technology and address equity, environmental sustainability and inclusion in smart city initiatives.

No city can successfully leverage smart city technologies separately and solely. Multi-sector partnerships are critical to address the needs of residents that span across a variety of services and experiences in their established environment. Additionally, smart city partnerships are necessarily interdisciplinary and can include diverse stakeholders from academia, civil society, public and private sectors with

different competences.

Aside from working with external partners, smart cities should also invest in their existing talent and adapt their recruitment practices to be flexible and competitive with today's technology labour market. Cities should invest in training and upskilling their existing workers and strengthen processes for attracting and retaining digital talent as well as introduce opportunities for participatory leadership in digital transformation, and also take steps to mitigate workforce disruptions caused by adopting new methods of working.

All these investments must reach a quantifiable return. That's why the establishment of key performance indicatorsKPIs for smart cities is vital for organizations, in order to demonstrate and evaluate progress towards their goals. Setting KPIs can increase transparency both inside and outside the organization, and it can help governments pivot from solutions that do not meet their goals.

Conclusion

A people-centered smart city requires leadership, effective governance, capacity, and a solid commitment to sustainability, inclusion, and quality of life. UN-Habitat is committed to keep working with UN Member States, key stakeholders and partners to make people-centered smart cities a reality. We will continue to publish cutting-edge research and analysis, work with countries to formulate smart city guidelines, develop national urban policies, produce normative guidance, build the capacity of local governments and provide technical support on digital governance, digital rights and urban digital public infrastructure.

A key-component of the people-centered smart city approach is multi-stakeholder cooperation. By understanding local uses, from citizens but also municipalities' staff, the needs and gaps within the smart city will be better-targeted. Nowadays, smart cities have to face different challenges: digital divide, inclusion, cybersecurity attacks, data surveillance, digital equity and many others, which exist within all countries and all city sizes. While some States, such as Brazil or Germany, have produced national guidelines in order to guide their smart cities model, many countries lack such guidance and need international guidance on people-centered smart cities. An international smart city charter, incorporating people-centered principles, can be one way of to ensure a global human-centric approach in the digital transformation journey of cities and human settlements.

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Smart Journeys of Developing Cities:

Key Takeaway from the World Bank's Smart City Engagement

개도국 도시의 스마트 여정:
세계은행 스마트시티 지원의 주요 시사점

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ABSTRACT

Smart cities have captured many people's imagination and such interest cuts across the public, civic and private sectors, and both in developed and developing countries. The World Bank has supported developing countries through the Global Smart City Partnership Program (GSCP) in navigating this fast-evolving and complex field. This paper presents GSCP's engagements with developing countries in defining, planning for, and realizing their smart city goals. Using several successful engagement cases, the paper demonstrates how both high-level strategies and specific solutions can contribute to the aspirations of developing cities and draws lessons for better supporting them, mainly by strengthening the link between upstream and downstream engagements.

KEYWORDS

Demands for smart cities, Developing countries, Top–down and bottom–up approaches, Smart city portfolio management, Institutional and human capacity development

초록

스마트시티 개념은 많은 사람의 상상력을 사로잡았다. 스마트시티에 대한 관심은 공중과 시민 영역, 민간 영역을 가로질러, 또한 선진국과 개도국 모두로 확산되고 있다. 세계은행World Bank은 스마트시티라는 빠르게 진화하는 복잡한 분야를 개도국이 잘 헤쳐 나가도록 글로벌 스마트시티 협력 프로그램Global Smart City Partnership Program, GSCP을 통해 지원해 왔다. 이 글은 개도국이 스마트시티 목표를 정의하고 계획하여 실현하는 과정에서 GSCP가 기울여온 노력을 소개한다. 몇몇 성공적인 사례를 통해 고도의 전략과 구체적인 해법이 어떻게 개도국 도시의 열망에 기여할 수 있는지를 보여준다. 또한 지원을 더 잘 하는 방안, 주로 상향 지원과 하향 지원 사이의 연계를 강화하는 방안에 대한 시사점을 도출한다.

키워드

스마트시티에 대한 수요, 개도국, 상향 접근, 하향 접근, 스마트시티 포트폴리오 관리, 기관·인적 역량 개발

Introduction

With the evolution of data-driven digital technologies, smart cities have captured many people's imagination. Having no universally agreed upon definition, smart cities can have a variety of meanings to different people, amplifying expectations put on their potential. At the World Bank, we focus on the contribution of data and digital technologies to improve urban planning, management, and service delivery towards more efficient, innovative, resilient and inclusive cities.

The interest in smart cities cuts across the public, civic and private sectors, and both in developed and developing countries. Notably, over 250 cities had smart city strategy documents and 153 cities had officially published it,[1] illustrating high ambitions for smart cities. However, only eight were implemented to an advanced stage, while others encounter challenges in translating their ambitions into implementation. Mirroring the plethora of smart city strategies on the other side, is a multitude of smart solutions that are often problem- or sector-focused and disconnected from one another.

The World Bank has supported developing countries through the Global Smart City Partnership Program (GSCP) in navigating this fast-evolving and complex field. This paper presents GSCP's engagements with developing countries in defining, planning for, and realizing their smart city goals, through high-level strategy development and specific solutions. First, this paper will briefly introduce GSCP which has been running for over four years. Second, the paper will discuss the nature and pattern of demands for smart city development from developing countries, as observed under the program. Third, the paper illustrates how GSCP has met such demands, using several successful engagement cases. The last section will summarize key takeaway and lessons learned from GSCP experiences to help improve the quality of smart city engagement in developing cities.

1 Roland Berger (2019). Smart City Strategy Index. The Smart City Breakaway: How a small group of leading digital cities is outpacing the rest. https://www.rolandberger.com/en/Insights/Publications/Smart-City-Strategy-Index-Vienna-and-London-leading-in-worldwide-ranking.html

Global Smart City Partnership Program (GSCP)

GSCP was launched by the World Bank in 2018, building on the long-standing partnership with Korea. The program aims to support the World Bank GroupWBG teams and clients in accessing smart city good practices and solutions for enhancing their capacity to plan and implement smart city investments. The Korea Ministry of Land, Infrastructure and TransportMOLIT and Korea-World Bank Partnership FacilityKWPF at the World Bank have contributed nearly US$3.5 million to this end.

Over the past four years, the program has supported almost 50 smart city engagements around the world by mobilizing experts to meet specific demands through technical and operational advisory services. The Figure 1 shows the geographical spread of the proposals from WBG teams that GSCP supported across seven rounds of a call for proposals. The program has also facilitated over 55 knowledge sharing and learning activities, mainly, seminars, workshops, conferences, and knowledge exchange programs, both in-person or in-country and virtually. As the program's name indicates, partnership with leading smart cities and global technical experts is at the core of the program design, whereby extensive networking through knowledge activities has contributed to identifying relevant experts and finding solutions.

What are demands for smart cities from developing countries?

Goals cities aspire to achieve are similar globally – being more efficient, innovative, inclusive, and resilient – as most comprehensively captured by the Sustainable Development Goals.

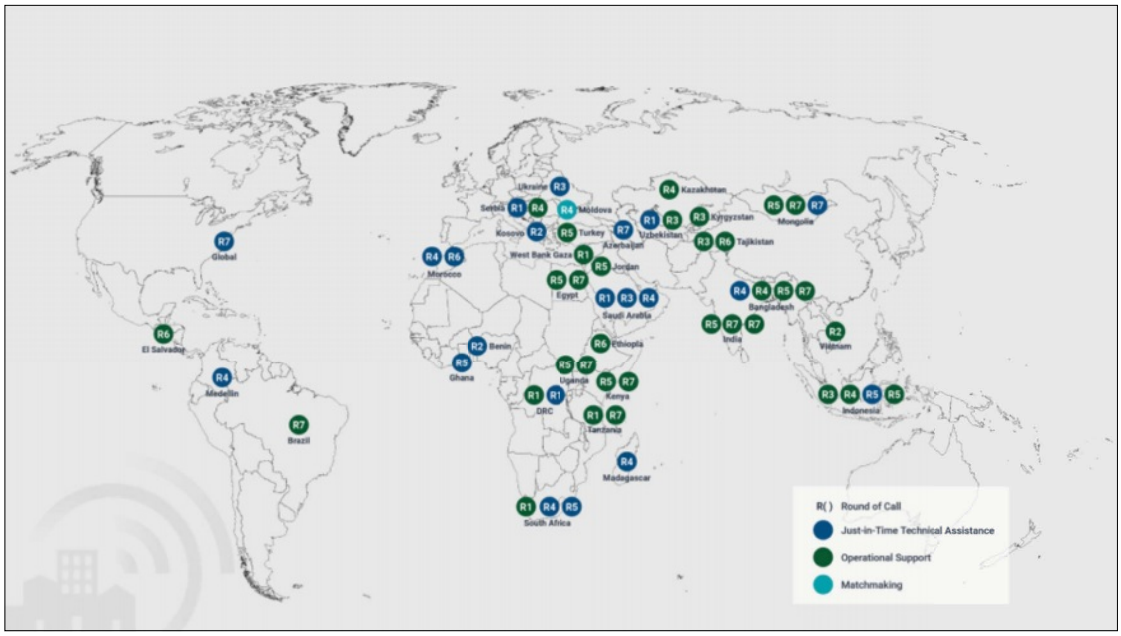

Figure 1. Geographical scope of the GSCP engagement

Key enabling factors are also relatively common across various definitions such as those by the International Organization for StandardizationISO, International Telecommunication UnionITU, and others. They include use of information and communication technologyICT and data, innovation of city operations and public services, and integration of physical, digital, and human systems.

Views may vary widely, however, on how to achieve such common goals in a “smart” way. It is not straightforward what the best formula for mixing key enabling factors – data, digital technologies, and urban institutional and human capacities. In fact, there is a notable tension among those working in the smart city space as their attention is somewhat divided between how far data and technology evolution can reach on the one hand and what they can deliver(or have delivered) in practice on the other hand. Although the earlier emphasis on advanced digital technologies has shifted to a more holistic approach to smart cities, disruptive technologies and frontier innovation are still important pulling forces in smart city discussions.

Yet, many cities in developing countries that GSCP has supported are still at the stage of digitization and digitalization(Figure 2), although their goals are equally ambitious. Several GSCP engagements revolve around how to digitize and organize information (i.e., digitization). For example, under the Indonesia National Affordable Housing Project, the Ministry of Public Works and Housing in Indonesia now endeavors to establish a methodology to analyze rich housing data that is already digitized through the Housing and Real Estate Information SystemHREIS. In Uganda, the Ministry of Lands and Housing and Urban Development developed the Physical Planning and Urban Management SystemPPUMIS to digitize various information for computerized monitoring and planning of urban development. After the pilot application, the Ministry is in the process of optimizing the system to improve the use rate and experience. System improvement not only involves digital system enhancement but more importantly requires development of an analytical framework for urban data and transition to a computer-based urban planning, both of which relies on overall capacity

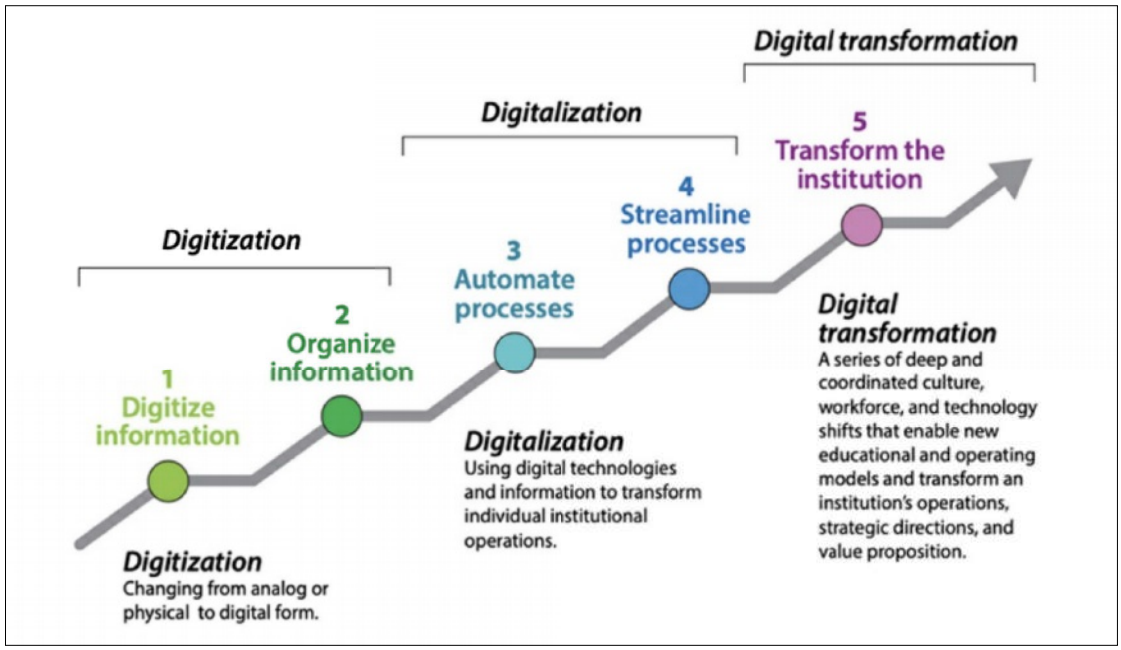

Figure 2. Digitization, Digitalization and Digital Transformation
(Source: Iosad et al. (2020). Digital at the core: A 2030 strategy framework for university leaders. https://www.jisc.ac.uk/guides/digital-strategy-framework-for-university-leaders)

enhancement. It is a challenging task in an environment where unstable electricity and internet connection makes reliable access to, and use of, the system difficult.

Other countries are trying to use digitized information for improving or transforming their operations (i.e., digitalization). In Demographic Republic of CongoDRC, the Kinshasa Multisectoral Development and Resilience Project plans to develop an application to collect and use data on crime and violence for identifying crime hotspots within neighborhoods and referring victims to relevant services. In Bangladesh, restrictions at the onset of COVID-19 necessitated the government to make a rapid transition to a remote working environment, which most municipalities were not well prepared for. Based on a survey with all 329 municipalities and 10 city corporations(with over 99% response rate), the Local Government COVID-19 Response and Recovery Project now incorporates technical assistance to enhance the capacity of municipal officers to adapt to remote working and permits municipalities' investment in necessary hard- and soft-ware as eligible expenditures of block grants that they will receive from the central government.

While pushing through digitization and digitalization, many countries are also preparing for digital transformation by developing a smart city vision, goal, and strategy. The process of discussing and agreeing on a shared direction and roadmap is particularly critical for smart city development which requires a multi-sectoral and long-term approach. GSCP has accompanied several cities in their journey to engage and coordinate multiple stakeholders, assess their smart city readiness, and take stock of existing and planned initiatives. In Izmir, GSCP experts worked closely with key actors across city departments and service partners through regular engagements over a year between 2021 and 2022 and drafted a structured and visual strategic framework including a roadmap which is closely connected with an integrated portfolio of priority and supplementary initiatives. Izmir Metropolitan Municipality has now identified an initial set of neighborhoods to tailor and apply several common solutions that are appropriate to each location and can demonstrate improvements.

How can smart city development be better supported?

The reality is that many developing countries are at various points of the spectrum towards digital transformation. This requires a further expansion of the smart city definition to view it as a continuous journey rather than a developmental state to arrive at. Since it is usually a long journey, it certainly helps to have a good sense of direction with a detailed but flexible map to prioritize actions and adjust next steps. Creating an environment and building a system to learn from earlier experiments and correct and improve courses is essential. Korea's smart city journey, which has taken place over decades and is still evolving, illustrates both points well – the importance of having a national strategy and learning from experiences.

Korea's smart city development journey: institutionalization and innovation

As an early adopter of the smart city agenda, the Republic of Korea has experienced both opportunities and challenges of smart city development. Over the course of two decades, it has gone through phases of smart city conceptualization, institutionalization, and innovation. The early implementation phase of smart city projects, known as "ubiquitous city" or "u-City" projects in the early 2000s, faced unexpected challenges for a variety of reasons, including the absence of a basic technical and institutional framework to serve as the foundation for sustainable maintenance and operation of the implemented projects and to provide a solid groundwork for innovation.

Drawing on lessons from the u-City projects, the Korean government began laying the groundwork to institutionalize smart cities by stipulating laws and regulations, establishing institutions, and defining potential enablers. The central government officially embraced the new concept of a smart city, which was technically defined as a platform, and holistically created a new form of integrated urban governance. To this end, the Special Act on the Construction of u-City, Korea's first smart city law, was enacted in 2008, and the first national comprehensive plan for smart city implementation was developed in 2009.

In accordance with the law, local governments were mandated to formulate and submit their smart city plans to the Ministry of Land, Infrastructure and Transport of Korea for approval before

officially launching individual projects both greenfield and brownfield. In addition to better organizing the government's own institutional setting, Korea has established public-private consultation systems to review and implement the national strategy for smart cities. Notably, open public data enabled private companies to provide public services on their own platforms, and the analytical activities performed by citizens allowed the government to deliver services proactively.

Source: Hwang,Jong Sung; Heo,Yoon Ju; Han,Ahram; Hwang, Jun Seok; Ju,Bora.
Smart Cities in the Republic of Korea : A Journey Toward Institutionalization and Innovation (English). WBG Korea Office Innovation and Technology Notes Washington, D.C. : World Bank Group.
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The national government's role is important not only in setting policy directions, creating an enabling institution, and providing technical support to cities, but also in incentivizing cities and facilitating coordination. Considering that digital infrastructure and technologies often require substantial investments, creating a common market for the economy of scale will be beneficial, particularly for secondary or smaller cities. It can also be cost-effective for the private sector.

The national government can also directly incentivize cities to plan for and invest in smart development. In Serbia, GSCP supported the design of the Serbia Local Infrastructure and Institutional Development Project, which aims to improve the capacity of local self-governments (LSGs) to manage sustainable infrastructure, including urban transport systems. Smart mobility, which encourages citizens to use modes of transport other than gas-powered vehicles, is one of the key components of the Smart City programs. The GSCP expert assessed the current mobility situation in 145 Serbian cities and benchmarked smart-mobility projects in other countries. Based on this, the national government designed a competitive funding program that LSGs can access for smart mobility initiatives, with a comprehensive eligibility and selection framework to assess proposed investments against the project goals and confirm their eligibility for financing.

While smart city development can start from the national- or city-level strategies and programs, smart city projects on specific sectoral challenges can contribute to build a foundation for smart cities. The One Map project in Indonesia is a great example whereby the development of a three-dimensional cadaster for smart land and infrastructure management facilitates digital twinning, which is one of major drivers of smart cities.

Using a Digital Twin and Three-Dimensional Cadaster for Smart Land and Infrastructure Management in Indonesia

Indonesia's cadastral maps display land parcels, along with their associated legal rights, only in two dimensions2D. This is inadequate for multi-level properties. A new method called "digital twin" — a virtual representation of a city's objects that allows dynamic analyses under simulated real-world conditions — can help Indonesia achieve its Smart City goals and better manage complex assets, by enabling the definition of property rights, restrictions, and responsibilities in three-dimensional3D space.

The World Bank finances the One Map Project that is designed to assist Indonesia's Ministry of Agrarian Affairs and Spatial Planning/National Land AgencyATR/BPN with conceptualizing and developing a 3D cadaster mapping system and geospatial solutions based on a digital twin. The project aims to (i) improve the recording and transacting of rights in multilevel properties; and (ii) enable needs assessments of stakeholders and analysis of data availability, systems, services, and potential barriers.

The experts mobilized under the Global Smart City Partnership ProgramGSCP participated in assessing the government's existing mapping systems and service delivery status, and its technical capacity. They also identified needs through a bottom-up approach, and assessed opportunities and constraints in relation to relevant global good practices. The second support phase focused on working with the government to develop business models for the 3D cadaster and define the system architecture, boosting ATR/BPN's technical capacity and strengthening institutional enablers.

ATR/BPN plans to demonstrate Jakarta's cadaster-based indoor/outdoor map services covering an area of 10 square kilometers. It is also considering public-private partnership models suggested by the project experts. Further, through GSCP facilitation, they are now selected for the Korea City NetworkKCN program by MOLIT and are receiving deeper technical assistance to scale up the effort for 2022-2023.

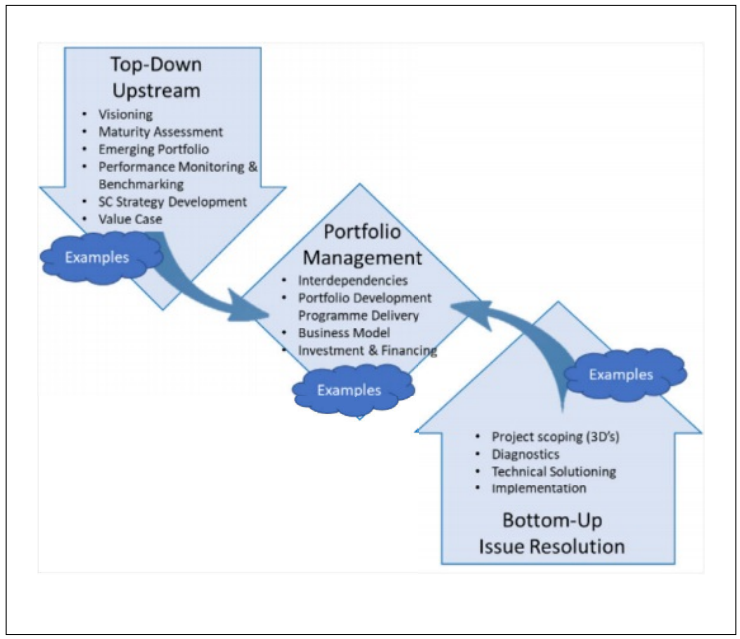

Figure 3. Integration of top-down and bottom-up approaches through portfolio management

GSCP has contributed to both upstream smart city strategic planning and downstream investment design and implementation. Over the years, the program observed, however, a missing link between upstream and downstream smart city engagements, with most cases belonging to only one of the two streams. The earlier engagement experiences under GSCP Phase 1 (2018-2021) illustrate the challenges of translating smart city strategies into robust projects and those of going beyond disparate, individual investments in silo smart solutions to generate a city-wide impact. This is likely because investment decisions by both public and private actors, including those by WBG, is affected by multiple factors such as countries' readiness, development priorities, and bankability of projects.

The weak middle can be strengthened as the top-down, strategic, whole system approach and the bottom-up, sector-focused, issue-specific approach come together at a common point. It happens when the top-down approach is implemented in a coordinated manner across a portfolio of cross-sector and enabling projects; or when cities start to make connections between a growing set of smart pilots

or sector-specific projects that are exploiting digitalization (Figure 3). Either way, this common point requires cross-sector collaboration and effective portfolio management, geared towards systemic improvement. Encouraging cases are emerging from GSCP along this line, as highlighted by the engagement in Amman, where a year-long process of developing the green, smart city strategy has led to a roadmap and list of priority projects.

Towards a smarter and greener Amman

Greater Amman MunicipalityGAM is ambitious in seeking to transform Amman, the capital and largest city in Jordan, into a smart and green city, and has taken some significant measures to achieve this, mostly focusing on transport-related activities in collaboration with various partners. GAM published a Smart City Roadmap and Traffic Monitoring Platform report in 2021. Further, Amman is the first Arab city to adopt a Climate Action Plan and has launched a substantive Resilience Strategy to steer progress, including goals to reduce Green-House GasGHG emissions by 40 percent by 2030. Besides these strategies, GAM has a competent governance structure for smart city developments, with dedicated units and qualified staff to steer and execute the smart city portfolio of projects.

However, most smart city activities in Amman are currently limited to the planning stage. Solutions and relevant systems that have been developed so far are addressing a certain problem or situation within a department or organization. Moving from planning to implementation requires an integrated cross-functional approach.

The WBG engaged with the smarter greener Amman agenda in mid-2021, with the GSCP support. GSCP experts prepared and ran eight virtual workshops with GAM, involving over 100 staff members in total, resulting in a draft city transformation program, with two priority areas for action: (i) identifying and agreeing on where tangible implementation of Amman's Smart Neighborhoods(Lighthouse Neighborhoods) will occur, to demonstrate visible improvements to trigger city-wide transformation through interventions such as an innovative new mobility model and open space; and (ii) strengthening a digital foundation by developing a smart city platform with data and asset management functions.

GAM is committed to implement smart city plans developed through comprehensive consultations and now with a list of priority initiatives, investments, and timeline. This in turn contributed to the WBG team's ongoing dialogue with Amman towards designing a new lending operation.

What are key lessons for smart city development?

As a demand-driven program, GSCP implementation indicates a high interest in smart cities from developing countries. It also demonstrates that providing strategic and technical input to capitalize on these interests does not necessarily require huge resources. The key is to find and mobilize right experts at an optimal engagement point but that is challenging. Smart city experts, who understand the context specific constraints and leverage global knowledge for identifying actionable entry points, are rare. Curating an ideal match has been the major value addition of GSCP, which requires an in-depth understanding of both engagement contexts on the demand side and expert profiles on the supply side. Building a credible expert pool is critical for effective matching and is an area that can improve further through global networking and knowledge sharing.

Smart city engagement is multisectoral and requires time for cultivating meaningful collaboration across sectors. Even though the total time input is not huge, commitment to what is often a lengthy, complex, and intense process can be demanding. This may in part explain how the link becomes weak between strategic planning upstream and tangible investments downstream because not many investors including public funders do have a sufficiently long engagement window to see (or wait for) concrete investment opportunities to arise. The abovementioned Izmir case is a counter example illustrating the importance of long-term engagement for successful results. The International Finance CorporationIFC has invested in and mobilized several infrastructure projects in Izmir over the past 10 years and thus could generate strong ownership from the municipal leadership and across the institution in the smart city strategy development process.

That development priorities also change over time, even though the essence of urban challenges may remain the same, also requires any partners or funders of smart cities focus more on

fundamentals of urban development: building and improving institutions and human capacity to move the city agenda forward, so that they survive political changes and other challenges. For capacity development, partnership and knowledge sharing are important. All GSCP engagements utilized good practices from other countries to stimulate dialogue. International benchmarking has been well received by all cities, some of whom have used it to develop bilateral partnerships and inform their decision-making on adopting smart city initiatives. The abovementioned One Map project in Indonesia has drawn heavily from other countries' successful experiences with digital twining and 3D cadaster, including those from Jeonju, Korea, and is itself now becoming an important good-practice benchmark for the World Bank's land and geospatial business line. It is noteworthy that cities have sought after tacit knowledge on smart city development processes the most. Countries with more advanced smart cities such as Korea can put more efforts into documenting and sharing their smart city journey including trials and errors, to effectively understand and meet specific needs of counterparts.

Conclusion: "smart" technologies as enablers for better "cities"

In a field where heavy interests in technological solutions can often override a deeper understanding of problems to solve, the value addition of this paper and more broadly that of the WBG's work is to shift our focus back on cities, by asking first what goals cities want to achieve, and exploring how smart technologies can help cities address their challenges – institutional, human, and financial – in a more integrated and innovative manner. By engaging across upstream strategic planning and downstream investments in priority projects, WBG is well positioned to connect the two and strengthen the overall smart city development value chain in the long run.

Building on the lessons from smart city engagements in developing countries, WBG will continue to support their journey through digitization, digitalization and digital transformation and facilitate partnership and learning on smart, sustainable cities.

The Increasing Role of Data in Infrastructure Financing:

Digital Twins, Informational Efficiencies and Blockchain Tokenization

기반시설 자금조달에서 더 커지는 데이터의 역할:
디지털 트윈, 정보 효율, 블록체인 토큰화

Peter Adriaens

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ABSTRACT

The needs for resilient and sustainable infrastructure continue unabated as demands for improved and equitable services are increasing globally. Whether drinking water delivery, waste- or stormwater management, energy services, or transportation mobility needs, public funding and financing of infrastructure is under pressure. This demand is resulting in private sector engagement to meet the financing gap via public-private partnerships (P3). A key challenge is the mismatch between capital performance expectations and long-term cash flows from public infrastructure design. Most investments in infrastructure projects take the form of bonds, public and private debt and private equity, types of financing that cannot be easily converted to cash, or do not reflect up to date asset valuations. This limits the type of investor who will engage in projects.

Digital twins provide near real time insights into asset performance, structural health and use. This transparency of information has the potential to decrease the cost of capital to build and operate services, by lowering interest rates and improving credit scores, and will impact digital project delivery through performance-based financing and integration of blockchain tokenization. The increasing consumerization of infrastructure services is resulting in new business and financing models, insights in the potential for new revenue streams, and coupling data to automation of financial transactions using software-as-a-service (SaaS)-like agreements.

By envisioning data as the informational stock of infrastructure, better pricing of its value, and improved liquidity of investments, are already starting to change project designs and financing mechanisms that maximize performance delivery. Importantly, by decreasing reliance of infrastructure financing on the community tax base of communities, access to quality infrastructure will become more democratized, as data-driven revenue starts contributing to the funding mechanism. This paper discusses how application use cases are exploring the potential for data-driven funding and financing mechanisms by leveraging digital twins of infrastructure systems.

KEYWORDS

Digital infrastructure, Data, Tokenization, Smart cities, Financial models

초록

개선되고 공평한 도시 서비스에 대한 수요가 세계적으로 증가하면서 탄력적이고 지속가능한 기반시설에 대한 수요 역시 수그러들지 않는 상태를 이어가고 있다. 식수의 공급과 쓰레기 처리, 폭우 대응, 에너지 공급, 교통망 확충 등 분야를 막론하고 공공 부문의 기반시설 자금 조달은 빠듯한 실정이다. 그 격차를 좁히기 위해 민간 부문이 참여하여 공공-민간 제휴public-private partnership, P3가 이루어지고 있다. 이 경우 주요 과제는 자본 성과에 대한 기대와 공공 기반시설로부터 나오는 장기 현금흐름 사이의 불일치이다. 기반시설 프로젝트 투자는 대부분 채권 발행이나 공공·민간 차입, 사모펀드 등으로부터 조달되는데, 그런 방식은 쉽게 현금으로 전환되기 어렵거나 최근의 자산 가치를 반영하지 않는다. 이런 한계로 인하여 투자자의 유형이 제한된다.

디지털 트윈은 자산의 성과와 구조적인 건전성, 활용을 거의 실시간으로 들여다볼 수 있게 지원한다. 정보의 투명성은 기반시설을 만들고 운영하는 데 투입되는 자본을 조달하는 비용을 줄일 수 있는 잠재력이 있다. 예를 들어 금리를 낮추거나 신용점수를 향상시킬 수 있다. 또한 성과 기반 자금조달과 블록체인 토큰화의 융합을 통해 디지털 프로젝트 전달에 영향을 줄 것이다. 기반시설 서비스의 소비가 확대됨에 따라 새로운 사업·자금 조달 모델이 등장하고 있다. 또 새로운 매출 흐름의 잠재력에 대한 통찰이 나타나고 있다. 아울러 서비스형 소프트웨어SaaS를 활용한 데이터의 자금거래 자동화와의 연계가 이루어지고 있다.

데이터를 기반시설의 정보 자산으로 여김으로써 가치를 더 잘 평가할 수 있고 투자의 유동성을 향상시킬 수 있다. 그럼으로써 성과 전달을 극대화할 수 있게끔 프로젝트 설계와 자금조달 메커니즘을 이미 개선하기 시작하였다. 중요하게는 데이터 기반 매출이 자금조달 메커니즘에 기여하기 시작하면서 지방세를 원천으로 하는 기반시설 자금조달 의존도가 낮아지고 기반시설에 대한 접근이 더 민주화될 것이다. 이 글은 기반시설 시스템의 디지털 트윈을 활용하는 애플리케이션 활용이 데이터 기반 자금조달 메커니즘의 새로운 잠재력을 열어놓고 있는지 논의한다.

키워드

디지털 기반시설, 데이터, 토큰화, 스마트시티, 재무적 모델

Data and the Emerging Business Models for Smart Infrastructure

Premise of Smart Infrastructure Systems

Rebuilding and upgrading infrastructure projects with emerging technologies and innovative procurement initiatives is seen as a potential path to sustainable development, improved safety and health, performance and management of built infrastructure.[1] We define infrastructure beyond transportation assets, to include both public and private assets such as ports, airports, water and energy systems, and waste management. The increasing integration of digital infrastructure seeks to further the goal of adaptation, resiliency and operational efficiency driven by performance measurements using embedded or remote sensing IoT.[2] In this context, data is emerging as a separate asset class undergirding infrastructure asset valuation and accounting, not only from an environmental, social and governance (ESG) perspective or alignment with the UN Sustainable Development Goals SDG, but from the perspective of new revenue (cash flow) and financing models. A core challenge is the veracity, transparency and communication of measurements of infrastructure data and administration of the processed insights in an organizational context for the effective application by private enterprises and the public sector.

Delivery of Smart Infrastructure

The expenditure required to scale up smart infrastructure projects is significant and is affecting delivery and procurement models.[3] City governments are faced with the challenge of exploring the economic

1 https://www2.deloitte.com/global/en/pages/public-sector/articles/three-steps-for-financing-smart-cities.html

2 Imoize, A.L., Adedeji, O., Tandiya, N. and Shetty, S., 2021. 6G enabled smart infrastructure for sustainable society: Opportunities, challenges, and research roadmap. Sensors, 21(5), p.1709

3 Jayasena, N.S., Chan, D.W. and Kumaraswamy, M., 2020. A systematic literature review and analysis towards developing PPP models for delivering smart infrastructure. Built Environment Project and Asset Management. Vol. 11 No. 1, pp. 121-137

return in smart city investment, the business models, the value that it brings to citizens and the role that they should play within an ecosystem of delivery partners and stakeholders. They must decipher funding and financing options, contractual measurement and reporting regimes and the implications for their organizational structure, operational requirements and governance.

Public financing of smart infrastructure assets is limited because of constrained budget cash flows. Municipal bonds require underwriting by guaranteed fee or tax structures, or can be structured against future grant income, but are not a good candidate because of the uncertain revenue expectations from digital infrastructure assets. Project finance for smart infrastructure is not feasible at this time because (1) the projects are too small (high cost of capital requires large or bundled projects); (2) smart infrastructure is exposed to utilitarian risk from users or paying customers; and (3) lack of guaranteed cash flows unless government or private partners provide a 'floor' – hence data-driven offtake contracts tend to be more of a 'merchant type' (structured one-off agreements with diverse buyers). In addition, the more uncertain the cash flows, and the more dependent the revenue on market demand for the infrastructure services, the higher the return expectations on risk of invested capital will be. This presents a further challenge for public agencies. Despite these challenges, innovative public–private partnership PPP models[4] or tokenized (blockchain-based) governance models[5,6] are increasingly viewed as viable solutions for addressing the financial barriers to scaling smart infrastructure projects. The range of PPP models is shown in Chart 1, and depends on the ownership, financing and operational expectations of the public and private sector partners. Given that social infrastructure traditionally tend to be in ownership of the public sector, the financing challenges for smart infrastructure will undoubtedly push PPP delivery contracts more towards private operations, co-financing, and

4 Selim, A.M., Yousef, P.H. and Hagag, M.R., 2018. Smart infrastructure by (PPPs) within the concept of smart cities to achieve sustainable development. Int. J. Crit. Infrastructures, 14(2), pp.182-198

5 Tezel, A., Papadonikolaki, E., Yitmen, I. and Hilletofth, P., 2020. Preparing construction supply chains for blockchain technology: An investigation of its potential and future directions. Frontiers of Engineering Management, 7(4), pp.547-563

6 Maciel, A., 2020. Use of blockchain for enabling Construction 4.0. In Construction 4.0 (pp. 395-418). Routledge

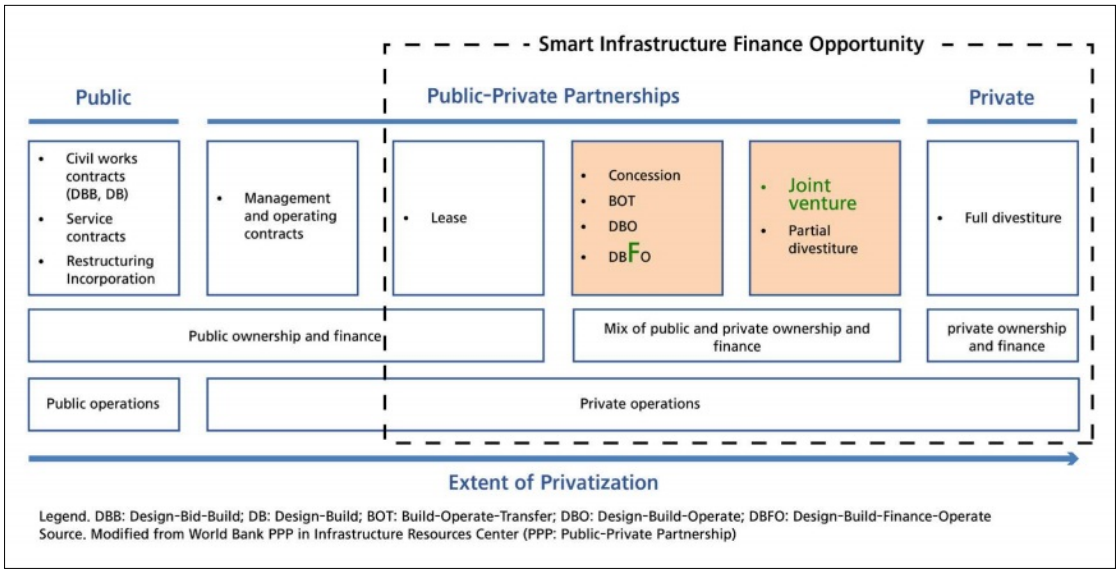

Chart 1. Structures of PPP delivery contracts for infrastructure assets

potentially partial private ownership rights.

Data Monetization of Smart Infrastructure

Data monetization generally refers to "the process of using data to obtain quantifiable economic benefit." Internal or indirect methods include using data to make measurable business performance improvements and inform decisions. External or direct methods include data sharing to gain beneficial terms or conditions from business partners, information bartering, selling data outright (via a data broker or independently), or offering information products and services (for example, including information as a value-added component of an existing offering)".[7] Processing and converting the information from IoT data into insights is where the ultimate value is generated, much like a manufacturer refines raw material and converts it into products. In this context, data productization particularly for infrastructure risk management and project account reporting may provide better financial accounting and investment risk-based decision-making, transparency and

7 https://www.gartner.com/en/information-technology/glossary/data-monetization

economic benefits for infrastructure assets. The case for increased sustainability data disclosures (transparency), including in relation to project credit ratings and the cost of borrowing, presents an 'on-ramp' opportunity for data-driven valuation and financing. Lastly, data offtake contracts such as for advertising, insurance-related purposes, business intelligence, demographics, personal information, or research present new revenue opportunities that supplement the cash flows for debt service and operations.

Data as a Capital Markets Risk Management Solution for Sustainable Financing

Meeting financial (return on investment, internal rate of return) and environmental (e.g. reducing CO_2-equivalent emissions) targets requires high quality and sufficient quantity of data. This data needs to be collected at the asset level, processed and aligned to the asset's financials whether as a project financing or other infrastructure financing structure. All data collected to inform construction and operations need to be financially material to inform corporate profit and lossP&L statements and cost targets. A traditional income statement is static and updated on quarterly or fixed schedule, but for data to deliver different spatio-temporal granularities, whether for capital reduction, project cost reduction or new revenue generation entails using updated accounting practices, digital twins will be required.

Digital twins are virtual representations that serve as the real-time digital counterpart of a physical object or process. They have the capacity to resolve the data tracking complexities and provide **increased transparency and accuracy** to stakeholders such as financial institutions, asset owners and managers, governments, as well as insurance companies (Chart 2). Data streams from sensors

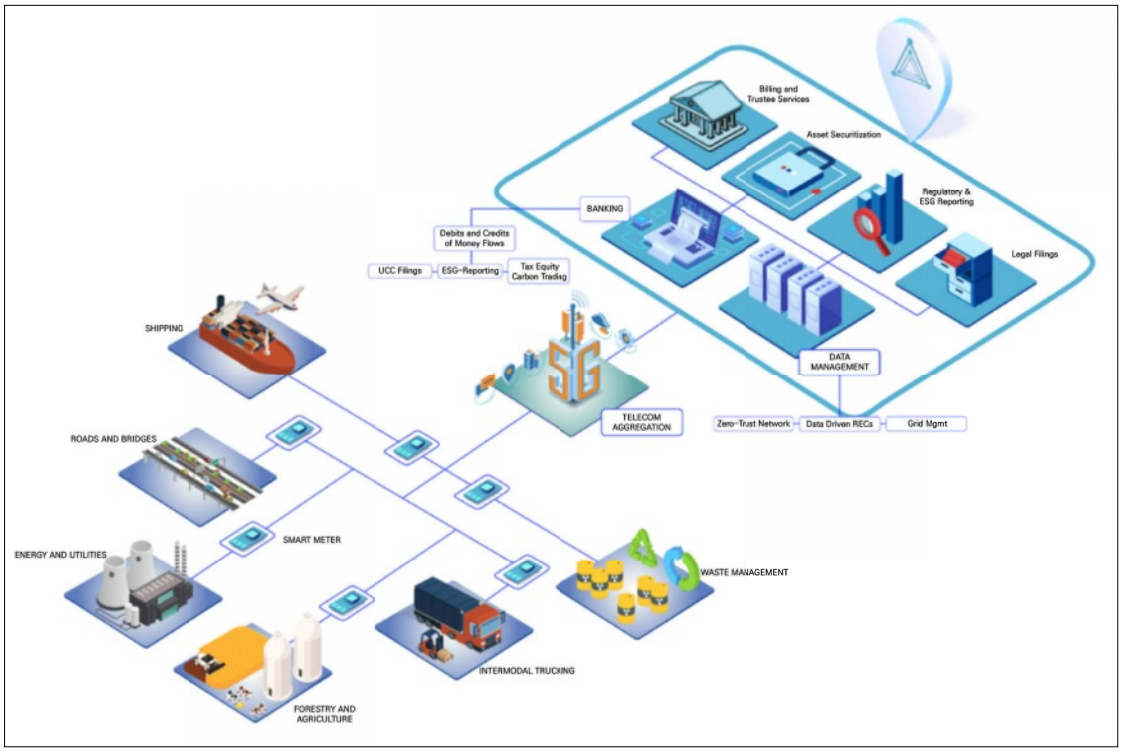

Chart 2. Linking operational performance of real assets to financial service providers and financing (Source. Blockchain Triangle)

or digital devices are collected and compiled at the digital twin level. They are analyzed, visualized and productized in multiple ways depending on the end user needs to inform operational efficiencies, data market demand, valuations and risk underwriting.[8]

Depending on the need, digital twins can deliver insights to: (1) manage asset TECOP(technical, economical, commercial, organizational and political) risks; (2) environmental and climate resiliency risks; and (3) ESG performance and compliance risks. Risk-based decision making emphasizes reducing the cost of capital, providing transparency (efficient finance through near real-time disclosure), and improving asset valuation and cash flows. Another key outcome of quality and quantity data is the opportunity of predictive analytics on costs and revenue.

8 Adriaens, P. and N. Ajami. 2021. Infrastructure and the Digital Economy: Impacts of Data on the Design, Financing, and Governance of Essential Services for Society. J. Environ. Eng. 147 (5), 02521001

Due to these benefits, data insights are being piloted to unlock new cash flows and to structure data (SaaS) - driven business models to deliver infrastructure services. In addition, new derivative investment structures such as tokenization and securitization are possible because high quality data can provide transparency into an asset's functioning and cash flow projections.[9] For example, Blockchain Triangle, a digital asset manager and issuer in Bermuda, connects asset-specific operational information with financial institutions and other stakeholders over the blockchain.[10] Unlocking financial risk data and ESG metrics from infrastructure assets through digital twinning is a core value proposition of Blockchain Triangle in the shift towards digital financing and disclosure. Recently, the Center for Digital Asset Finance at the University of Michigan explored the integration of decentralized oracle networks to bring off-line performance data onto a smart contract for the financing and tokenization of infrastructure assets (Chung et al., 2022).[11]

Execution at a strategic level

The focus of strategic-level data-driven action is outlined in Chart 3 and includes the following components:

Decide on Metrics and Key Performance KPIs

City and community managers will need to make decisions on design objectives and functionality of smart infrastructure assets. For example, for transportation assets, is the objective of digitization

9 Tian, Y., P. Adriaens, R.E. Minchin, Z. Lu and C. Qi (2021). Asset Tokenization: A Blockchain Solution to Financing Infrastructure in Emerging Markets and Developing Economies. ADB-IGF Special Working Paper Series "Fintech to Enable Development, Investment, Financial Inclusion, and Sustainability. Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3837703

10 Darren Wolfberg and Peter Adriaens. 2021. The Blockchain Triangle Solution. https://www.bctriangle.com/resources

11 Chung, K, D. Li and P. Adriaens. 2022. Technology-Enabled Financing of Sustainable Infrastructure: A Case for Blockchains and Decentralized Oracle Networks. Technological Forecasting and Social Change, In Press

to automate weigh in motion of trucking or is the purpose the development of a road to become a managed service platform that generates data and demographics on traffic, emissions, and safety. The design and functionality inform the types of sensors, data and insights that need to be delivered.

Deploy IoT(Internet of Things)

Equipping existing (brownfield) or new-build (greenfield) assets with hardware and software that enables the acquisition, aggregation and analysis of data as required. While in some cases plug-and-play (i.e. toll collection) solutions might work, in most cases bespoke solutions will need to be designed. The impact of choice of technology and software platform, and lifetime replacement value relative to the real asset, on the economics of digital infrastructure deployment needs to be considered in light of the risks addressed or benefits (KPI) measured.

Implement Data Governance

Organizations also need to build adaptive frameworks and governance structures to enable management of change of the digital twin. This is because as the asset ages, it's operational efficiency and types of services will likely shift from its built baseline. The digital twin will need to mirror such adjustments. While city governments are starting to spend on the deployment of digital infrastructure for smart cities, they don't necessarily have the governance structure in place to monitor and manage this infrastructure. The transaction cost economicsTCE of deployment favors automatic execution of contracts as can be afforded through blockchain-based smart contracts.

Execution of Financial modeling

Connect the digital twin to the agency, municipality or project company's financial cash flow model and

operating reports. The digital twin serves as a data source for financials of the project company or infrastructure project. Every line in the P&L can be associated with a data stream that is a representation of the cost and revenue of the asset. Organizations can also use this data to run complex simulations and gain latent insights in performance risk impacting operational metrics. For example, traffic measurements become insights for green disclosures (tailpipe emissions or car demographics), insurance risk underwriting, corporate real estate valuations or pricing of registrations.

Verification of regulatory compliance

Qualified data experts and independent engineers (or a board of elected data commissioners) and auditors maintain these digital twins and report quarterly infrastructure performance checks to a central regulator. Credible third-party firms should also be able to audit these twins to ensure compliance.

Execution, Tools & Operational Focus

High quality and quantity of data streams are required from physical assets to build accurate digital representation. However, accessing high quality data is difficult in many situations. This is especially relevant for older assets that were not built for digital twinning. In other cases, the assets run on archaic technology that cannot be upgraded easily. For a brownfield asset, a thorough audit of the asset's hardware and software infrastructure helps engineers understand the information gaps and find appropriate solutions to acquire the required data streams. In many cases, bespoke hardware needs to be built to capture reliable data streams. Engineering firms can then upgrade the required systems as needed to ensure end-to-end compatibility and long-term reliability.

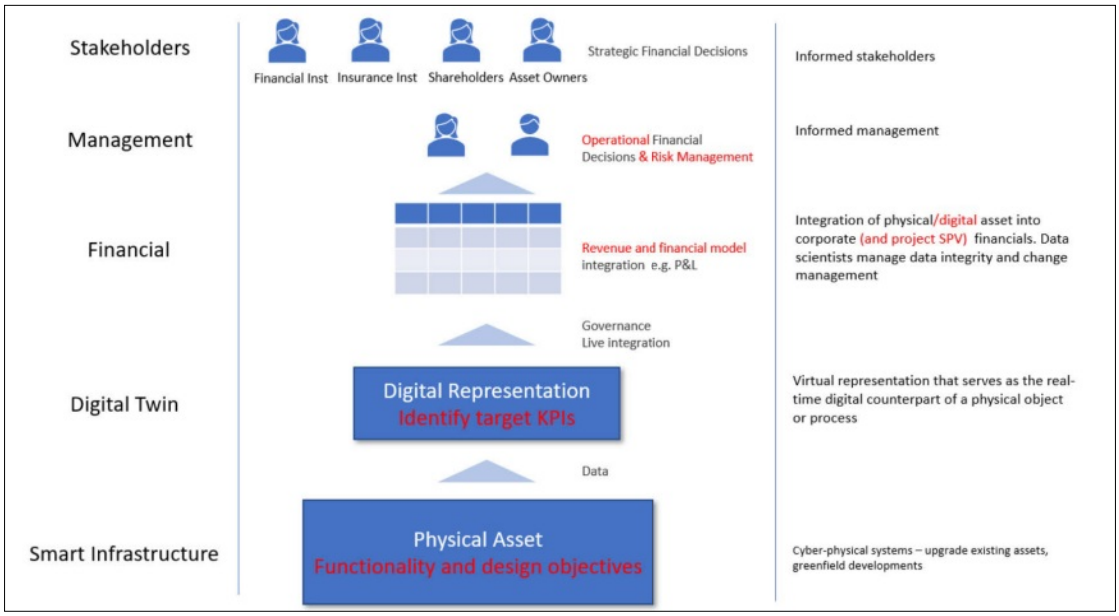

Chart 3. Organizational structure for strategic implementation of digital twins

For a greenfield asset, engineering and digital firms design smart systems at the onset of the project in the conceptual phase. Engineering firms can help provide technical due diligence reports that can help financial investors understand the value additive factors of digital twinning an asset. Depending on the needs, data scientists might need to transform the data to meet the facility technology requirements. The data is then collected from various nodes like asset historians, advanced process control units, facility maintenance systems or computerized managed maintenance systemsCMMS. Each of these nodes could provide a unique perspective about the asset though they might be connected to the same data collection points.

Many cities have begun publishing extensive data sets that include geo-referenced data (e.g. https://data.boston.gov/) ranging from flood risk from storm surges to snow emergency parking lots to food truck schedules, wind gust patterns during storms, and more (Chart 3). While these data sets have been readily available for years, they're typically stored in formats that are not user-friendly

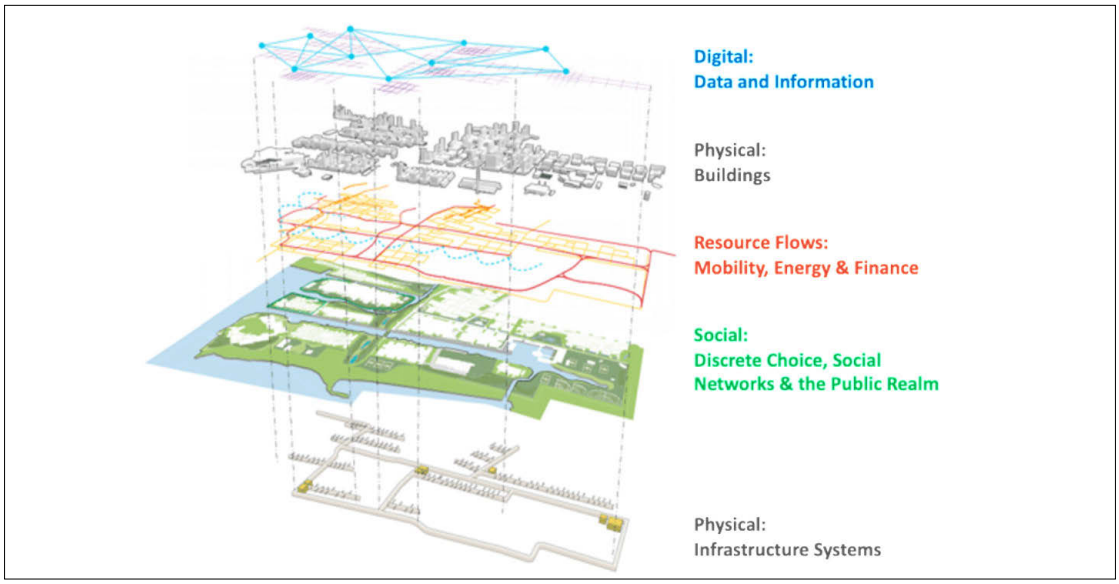

Chart 4. Digital twin of Toronto comprised of physical asset data, resource flows, and social metrics (Courtesy: Sidewalk Infrastructure Partners)

as standalone resources. Importing them into digital twins (as detailed in Chart 4) provides a more intuitive means for understanding the data and for using them in the design, risk management and financing of smart city infrastructure.

- The CAD (computer-aided designs) and BIM (building information modelling) data sets of a new project are likely readily available.
- Geo-referenced data sets for data overlays come from a wide variety of sources including IoT sensors, municipal data, digital feeds from public data providers, or location-based workflow apps (such as inspection or approval processes).

This information becomes the input into the digital twin that integrates all the information and provides a single source of truth. Data scientists actively manage these data streams to ensure the data's reliability. Digital twins allow stakeholders to analyze and visualize data in ways that

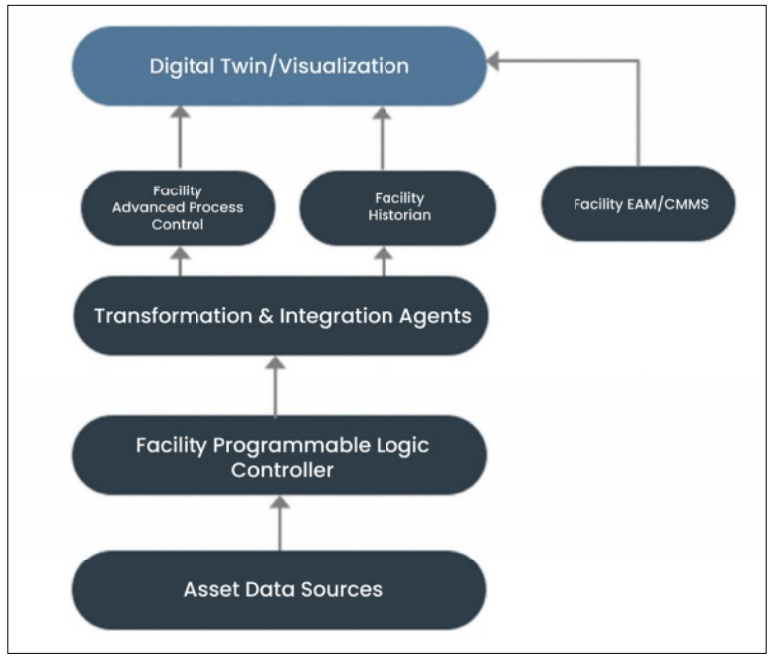

Chart 5. Process flow of digital twinning

were not possible. Stakeholders can monitor complex assets in real time and make adjustments to gain significant operational, financial, and other advantages. Advanced digital twins provide accurate predictive capabilities that are not generally possible with human operators. The development, design and integration of data into digital twins is a complex issue and requires expertise from various fields and collaboration at multiple levels (Chart 5).

- **Government** - Government buy in is crucial to defining policies, enabling long-term macro vision building and providing support for this initiative in all phases of execution. One could argue that without government support such initiatives are very difficult to mobilize. Such initiatives help citizens in the long-term by providing innovative solutions to complex problems and improving the quality of life of the general population.
- **Financing bodies** - Financial institutions such as public and private banks, multilaterals, private equity investors, etc, are needed to provide the initial and ongoing investment in new

ventures. Financing institutions have the power to replicate success across multiple industries and regions potentially benefitting developing nations.

- **Advisors** - Qualified and forward-thinking advisors provide thought leadership, industry feedback and networks to execute on ideas. Advisors can help gain crucial early consensus and momentum so that these projects are set on a path to success.
- **Engineering & Digital firms** - These firms provide technical expertise on various types of asset types. They also have the capability of executing large mandates from conceptual phase to deployment phase.

Experience with Data- and Technology-Enabled Financing of Smart Infrastructure Assets

The experience with novel data-driven financing and business models is still largely relegated to operational efficiency and OPEX financing, with few examples of pilot applications in CAPEX structuring and data monetization for different infrastructure assets. Not surprisingly, revenue-generating assets such as water, energy, mining, and concessionary contract agreements such as toll roads tend to lend themselves to new efficiencies and real time valuation. An exemplary list of relevant use cases is illustrated hereafter.

- **Smart Highways** - In India, state governments are collecting data points through digital technologies to monitor traffic patterns and predict future cash flows from toll booths. The same data is also sold to insurance companies who use this data for insights on risk underwriting and cash flow reserve position management. In the US, experimentation with weigh-in-motion (WIM) sensors coupled to video monitoring informs the impact of logistics

on the life cycle of roads, and can be used to recover 'wear and tear' fees from trucking companies through registrations or other mechanisms. These so-called 'smart slabs'[12] can be integrated in roadways and bridges and outfitted with sensor hubs to inform the KPIs(key performance indicators of P3(public private partnerships)) contractual agreements on structural health, traffic type and driver demographics. While the business model and cash flows models are still under development and being tested, provisional P3 agreements are being negotiated between technology companies and state agencies in Kansas and Colorado.

- **Smart Water Plants** - Many municipalities, including in the US, Canada and Australia[13] are facing budget pressures and are turning to digital solutions. Water plants have started integrating data from various sources to gain operational efficiencies (e.g. 'non-revenue water', i.e. water losses from pipeline breaks) and invaluable insights to help them avoid major outages and reduce risk. The data solutions also include the conversion of capital expenditures to long term operational cash flows to pay for the delivery of water services (i.e. water-as-a-service). Municipalities are forming public private partnerships to develop long term solutions to this problem. The municipalities mandate contracts that include rights to the data collected from sensors and in some cases stipulate on-premise solutions with high security measures.
- **Variable interest rate stormwater bonds (also referred to as EIBs, Environmental Impact Bonds)** - In the US, water agencies are working with investment banks such as Morgan Stanley and Goldman Sachs to structure variable interest rate revenue bonds where the payout to the investor is dependent on the data performance of the stormwater asset. The focus is on green infrastructure to replace grey infrastructure at lower capital cost, as work with DCWater, the Buffalo NY Water Authority, Milwaukee Municipal Water District and others shows.[14]

12 https://integratedroadways.com/

13 https://watersource.awa.asn.au/technology/trends/sydney-water-digital-twins-build-smarter-infrastructure/

14 Brand, M., K. Quesnel, P. Saksa, N. Ulibarri, A. Bomblies, L. Mandle, M. Allaire, O. Wing, J. Tobin-de la Puente, E.A. Parker, J. Nay, B. F Sanders, D. Rosowsky, J. Lee, K. Johnson, N. Gudino-Elizondo, N Ajami, N. Wobbrock, P. Adriaens, S.B. Grant, S. Wright, T. Gartner, Z. Knight, J. P. Gibbons. 2021. Environmental Impact Bonds: a common framework and looking ahead. Environmental Research: Infrastructure and Sustainability 1 (2), 023001

Flow sensors, water quality sensors and weather data inform the risk and performance of the asset, and resulting in a low yield spread on the revenue bond, which can range over a few 100 bps. This model has been deemed attractive by investors due to it being uncorrelated to other financial assets.

- **Revenue-backed debt securities for water infrastructure** - In Italy, communities looking to upgrade and expand their water distribution and treatment systems have bundled unrated (and expensive) minibonds in an SPV (special purpose vehicle) and converted to rated debt securities which are sold to pension funds and development banks (EIB). The credit rating and liquidity of the Viveracqua Hydrobond[15] securities were a financially attractive alternative relative to unrated bonds too small and lacking sufficient data to justify the administrative cost while also spreading the credit risk. The SPV received a cash buffer, which can be backed by the utilities, performance options contracts or a liquidity facility and receive a favorable rating. Integration of performance data on - for example - changes in ratepayers, pipe leakage, or cost of water quality impairments can be structured in forward contracts. Asset-backed securitization under public private partnership (ABS-PPP) contracts is a new financing model that is being heavily studied as a form of structured finance for infrastructure projects, though it is not clear how many projects have been executed.[16]
- **Credit enhancement for infrastructure projects** - Proxy revenue swapsPRS are becoming a new data-driven options model to fix floating revenue of projects such as wind power and water provision for asset owners. The PRS serves to reduce uncertainties for debt or bond investors in the projects resulting in a higher credit rating and less conservative credit covenant requirements, thus rendering the project more bankable. Offered globally by insurance companies such as Nephila Climate[17,18] short-term options are structured against a long-term

15 The Viveracqua Hydrobond; https://www.eib.org/en/projects/pipelines/all/20130515

16 Lu, et al. (2019). Assessment Framework for Financing Public–Private Partnership Infrastructure Projects through Asset-Backed Securitization. https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29ME.1943-5479.0000708

17 https://www.reinsurancene.ws/tag/nephila-climate/

18 https://www.prnewswire.com/news-releases/nephila-climate-announces-first-proxy-revenue-swaps-for-wind-project-re-powering-300804074.html

cash flow trend and are triggered by independent indexes for wind, rainfall or other metrics.

- **Smart Mining** - Mining companies are increasingly moving towards digital twin technologies to gain valuable insights into financial and environmental aspects of operations. They have installed systems to gather multiple data points from their mobile assets such as trucks, shovels, etc. This helps them gain transparency into operating costs and emissions. In some cases, these companies worked with engineering firms to develop bespoke solutions to meet data acquisition needs.
- **New Blockchain-Based Energy and Mobility Infrastructure Business Models** - In the US,[19] Germany and the Netherlands,[20] technology companies are piloting blockchain applications to aggregate, distribute and manage decentralized energy supply and demand. The application allows for the residential owners to buy and sell energy within an energy marketplace of consumers using so-called smart (automated) contracts and helps utilities to manage base and peak load demands. The applications of blockchain in mobility include pilots to have cars as unique identifiers (digital wallets) pay for infrastructure needs.[21] As more data becomes available from infrastructure assets, more data-driven rules-based contracts can be coded and executed automatically, reducing costly middlemen and allowing for the design and payment systems for connected digital infrastructures (e.g. roads and stormwater assets) rather than siloed assets.[22]

The experiences and results from relevant examples allow for organization of data-driven (digital) financing opportunities in a risk – return diagram (Chart 6), which maps barriers for integration against the upside potential of the opportunity. Barriers to integration include technical (e.g. integration of cost and revenues with assets) and non-technical (e.g. stakeholder alignment) integration. The upside potential reflects the total possible return. For example, tokenization of infrastructure should be able

19 Brooklyn Microgrid. https://www.brooklyn.energy/

20 https://www.tennet.eu/our-key-tasks/innovations/crowd-balancing-platform-blockchain-technology/

21 Mobility Open Blockchain Initiative, https://dlt.mobi/

22 Tian, Y. 2022. Financing Infrastructure through Blockchain Tokenization. Ph.D. Dissertation. University of Florida

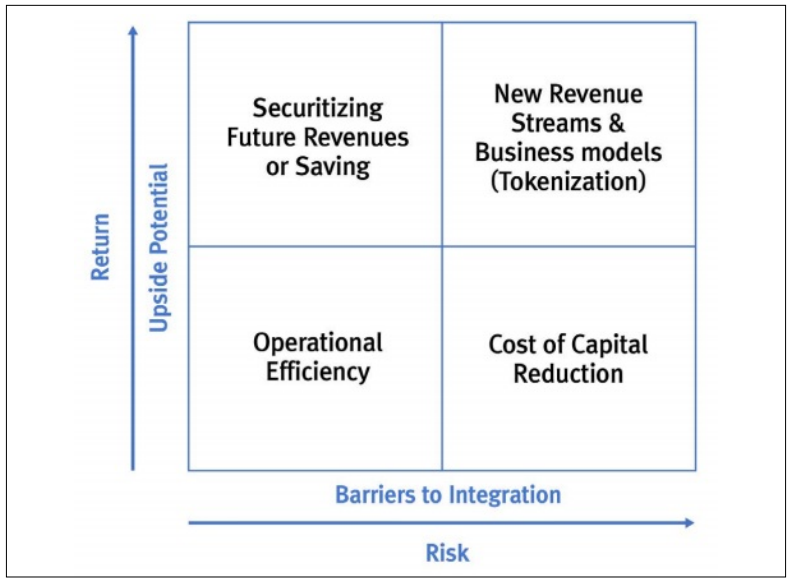

Chart 6. Risk and return diagram for data-driven financing of infrastructure projects

to draw the maximum returns, because of new monetization mechanisms based on smart contracts, and unlocking of efficient capital from institutional and retail investors. However, the technology is still immature, market demand very volatile, smart contracts not (yet) enforceable, and financial institutions not yet aligned with private contractors and government partners.

Operational efficiencies could net benefits in the billions of dollars, and indeed projects have demonstrated how this can be done using tokenized green bonds.[23] Cost of capital reduction requires monitoring (digital infrastructure) to assure investors, insurance underwriters and ratings agencies. Securitization-based infrastructure financing is more mature and well understood (lower risk, but still a challenge for ratings agencies), has a significant capacity for forward selling of revenues and savings (note the increasing interest in asset backed security-public private partnershipsABS-PPP or aggregating sub-scale assets (too small for project finance) in novel SPVs.

23 https://www.bis.org/about/bisih/topics/green_finance/green_bonds.htm

Emerging Financial Applications and Conclusions

As the aforementioned examples indicate, while digital twinning is increasingly mature across many infrastructure asset types, the financial opportunity from digital twinning is at the cusp of developing. For instance, while the integration of ESG in the equities market has become an established practice, standards and benchmarks of how to report and validate this information are still under development. Yet, both primary and secondary market pricing indicates that ESG (or green) discounts can be realized.[24] The application of ESG data to infrastructure assets is in the pilot stages in collaboration with municipal bond holders (investors) and issuers. At present, data-informed variable interest rate bonds, risk transfer options, and securitization of infrastructure cash flows are commercialized and help with cost of financing. However, SaaS-based OPEX-like financing of infrastructure services has only seen limited application, in part due to the desire of public asset managers to own the asset outright (100% public). Blockchain applications for infrastructure financing and funding of so-called 'cyberphysical systems' (i.e. smart) are also just emerging as pilots.

What is missing is a direct integration of novel infrastructure data uses in traditional infrastructure finance models focused on bonds, debt and equity (Chart 7). The direct linkage between data or insights, P&L and investment risk and return decisions by selling or licensing infrastructure data is the future for digital financing and asset management, but has, aside from pilot deployments, not seen full scale application yet, especially for infrastructure financing. This is the realm of development banks and private equity firms which are seeking to facilitate the de-risking of these new financial models, with specific focus on:

24 Adriaens, 2021. https://greatlakesimpactinvestmentplatform.org/media/omggyxu1/gliip_analysis-of-municipal-bonds.pdf

- Linking digital twins to P&L
- Linking digital twins to investment risk and return
- Linking digital twins to retail investors through tokenization

Given that data collection, computation and integration, as well as interpretation for real-time infrastructure asset valuation, risk assessment and management is complex and emergent, and revenue streams short-term (at this time) volatile, full-scale applications will require further testing and business model innovation. For example, various agencies and investment groups are experimenting with near real-time tracking of availability payment-linked KPIs for road and bridge maintenance (e.g. monitoring of cracks per linear mile), green asset-backed securities (e.g. building energy efficiency), and smart financing of agriculture to reduce pollution from fertilizers. The observations to date are summarized in Chart 7.

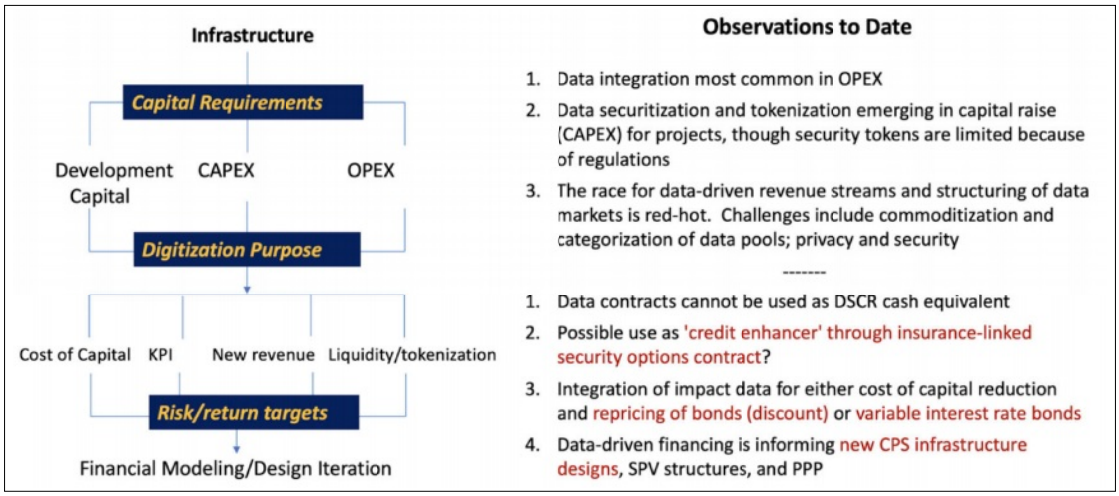

Chart 7. Integration of Data in Infrastructure Finance Models

Summary

The premise of using data to fund infrastructure is laid out in my Bloomberg CityLab piece[25] and is more nuanced than just packaging and selling data, as it requires deeper insights and tailored applications. While cities encompass massive data oceans, the challenge of extracting IoT data and processing value-added insights that result in revenue generation through data offtake contracts to supplement tax- or fee-based funding is central to future adoption of technology-enabled financing. The City of Chicago and District of Columbia, for example, are using data strategies to help craft improved insurance and capital allocation insights in the governance of their assets.[26] Integrated Roadways,[27] a partner of the Center for Digital Asset Finance, sells digital infrastructure for integration in transportation asset contracts, and sees revenue streams from operating roads as 'managed service platforms', with revenue streams from traffic management, advertising, and business intelligence. Blockchain Triangle, a digital platform operator for climate (carbon) data, captures performance metrics from utilities and agricultural operations for investor ESG compliance, to reprice asset risk and to structure sustainability-linked loan products with discounted interest rates. Lastly, technology-enabled financing of infrastructure through tokenized bond products is piloted by the Bank of International Settlements in Hong Kong, with technology providers in Germany and Switzerland. The purpose is to engage retail investors and to automate payout models based on smart contracts, thus reducing the cost of intermediaries and the cost of financing.

Based on the arguments presented herein, the opportunity to reduce the cost of financing, improve governance of data, and engage citizens in retail investments of infrastructure forebears an exciting future.

25 https://www.bloomberg.com/news/articles/2021-04-07/use-data-not-taxes-to-pay-for-infrastructure

26 https://home.kpmg/xx/en/home/insights/2021/08/data-and-analytics-unlocking-the-power-of-claims.html

27 https://integratedroadways.com/

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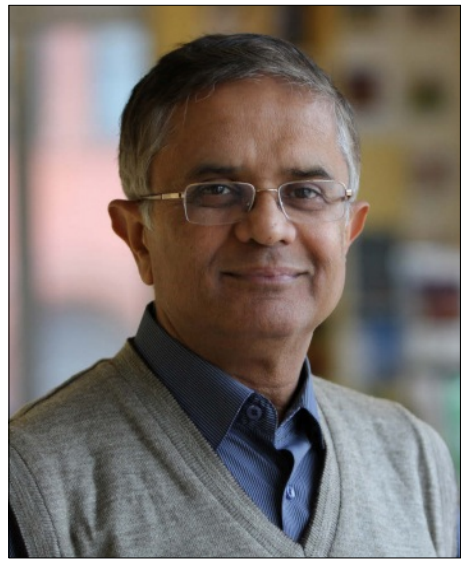
Elements of Smart City Management

스마트시티 운영의 요소들

Vijay Jagannathan



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ABSTRACT

In the past decade the digital revolution has changed the way cities are managed, and more importantly on how stakeholders interact with providers of various urban infrastructure and social services. These trends have given to great hope that smart cities have the potentials to revolutionize urban governance. This paper argues that while smart cities are viable concepts in the more advanced countries (also described as the Global North) the application of similar ideas in developing country cities (described as the Global South) require some key constraints to be addressed. Three constraints are elaborated. The first explaining the massive infrastructure services gap that requires to be bridged, but for which public financing is inadequate. The second constraint describes chronic institutional inertia, which often diminishes the capacity for effective planning and delivery. The third constraint is the presence of incentive incompatibility because market failures result in the inability to complement inelastic public finance with interest from global capital markets despite the attractive city-level opportunities to support low carbon investments. The concluding part explores some options for addressing the above three constraints. It emphasizes the critical role required from city-level leadership to attract green finance by offering 'climate friendly products' that serve the local community while also benefiting the global commons.

KEYWORDS

Smart cities, Digital platforms, Infrastructure gaps, Institutional inertia, Incentive incompatibility

초록

지난 수십 년간 디지털 혁명은 도시의 운영 방식을 바꾸었다. 더욱 중요하게는 다양한 도시 기반시설과 사회서비스를 공급하는 기관과 도시의 이해관계자가 상호작용하는 방식을 바꾸었다. 이러한 추세는 큰 기대를 낳았는데, 스마트시티가 도시 지배구조를 혁명적으로 변화시킬 잠재력이 있다는 것이었다. 이 글은 스마트시티는 선진국 중에서도 앞선 국가들(이른바 북반구 선진국Global North)에는 가능한 개념이지만, 비슷한 아이디어를 개도국(이른바 남반구 개도국Global South)에 적용하려면 몇몇 주요 제약이 해결되어야 한다고 주장한다. 첫째 제약은 대규모 기반시설의 서비스 격차가 좁혀져야 하지만 공공 재정은 부족하다는 것이다. 둘째는 고질적인 기관의 타성이 종종 효율적인 계획 및 전달 역량을 감소시킨다는 점이다. 셋째는 인센티브 불일치인데, 도시 수준에서 저탄소 투자를 뒷받침할 매력적인 기회가 있음에도 불구하고 공공 재정은 비탄력적이고 글로벌 자본시장은 공공 재정을 보완하지 못하는 시장 실패가 발생하고 있기 때문이다. 결론 부분은 이들 세 제약을 해결하기 위한 선택지들을 모색해 본다. 도시 수준의 리더십이 녹색 금융을 조달함에 있어 결정적인 역할을 해야 함을 강조한다. 녹색 금융은 지역 공동체는 물론 지구 환경에 도움이 되는 '기후 친화적인 제품들'을 제공함으로써 조달할 수 있다.

키워드

스마트시티, 디지털 플랫폼, 기반시설 격차, 기관의 타성, 인센티브 불일치

Introduction

"A sustainable future occurs when planning lays a foundation; resilience guards against future risk; smart cities deploy the best technology for the job; and financing tools help pay for it all. Getting these essentials right in cities today is vital in order to adapt to the demands of tomorrow."[1]

The ongoing digital revolution offers phenomenal opportunities for integrating various data sources to deliver sustainable services to city residents while also safeguarding the ecosystem and the global commons. These aspirations have given rise to considerable enthusiasm among all city leaders to launch their cities into Smart City pathways. In the global North, many cities have demonstrated the benefits of adopting digital platforms for social, environmental and economic value creation through a variety of actions that improve administrative efficiency, foster accountability of city officials to residents while also generating vigorous citizen-centric participation and cooperation.[2]

Paradigm changes also took place in the way urban services delivered through sectoral verticals or silos (such as electricity, water supply and sanitation, transport, solid waste management, housing etc.) were transformed with a more collaborative process focusing on the circular economy, sustainable water management and reduced urban dependence on fossil fuels. These smart cities were anchored in institutions with similar characteristics: regulatory and institutional practices, such as having active stakeholders' participation, encouraging information diversity and transparent disclosure of performance, crafting agile responses to tackle problems faced by business enterprises, and a facilitative environment for local innovations, good research capabilities, etc.[3]

1 Quoted from: UNESCAP and UNHCS (2019); The Future of Asian & Pacific Cities. Transformative Pathways towards Sustainable Urban Development

2 Yoo, Yejin; "Toward Sustainable Governance: Strategic Analysis of the Smart City Seoul Portal in Korea" Sustainability 2021, 13, 5886

3 Toward Sustainable Governance: Strategic Analysis of the Smart City Seoul Portal in Korea Yejin Yoo; Sustainability 2021, 13, 5886

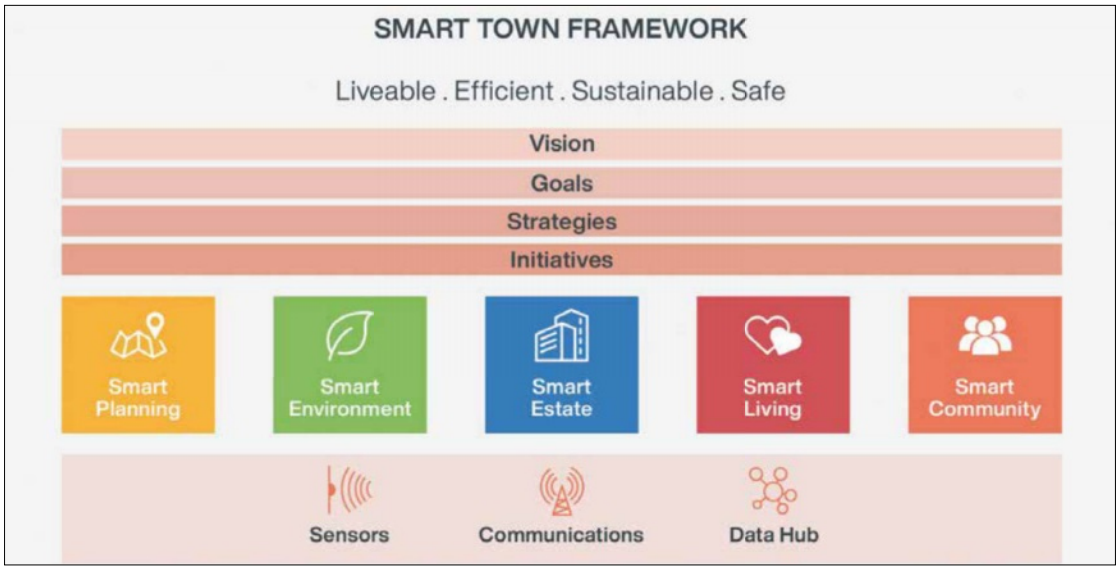

Figure 1. Singapore Smart City Framework

Singapore embodies the best elements of smart city management as described in Figure 1. Electronic sensors connected through Internet of ThingsIoT and from satellites provide very large datasets on a real time basis that get analyzed and used as inputs for improving the quality of life for residents, safeguarding the natural ecosystem while also improving the delivery of urban service through smart planning. In sum, the Singapore Smart City Framework relies on data driven decision making that leads to livable, efficient, safe and sustainable experiences for city residents. The underlying governance framework plays a key role in achieving the observed outcomes that closely mirror the desired outcomes.

By contrast, in many cities of the global South, management of urban services is fragmented, there are significant infrastructure investment gaps and often as much as a third of the urban population survive on marginal incomes acquired through precarious vocations in the urban informal sector. Chronic urban poverty will only be exacerbated in the decades ahead: between 2015 and 2050, cities in sub-Saharan Africa and South Asia are projected to add 795 million and 568 million urban

residents, respectively. More than a billion additional urban residents will there for require significant stepped-up investments to access basic urban services at the levels of coverage taken for granted today in Singapore, Seoul or Barcelona (World Health Organization & UNICEF, 2015).[4]

In situations where governance arrangements work on informality rather than in accordance with the formalized national legal and regulatory mandates, performance of service providers usually does not represent good value characteristics.[5] Typically, informal norms and conventions are more socially valued (or feared) than national or local government directives. For example, a homeowner illegally pumps out water from a piped network to an overhead water tank on his or her property, thereby reducing water pressure for downstream customers, but the utility does not take remedial punitive action because employees do not report the violation. Perhaps there could be even a payoff or bribe that is accepted as a "perk" of the job by the utility employee, reminiscent of "markets for public offices" as elaborated for the Indian water sector.[6]

The coexistence of two contradictory normative pressures describe external and internal dimensions of accountability, which erodes organizational performance:[7]

Internal accountability describes the extent to which institutional rules incentivize urban service delivery organizations to diligently strive for the organizational goals. In situations where organizational rules are not enforced, these employees as agents face incentives that may diverge

4 World Health Organization & UNICEF. (2015). Joint monitoring programme for water supply|| sanitation and hygiene (JMP) <https://www.unwater.org/publications/whounicef-joint- monitoring-program-water-supply-sanitation-jmp-2015-update/>

5 Jagannathan, N. Vijay; Informal Markets in Developing Countries. New York: Oxford University Press 1987

6 Wade, R. (1985). The market for public office: Why the Indian state is not better at development. World Development, 13(4), 467–497

7 World Bank. (2007). Making the most of scarcity: Accountability for better water management results in the Middle East and North Africa (English) (MENA Development Report) <http:// documents.worldbank.org/curated/en/353971468280764676/Making-the-most-of- scarcityAccountability-for-better-water-management-results-in-the-Middle-East-and-North- Africa>

from those of their principals, including core values enshrined in an organization's charter or even in national policy guidelines.

External accountability describes the extent to which urban service organizations are customer-facing in terms of fully responding to priorities, concerns, and complaints received from service users. Typically, ensuring efficient solid waste management in low-income communities, providing universal access to water supply, reliable public transportation is lacking because of employee indifference, thereby forcing many urban residents to figure out alternative ways of managing their lives. For example, to name a few: septic tanks get cleaned by informal waste emptiers who dump the human wastes in the nearest water body rather than by vacuum trucks; ragpickers collect recyclable wastes and litter leftover wastes instead of municipal workers routinely collecting, conveying and disposing wastes; two-wheeler ownership and usage is essential for ensuring urban mobility between homes and workplaces because public transportation is unreliable.

The implication: cities in the global South face three significant constraints that need to be addressed before a Smart City status can be achieved. These are:

- Deficits in infrastructure: These cities face chronic deficits in the delivery of basic services, such as access to affordable housing, transport, basic water supply and sanitation and 24/7 electricity access.
- Institutional inertia: The institutional structures are inadequate and often unmotivated to address the several challenges city administrations face in tackling urban poverty, air and water pollution, crime and youth unemployment.
- Incentive incompatibility: Handicapped by infrastructural deficits and institutional weaknesses the incentives for investors and financiers to consider long term engagement with the cities of

the global South are considerably less than the potential win-wins through collaboration.[8]

Elements of smart city management therefore varies considerably from country to country, and regionally between the global North and global South. Superficially the narrative is similar - electronic sensors measure and track most services offered, while the expansion of social media and availability of digital platforms have become universal. However, drilling down are chronic problems because of the three 'I' described above – infrastructure gaps, institutional weaknesses and incentive incompatibility. These characteristics result in governance gaps that must be addressed before comprehensive smart city management systems could become a reality.

An important caveat, however, is that limited applications of 'smart' approaches are visible in global South cities. What has worked extremely well are digital applications that directly benefit city residents. A good example is the ubiquity of the smart telephony and the spread of internet: these have greatly improved communications, awareness and citizen participation, as evidenced by the recent protests in Chinese cities against the COVID 19 restrictions. Another is the explosion of software apps that have created thousands of new jobs in the Gig economy through ride hailing apps, home delivery of services etc. However, when it comes to universal inter-connected public good priorities, such as improving basic urban services, or improving multiple services (electricity, water and mobility), digitalization has not changed the basic narrative except in limited ways.

A frequent systemic challenge has been how to achieve cross-collaboration among the various vertical sectors, such as energy, water, transport and housing, which work in silos: even when digital data is shared through a common platform the incentives to jointly respond to a concern or problem is difficult to achieve. Typically, electricity and water supply delivery organizations report to national or state level agencies, and more likely to respond to their internal hierarchies, rather than to customer

8 While many cities in the Asia-Pacific region have a substantial well-trained population who could benefit from the job

complaints particularly from low-income urban communities.

Elements of Smart City Management in the Global South Cities

Smart city management requires to address the three 'I's described earlier before benefits can be achieved as illustrated for Singapore in Figure 1. These requirements are discussed next.

Tackling the Infrastructure deficits:

The focus on achieving Sustainable Development Goals (SDGs) provides a useful opportunity to appreciate the huge challenges of bridging infrastructure deficits. The Asian Development Bank estimates that in the Asia-Pacific region alone current annual investments of $881 represents only 60% of investment needed. The current sources of finance are through government financial transfers and sovereign guarantees, with limited mobilization through cost recovery from users. When funds are

Inadequate income in relation to food & nonfood income	Unsatisfactory water access	Unsatisfactory sanitation	Homeless estimates	Hunger	Inadequate housing in Slums	Malnutrition among children
1200 million	680 million	700 million	100 million	500 million	40~70% of population	25%~40% of Slum dwellers

Source: Satterthwaite and Mitlin (2020)

Table 1. The scale of Infrastructure Deficits in Developing Country cities

severely constrained significant deficits are observed in basic social and infrastructural services in global South cities, and unserved poor populations rapidly grow (Table 1).[9]

There are two elements that need to be addressed to bridge the infrastructure deficit gap.

A smart city strategy needs to track adverse environmental and health impacts of self-provisioning caused by the infrastructure service gap

Infrastructure service deficits lead to widely practiced 'self-provisioning' that leads to adverse environmental and social impacts. Typical examples include:

- investing in two wheelers to reduce the time taken to use public transportation increases congestion and perpetuates GHG emissions;
- buying diesel generators to compensate for irregular electricity supply increases GHG emissions, and
- solid waste disposal through informal waste collectors leads to littering, pollution of land and water, and to unmanaged methane emissions.

An illustration of the unintended consequences is in the Jakarta metropolitan area, a densely populated urban conurbation with more than 10 million persons packed into 660 square kilometers. Residents compensate for the lack of an adequate piped water and sewerage system by investing in borewells in the property, and in onsite sanitation systems such as septic tanks and pit latrines. The consequences are excessive groundwater extraction that have led to land subsidence, coupled with fecal contamination of groundwater and surface waterways respectively. A World Bank study estimated that Jakarta's self-provisioning actions on sanitation has an opportunity cost of $1.4 billion annually because of adverse environmental and health impacts.[10] Furthermore, as the city is situated

9 Satterthwaite, D., & Mitlin, D. (2020). Understanding urban poverty in low income and middle- income nations. International Institute for Environment and Development

10 World Bank. (2017). A thirst for change: Evaluation of the World Bank's water supply and sanitation sector

in a highly seismic coastal region and the entire metropolitan area is likely to be affected by rising sea levels according to climate change predictions.

The financing gap should be narrowed as an integral objective of smart city management

UN ESCAP's estimate of investment requirements in the Asia-Pacific cities alone is an additional $1.5 trillion annually to achieve the Sustainable Development Goals by 2030. The UNESCAP-UNHCS report calls for establishing strong intergovernmental relations and support to fiscal decentralization initiatives, so that cities are motivated to raise their own revenues. The reality is that resources raised by cities in the global South through local taxation and service fees are very limited. The rest is obtained through transfers and revenue sharing from higher levels of government, and with limited access to Official Development Assistance guaranteed by the sovereign. The latter funding sources are becoming inelastic constrained by the global economic slowdown after the COVID pandemic and the ongoing conflict in eastern Europe. By contrast capital markets are

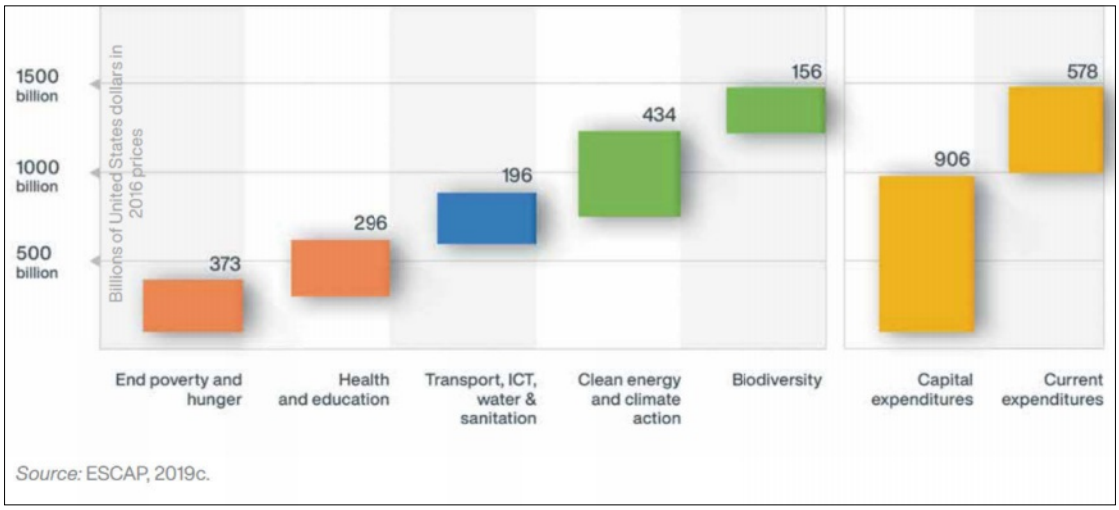

Figure 2. Financing Gaps by sectors

liquid with pension funds and other ESG investors looking for safe, sustainable climate-friendly investments, but these are not accessible by cities desperately in need for more investments.

Figure 2 breaks down sector-wide the city financing gaps for the Asia-Pacific region. Some of the identified sectors could attract private sector investments and blended green financing while others of a pure public good nature will require continued support from the public sector. Examples of the former are the physical infrastructure sectors (transport, ICT, water and sanitation, clean energy) that could once investors are satisfied that the outcomes have reasonable possibilities of achieving desired results. The latter covers programs to end poverty and hunger and much of the social infrastructure gaps are in health and education sectors. Biodiversity is a unique area that could also attract green finance.

To sum up, of the $906 billion capital expenditures requiring financing at least one half of the amount could be of potential interest to private investors and financiers if between the national and city governments the appropriate enabling conditions are established to achieve city development objectives while also addressing global climate priorities. This aspect needs to be an integral part of smart city policies.

Tackling institutional inertia

A second challenge is how to reform city level service institutions that currently lack internal and external accountability. A typical example is unmotivated city employees, earning relatively low salaries and fixed mindsets based on the training and skills acquired much before the digital revolution. The ongoing digital revolution is disrupting existing economic structures but having the potential to create new higher paying jobs and careers in city institutions that respond to emerging opportunities. Local municipal officials and service providers could therefore either accelerate this

process or retard the transition to benefit from the digital revolution, often described as the ongoing Fourth Industrial Revolution, which is "a new that builds and extends the impact of digitization in new and unanticipated ways".[11]

Transition from fixed institutional mindsets to flexible approaches that respond to emerging priorities

Apart from the Agency problem identified in the previous section, a systemic reason for the observed institutional inertia is the continued value attached to project based investments based on a 'linear' project cycle within fairly rigid public procurement rules. For example, an elevated highway project is viewed as a distinct investment, and the progress is tracked by stages: from a feasibility study to a detailed engineering design, construction, and inauguration. Effective management is interpreted as completing the project cycle on time, on budget to ease traffic congestion. However, the elevated highway could have unintended outcomes that were not envisaged in the original project plan: traffic may be much higher than projected; air pollution and congestion accelerated by traffic jams at the point where the flyover meets the city road, and homeowners' privacy affected by an unsightly elevated road traversing between high rise buildings.

Seoul decided to convert one such elevated highway into a green lung in the middle of the downtown area and restored the original river Cheonggyechon as a public amenity, with spectacular environmental and societal benefits that were never envisaged when the original project cycle was completed in a linear, sector-driven manner (Figure 3). Pedestrianization of downtown areas, such as the Times Square in New York city is another example of promoting healthy lifestyles, while reducing emissions and congestion from vehicular traffic.

11 Davis, Nicholas; "What is the Forth Industrial Revolution?" Quotation from page 1. World Economic Forum 2016 What is the fourth industrial revolution? | World Economic Forum (weforum.org)

Figure 3. A gift to Seoul Citizens and the Ecosystem: Seoul conversion of elevated highway

Similar institutional innovations are feasible in cities of the global south if city level leaderships adopt the attitude of delivering "products" having environmental, social and economic value rather than maintaining a narrow focus on delivering on single sector projects that often have many unintended adverse consequences on the society and the local ecosystem.

The key requirements for such a transformation to take place are two-fold. One is to change the design and delivery of infrastructure to fully incorporate cross-sectoral and citizen inputs in design and implementation. The second is to require city level officials to undertake continuous training and capacity enhancement, so that they learn and get inspired by how cities in the global North like Seoul, Yokohama and Barcelona have been on forefront of enhancing climate friendly development while also enhancing citizen and ecosystem welfare.

Build on local initiatives that have potentials to be scaled up

An important caveat is that local initiatives in global South cities have provided significant proofs of concepts that overall smart city management is possible. For example, in Hangzhou city, China, a cloud-based system called City Brain is a digital platform that utilizes artificial intelligence to analyze data collected from multiple sources (such as traffic data, video footage from traffic cameras,

location data of buses and cars from GPS others) to improve the management of traffic signals to reduce travel time, improve commuter experience and ease the traffic congestion on streets. This system improved coordination of traffic signals, in detecting road accidents on a real time basis and even illegal parking.[12] Another example is of young software developers working with the Nairobi City Water and Sewerage Company to modernize the complaint redressal mechanisms that benefited about 500,000 water service account holders in some of the largest cities in Kenya. Within a year of establishing the Maji voice system, customer complaints increased tenfold from 400 to 3,794 a month, and the digital tracking halved the redressal turnaround time by the utility. The data gathered through this process was also an invaluable source of information for the national water regulatory office, the Kenya National Water Services Regulatory BoardWASREB in improving its oversight of water supply performance in urban Kenya's.[13] In Jakarta, the PROPER digital platform has been successfully disclosing water pollution levels in the urban water courses for more than 25 years through a easily understood system of color coding, with gold representing the highest water quality in a subdistrict, and red being in violation of national environmental regulations. This simple disclosure mechanism enhanced citizen awareness and more importantly pressured polluters to adhere to national regulations on waste disposal from their factories by investing in the required industrial pollution abatement.[14]

Data platforms that "de-siloize" by integrating key urban services information and professionally managed by third parties could merge citizen feedbacks with ground-truthed information and digital data collected from electronic sensors that now embed every infrastructure activity in the city. Such an innovation could improve service quality, reliability, and sustainability of urban services.

12 Future of Asia-Pacific Cities Report (op cit)

13 Belcher, M., Lopez, C., Sjoberg, F., & Mellon, J. (2018, December). Majivoice Kenya. Better complaint management at public utilities. In G. Grossman, M. Belcher, & J. Rodden (Eds.), Crowdsourcing accountability: ICT for service delivery. World Development

14 Afsah, S., Blackman, A., Garcia, J. H., & Sterner, T. (2013). Environmental regulation and public disclosure. The case of PROPER in Indonesia. RFF Press

It will provide credible information to potential investors and financiers of city level investments because independent digital data management and disclosure improves internal and external accountability. Once the performance system gains credibility, it becomes accepted by all sections of society and by global market participants.

Institute a program for institutionalizing Continuous Performance Monitoring and Benchmarking of Desired Outcomes:

The above examples from China, Kenya and Indonesia respectively illustrate three of the many ways in which locally relevant smart solutions were developed at the city level. The larger challenge, however, is how is to replicate good practices across all key infrastructure service delivery sectors through a city-wide program. In theory this is possible by reporting on different aspects of urban services performance and tracking outcome pathways until a minimum globally accepted standard is met. They could not only serve city level customers but also be build institutional credibility with foreign direct investors, and financiers from global green capital markets (whose roles are vital to bridge the infrastructure gap).

An action-oriented approach needs to be designed, which reports on a continuous basis how far key city service delivery agencies are performing to achieve the desired development outcomes. A continual performance monitoring and benchmarkingCPMB system anchored in a digital platform could transform planning and implementation processes and enable effective tracking of multiple cross-sectoral and environmental goals.[15] A good illustration of one such initiative is the performance focus Chinese cities have adopted for the past few years to report to the national government on the speed of progress in 'bending' the city-level GHG emissions curve, latest by 2030. The required planning and investment actions to achieve the overall cross-sectoral outcome

15 Afsah, Shakeb and Chris Wolz (2004). "Using continual Performance Monitoring and Benchmarking Approach" Report to the Government of Egypt

include inter alia substituting renewable energy for fossil fuels, redesigning urban mobility that reduces dependence on cars while also improving air quality, refurbishing buildings to reduce energy and water intakes, building resilient water systems through the sponge city concept etc. Achieving performance targets latest by 2030 requires relevant sectors, such as electricity, housing, transport to work collaboratively to achieve city-wide low carbon targets.

CPMB should have the following features:

- A focus on results, not just on the process of achieving results
- An initial assessment and discussion process with various stakeholders to reach a common understanding of what is meant by city transformation, and the underlyin g process for continual improvements.
- Embed the performance results information into the city management level decision making processes by city leadership, and as internalized behaviors among employees of relevant sectors and organizations.
- Continuous measurement of performance enabled by connecting electronic sensors to a digital data platform that uses advanced data analytics to institutionalize a performance driven culture.
- Systemic performance disclosure to secure city stakeholder engagement and provide feedback on performance. Data and information help identify city level priorities and strengthens the urban planning process.
- The disclosure system will serve as a valuable source of information for investors and financiers to assess the risks of committing funds to support city-level investments.

A CPMB system is therefore a form of network governance that institutionalizes autonomous reporting on multiple aspects of urban services and provides data of use for autonomous but interdependent

actors. The underlying premise is that each sector requires collaborative solutions with inputs from other sectors and robust feedback from urban communities.

Reslving incentive incompatibility

As described earlier, attracting additional $1.5 trillion of investments and finance annually to achieve the Sustainable Development Goals by 2030 requires massive inflows of foreign direct investments and capital from global markets. Most cities of the global South - perhaps except for Chinese cities - have so far been unable to attract financial resource flows to the sub-national level for public good infrastructure. Success has been reported through single sector project investments, such as improving transportation links, ensuring 24/7 water supply and electricity, expanding urban housing to name a few, through Public-Private PartnershipsPPPs. However, one could generalize that the overall policy and institutional environment for an investor or financier the incentives to engage in a long-term partnership is constrained by perceptions of significant governance and political risks dealing with subnational institutions.

A pathway to mitigate these perceived risks of partnering at the subnational level is to package climate-friendly investments offers that could be of interest to voluntary carbon markets, ESG-oriented corporations and other institutions interested in green finance. Two examples below illustrate how this can be done.

Designing Zero waste programs at the city level. Zero waste outcomes are essential to achieve global climate goals, while also universalizing the idea that all cities should be healthy, livable and urbanization benefits shared between humans and natural ecosystems.

The volumes of solid and liquid wastes rich in Methane are enormous and growing as urbanization

rates increase. Asia-Pacific cities have witnessed growing income levels and rise of consumerism that has multiplied waste generation - these rates are expected to grow at twice population growth rates between now and 2050. Overall, UNEP estimates that 11.2 billion tonnes of solid waste alone are generated worldwide each year. Current trends indicate that global solid waste related GHG emissions will increase to 2.5 billion tonnes of CO_2 equivalent by 2050 unless effective zero waste policies and programs are implemented.

Zero waste outcomes are therefore as good for city residents as it is for the global commons. Domestic waste contains organic matter from solid wastes and emissions from sludge and sullage, textiles and paper, with the methane gas having 28 times the potency of carbon dioxide. Already, an estimated 1.6 billion tonnes of CO_2 equivalent greenhouse gas emissions are generated from solid wastes, amounting to about 5 percent of global emissions; with significant additions from slowly decomposing sludge and septage. There should be a natural interest for investors from voluntary

Compliance Markets	Price/Tonne		Year-to-date Change
European Union	€87.98	–	+9.67 %
California	$29.03	–	−9.34 %
Australia (AUD)	$32.50	–	-36.27 %
New Zealand (NZD)	$81.00	–	+18.33 %
South Korea	$12.25	–	−51.22 %
China	$8.23	-0.34%	+6.60 %
Voluntary Markets			
Aviation Industry Offset	$2.97	–	-62.88 %
Nature Based Offset	$5.33	–	-62.14 %
Tech Based Offset	$1.45	–	-71.46 %

Table 2. Carbon pricing December 1, 2022
(Source: Carbon credits.com, https://carboncredits.com/carbon-prices-today/?sl)

carbon markets and other participants interested in contracting for carbon offsets particularly when carbon prices are increasing (Table 2). However, a fundamental policy shift is required in the way biodegradable(organic) and non-biodegradable(inorganic) are managed, which is entirely within the mandate of local governments.

Effective zero waste programs also contribute to promoting circularity in resource usage instead of the linear economy paradigm of "extract-produce-discard". For example, when buildings are demolished as a part of continuous urban renewal, enormous quantities of concrete, glass, wood and plastics are generated that could be reused or recycled. Only some of these inorganic wastes are reused in construction and road building; the rest get deposited in unsightly dumpsites, burned to emit black smoke and dumped into waterways. E-wastes contain potentially highly toxic chemicals.

Achieving zero waste outcomes have therefore multiple benefits at the local, regional and global levels. Urban residents benefit from clean streets, vibrant neighborhood and clean waterways; regional ecosystem suffer less stress from harmful pollution through liquid and solid wastes, while the global economy benefits by eliminating harmful impacts caused by uncontrolled GHG emissions from methane.

A pilot effort to test the above ideas was undertaken in Xiangyang city, in Hubei province of China in 2017. Figure 4 summarizes the program, which aimed to capture methane from organic wastes or digested sludge and converted to products that were commercially sold.[16] The methane was converted to Compressed Natural Gas that replaced the fossil fuels used by the city's taxi fleet. The biochar produced through the hydrolysis process was utilized for urban forestry and sold as fertilizers for ornamental plants while Methane emissions to the atmosphere was eliminated.

16 Fu, Xiaotian, Lijin Zhong, Vijay Jagannathan and Wanli Fang; "Sludge to Eneregy: An Environment-Energy-Economic Assessment of Methane Capture from Sludge in Xiangyang city, Hubei province" Washington DC; World Resources Institute, Working Paper 2017

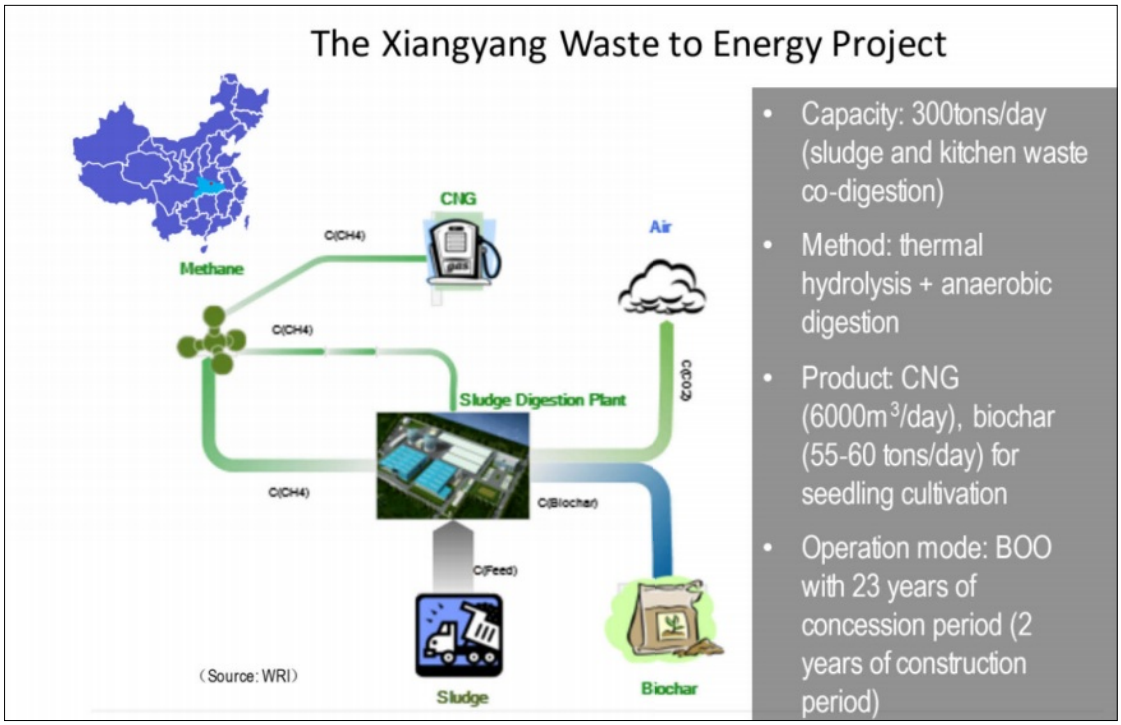

Figure 4. Offering city level products to green investors

The offer of waste to energy 'products' attracted private sector interest, with implementation through a Public-Private partnership framework. At the city level the effort required working across sectors, notably through close collaboration between water supply and sanitation, solid waste management and urban transport specialists before the investor was willing to bear the risk of investing in an entirely new business line.

Underlying the process were policy and organizational innovations by Xiangyang city leadership that changed the waste narrative from a 'linear' one (viewing waste as a public nuisance that has to be managed out of sight as much as possible) to a 'circular' one in which both city-level stakeholders benefit (from the waste value chain through clean neighborhoods, improved health outcomes, stable job opportunities) as does the private investor (by monetizing the capture of greenhouse gases and sale of biochar).

Figure 5. Taxonomy of Urban Green-Blue Solutions

Developing Urban Blue-Green Solutions to attract green financing

Figure 5 describes the key features of Urban Green-Blue solutions that could similarly change the narrative as far as the way water resources are managed at the city level. The measurable outcomes are described in the second column in terms of increased system efficiency that strengthens resilience to future disasters such as floods, droughts and sea level rise, while also lowering infrastructure investment costs by replacing nature-based solutions for many of the capital-intensive 'grey' investments. This approach also improves the quality of life for city residents, apart from having health benefits, which could improve economic productivity and enhance the attractiveness of the city as an investment destination. As in the Zero waste example these offers could increase green investor interest because

the outcomes are climate friendly.

Concluding Comments

Smart city management in developing countries is not identical to what is observed in cities in the global North. In the former group of countries, the digital revolution has taken place in a piecemeal manner in some sectors and in a few activities based on the initiatives taken by local entrepreneurs and communities, supported by big tech companies. However, a systemic institutional and incentive structure transformation has yet to take place.

The first challenge for the global South cities is to reverse the chronic institutional inertia in subnational governance institutions. City institutions are nested organizations, with many key personnel accountable to higher levels of government that view infrastructure development as a series of linear projects, rather than as city level 'sustainable product offers' package to interest climate-conscious investors and financiers. The solution is for local leadership to take a pro-active role and galvanize all stakeholders to advocate offers that benefit local communities as well as the global commons.

An alternative "top-down" approach, as in China is also feasible. The Central Government has made city mayors responsible for 'bending the GHG curve' within their respective jurisdictions. This policy change was accompanied by shifting the oversight and coordination function from the provincial or city level Development and Reform Commission (which is the powerful body responsible for all infrastructure project planning and implementation activities) to the City Environment Bureau, which reports to the Ministry of Ecology and Environment (and responsible for implementing low carbon policies).

Once city leaders recast their roles and commit to disrupt institutional status quo, the second challenge will be to constitute cross-sectoral teams that leverage technology advances and local entrepreneurship to promote climate friendly investment opportunities. These climate-friendly 'offers' maximize co-benefits between local community, the regional ecosystem and the global commons as illustrated in the previous section. A key part of this collaboration is to ensure action-learning from the successes and failures of peers, apply relevant lessons from smart cities of the global North and build partnerships with local academic institutions, civil society organizations and young entrepreneurs.

The third challenge is to sustain these processes such that the perceived governance risks are mitigated for potential green and ESG investors who currently are reluctant to engage at the sub—national level.

Urban Strategy:

Local Digital Twins for Sustainable Mobility and Livable Cities

도시 전략:
지속가능한 모빌리티와
살기 좋은 도시를 위한 지역 디지털 트윈

Hieronymus Christiaan Borst

Hieronymus Christiaan Borst is the manager of a cluster that studies social impact on accessibility and housing suitability since 2021 at the Transport Unit of the Netherlands Institute of Applied Sciences TNO. TNO is an independent Dutch applied science research institute founded in 1932. About 3,000 scientists act as a bridge between basic research and commercialization at this institute, the largest in the Netherlands. The specific research topic is the impact of digitization, automation and electrification on mobility and the built environment field. He is working closely with cities around the world on the mobility transition. In other words, to deal with the mobility and energy transition, he conducts research that cities develop and apply local digital twins. Previously, for about four years until 2020, he worked on the TNO urban strategy development as a program manager.

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ABSTRACT

The battle for space in cities due to urbanization in combination with transitions in mobility and energy cause big and urgent challenges. Local Digital Twins (LDTs) are gaining popularity in cities to help to gain insight and make well informed decisions to overcome these challenges. Amongst other issues, interoperability and perceived practical value tend to hamper the large scale uptake and practical applicability of LDT technology. This paper describes TNO's Urban Strategy to build Local Digital Twins for Sustainable Mobility and Livable cities. A technology overview provides insight in how the software components are developed along with an architecture to allow interactivity and interoperability between data and software components. An overview of models provide insight in how science in different domains is being made applicable for interactive usage. With examples in Delhi, Singapore, Curacao, Antwerp and Amsterdam the practical applicability as well as the implementation of Local Digital Twins are demonstrated. Lessons learned from these examples are that, beside a sound technical and scientific approach, features regarding interactivity, integrality and interoperability, key elements of successful LDT implementations are 1. Collaboration between city operations and innovation office, supported by elected leadership; 2. Cooperation with local stakeholders (triple helix), requiring interoperability of data and software components; 3.Connection to (local) knowledge institutes (e.g. universities) to secure the exchange of knowledge and local capacity building.

This way Local Digital Twins can contribute to Sustainable Mobility and Livable Cities.

KEYWORDS

Smart cities, Digital twin, Predictive modelling, Sustainability, Livability

초록

도시화에 따른 공간 압박 속에서 모빌리티와 에너지의 전환이 이루어지면서 도시는 크고도 급박한 과제에 직면해 있다. 이런 배경에서 지역 디지털 트윈Local Digital Twins, LDT이 인기를 끌고 있는데, 과제를 해결하기 위한 의사결정을 잘 내리는 데 필요한 정보와 통찰을 얻는 데 도움을 준다. LDT 기술의 대규모 확장과 현실 적용에는 방해 변수들이 존재하며, 상호운영성과 실질적인 가치가 대표적이다. 이 글은 지속가능한 모빌리티와 살기 좋은 도시를 만들기 위한 지역 디지털 트윈 개발의 측면에서 TNO의 도시 전략을 소개한다 (TNO는 1932년에 설립된 네덜란드의 독립 응용과학연구소이다. 네덜란드에서 최대 규모인 이 연구소에서 과학자 약 3,000명이 기초연구와 상용화의 중간 다리 역할을 수행한다. 역자 주). 이 글은 기술 부분에서 데이터와 소프트웨어 구성 요소 간 상호작용과 상호운영을 가능하게 하는 설계에 따라 소프트웨어 구성 요소를 어떻게 개발할지에 대한 통찰을 제공한다. 모델 부분에서는 상호작용하는 기능을 위해 다른 영역에 있는 과학이 어떻게 적용될 수 있는지에 대한 통찰을 준다. 델리와 싱가포르, 퀴라소, 안트베르펜, 암스테르담 등의 사례는 지역 디지털 트윈을 실용적으로 적용하여 실행할 수 있음을 보여준다. 이들 사례로부터 배운 교훈이 있다. 탄탄한 기술적·과학적 접근과 상호작용성·온전성·상호운영성 같은 특징 외에 성공적인 LDT 실행의 관건이 되는 요소들은 다음과 같다는 것이다. 1) 도시 운영 부서와 혁신 담당 부서의 협력. 이 협력은 선출된 리더십에 의해 지원받아야 한다. 2) 해당 지역의 이해관계자들과의 협력(삼중 나선). 여기에는 데이터와 소프트웨어 구성 요소의 상호운영성이 필요하다. 3) (지역) 지식 기관(예컨대 대학)과의 연결. 이는 지식 교환과 지역 역량 개발을 위해 필요하다. 이 같은 방식으로 지역 디지털 트윈은 지속가능한 모빌리티와 살기 좋은 도시에 기여할 수 있다.

키워드

스마트시티, 디지털 트윈, 예측 가능한 모델링, 지속가능성, 주거 적합성

Introduction

The global trend of urbanization is likely to continue, with the world urban population projected to grow from 54.5% in 2014 to close to 70% in 2050 (Karuri-Sebina, et al., 2016). Due to this trend, the pressure on public space is increasing (Balikçi, Giezen & Arundel, 2021). It is a challenge for cities to plan different activities such as living, recreation, mobility, leisure, retail and production and meet societal goals at the same time, to provide an attractive and healthy living environment and sustainable, safe and accessible transportation for all in line with Sustainable Development Goal #11 to make cities and human settlements inclusive, safe, resilient and sustainable.

Meanwhile three important trends are changing urban mobility: Digitalization, Electrification and Automation. Digitalization enables platforms to provide new forms of mobility, such as Mobility-as-a-ServiceMaaS. The two primary components of MaaS are (shared) transportation services (the wheels on the ground) and MaaS platforms (the apps which integrate finding, booking and payment services) which allow interoperability and easy use of multiple transportation modes and services. MaaS is thus part of the transition from mobility as a commodity (ownership of vehicles) to mobility as a service (access to trips) (Araghi, et al., 2020; Münzel, 2020). Data sharing in mobility is becoming increasingly important. In order for governments to keep a grip on the use of public space, insight into this data exchange is needed. Well-formed public/private sector collaborations may eventually prove to be the most effective strategy and can help to steer towards societal goals (Vonk Noordegraaf et al., 2020). Automation of vehicles and connected mobility will alter the role (and responsibility) of the driver. The most committed companies in the industry are targeting several different primary use cases including ride-hailing, also referred to as robotaxis. Autonomous vehicles AVs may significantly change traveler behavior and network congestion. (Levin & Boyles, 2015). Changes in value of travel time could make users accept longer commuting distances, e.g. choose to live in the suburbs or rural areas while working in the city (Fraedrich et al., 2016). This will have

a potential impact on land use and property values (Razin, 2018). Electrification of mobility will lower emissions of air pollutants and, at lower speeds, noise and the cost structure of mobility. These trends, and especially the combination of all three will affect the mobility proposition and therefore the way people move around in the city. If managed well these trends could lead to less car ownership, less car trips and therefore less use of space, cleaner air and a better living environment. Without regulation, however, these new technologies will lead to increased car usage, congestion and use of urban space, (Agarwal, Mani & Telang 2019). It is important for decision-makers, particularly those with transport responsibilities, to be aware of these trends and of the challenges posed not only by the electrification of mobility, where pure EVs will have a growing share, but also the challenges posed by autonomous vehicles and the increase in new forms of mobility, where the vehicle tends to move from individual ownership to a shared service such as carsharing (Pereirinhaa et al., 2018). Snelder et al. (2022) recommend decision makers to focus on all travel modes including cycling and public transport and to invest in automation, connectivity, sharing, and electrification and to create a multimodal vision on future mobility systems along with quadruple helix stakeholder engagement will be needed to decide where and when to invest in different solutions.

Local Digital Twins, or Digital City Twins, gain growing popularity and are applied more and more in the urban context (Raes et al., 2022). Ketzler et al 2020 described examples of how digital twins for cities are implemented in a global perspective. Most severe challenges found by Lei et al (2023) are related to interoperability and practical value.

TNO being the organization for applied scientific research, has the role to make science applicable for business and society. In order to help cities and local stakeholders to make Local Digital Twins applicable to overcome urban challenges, TNO has developed Urban Strategy (Borst et.al 2011; Borst, 2022). Urban Strategy technology allows cities, knowledge institutes (e.g. Universities) and private stakeholders to build interactive, integral and predictive digital twins of cities.

By describing the technology outline of Urban Strategy, this articles provides insight in how to overcome challenges related to interoperability between silos. Examples of applications demonstrate the added value of Local Digital Twins beyond the phase of the Proof-of-Concepts. The article concludes with a selection of future developments, to contribute to sustainable mobility and to improve livability in cities.

Methods: Local Predictive Digital Twins with Urban Strategy

Aim of the development of Urban Strategy is to enable the development of Local Digital Twins that are integral (covering multiple domains), interactive and predictive (simulation results in the timeframe of a workshop) and interoperable (enable data exchange). This section describes the principles of the Urban Strategy components and architecture as well as a selection of the predictive models that have been implemented to contribute to sustainable mobility and liveable cities.

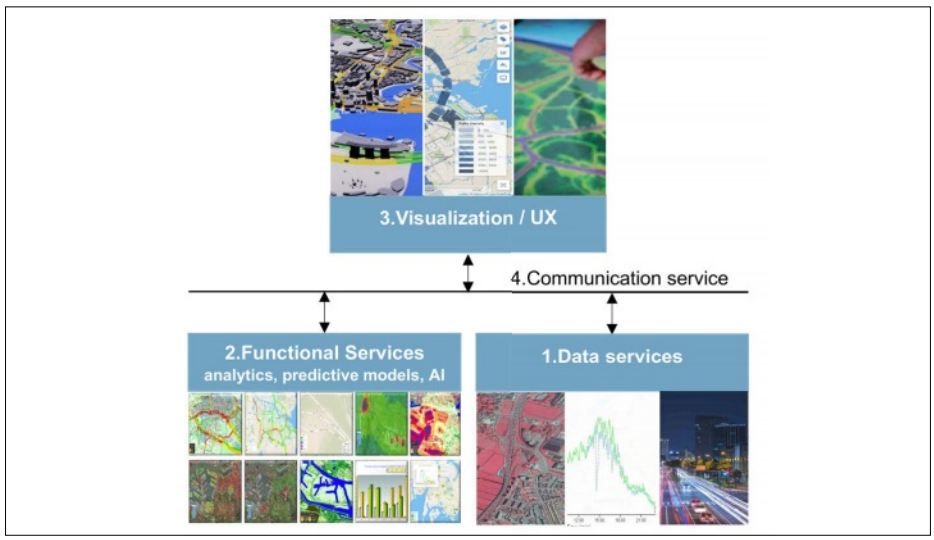

Figure 1. Urban Strategy architecture combining data services, functional services and visualization using a communication service.

In our definition, a Digital Twin platform consists of four elements as shown in figure 1:

1. **Data Services (Data storage and exchange):** services to unlock, request and thus exchange data from different data silos or the role of data spaces, in order to feed data into Digital Twins. For the data solution, an implementation is choses that adheres the FAIR principles as described by Wilkinson et al., (2016).
2. **Functional Services (analytics, predictive models, AI):** These services refer specifically to the need to orchestrate the models that are applied in the Digital Twin, whereby the models will for example be just to simulate what-if scenarios. In Urban Strategy, a range of models has been implemented, as described later is this section.
3. **Visualization and UX Services:** When it comes to Visualisation and UX Services, one can think for example of geospatial visualisation services or analytical visualisation tools. In Urban Strategy, a combination of 2D web interfaces, a 3D interface and an indicator dashboard are part of the UX suite (see figure 2).
4. **Communication services (integration framework, API's):** These services ensure, for example, that the interoperability in the Digital Twin is guaranteed or that APIs are available. For Urban Strategy, an integration framework, named IMB has been developed and applied (Hofman, Lohman & Schelling, 2011), connecting data services, analytical models and (web) visualizations. Platform agnostic implementation allows interoperability between components on premise, in a private cloud or in a public cloud (e.g. Microsoft AZURE).

In order for ensure the interoperability of Digital Twins developed on the basis of Urban Strategy, the FAIR principles as described by Wilkinson et al., (2016) have been adhered:

1. **Findable:** (Meta)data are assigned a globally unique and persistent identifier, data are described with rich metadata and include the identifier of the data they describe and data are

Figure 2. Example of interaction with the Urban Strategy Local Digital Twin of Amsterdam in the combination of an interlinked 3D representation (background) and a 2D web interface on an interactive MS Surface Table.

registered or indexed in a searchable resource.

2. **Accessible:** Clear access, data are retrievable by their identifier using a standardised communications protocol which is open, free, and universally implementable. The protocol allows for an authentication and authorisation procedure, where necessary. Metadata are accessible, even when the data are no longer available.
3. **Interoperable:** To allow integration with other data and interoperability with applications or workflows for analysis, storage, and processing, data use a formal, accessible, shared, and broadly applicable language for knowledge representation, including references to other (meta)data.
4. **Reusable:** Metadata and data should be well-described so that they can be replicated and/or combined in different settings and meet domain-relevant community standards.

In the policy brief from the EU project Digital Urban European Twins (DUET), Raes et al. (2022) recommended to build digital twins across silo's. In line with this recommendation, current models in Urban Strategy cover and integrate amongst others, the following topics:

- Transportation demand: the number of trips per mode, based upon activities per traffic zone. Currently, a traditional four stage model has been implemented as described by Ortúzar and Willumsen (2011). Zhou et al. (2019) describe how more elaborate (activity based) transportation models can be made applicable using high performance computing (HPC). Errampalli et al. (2018) demonstrated a demand model for urban logistics implemented in Urban Strategy.
- Multi Modal assignment to the transportation networks, including road traffic, public transport, cycling and shared mobility, including vehicle dispatching of Demand Responsive Transit (Van der Tuin et al., 2022) and the assignment of multiple modes of urban logistics (Errampalli et al., 2020).
- Air quality emissions and concentrations, based upon road traffic characteristics, fleet composition, local topology, meteorology, background concentrations and other sources. Implemented according to the Dutch standard calculation methods known as SRM-1 as SRM-2 (RIVM, 2014). These models, background and emission factors can be adjusted and validated for applications in other countries as demonstrated by (Uhlig et al., 2018).
- Noise emissions, propagation and impact, based upon traffic characteristics, topology (shielding objects), road surface types, locations of dwellings, according to the Dutch calculation methods (Borst et al., 2009). This model is implemented for mobile sources (road and rail) as well as stationary sources (industry). Also this model can be adopted for application in another context. On the basis of exposure assessment on the basis of noise maps, impact indicators can be derived (Borst & Miedema, 2005) according to dose response curves for noise annoyance (Miedema & Groothuis-Oudshoorn, 2001).
- Energy usage of mobility: expected electricity demand, including public transport, impact on

the power grid (grid congestion), impact of local renewable sources.

In order to meet the ambition to allow interactive planning of urban space, mobility, environment and energy. The models much faster than commercial off-the-shelf solutions, using parallelization on Graphical Processing Units (GPU's). Further extensions are foreseen in applying open standards and open link data for data collection and sharing. A REST API allows easy interaction with external software environments.

Applications for Sustainable Mobility: Delhi, Singapore and Curacao

The combination of models, allow integral testing of scenarios to improve sustainability and living quality. Digital Twins using Urban Strategy have been applied in a number of cities.

An example of application for sustainable mobility is described by Errampalli et al. (2020). In order to support policies to reduce the impact of urban freight transportation on congestion and air pollution in the city of Delhi (India), The Central Road Research Institute, Technical University Delft and TNO, built an urban freight transport model for the city of Delhi. This model considers trip generation, trip distribution, modal split and trip assignment. With the combination of newly observed freight, fleet and trip characteristics, as well as socioeconomic and land-use data, a four stage model was implemented using Urban Strategy. The model was applied to evaluate several transport policies, such as freight hubs and entry restrictions. On the basis of the model outcomes in terms of congestion and emission levels, authors found that fleet renewal measures such as vehicle age restrictions and electrification promise to be most effective.

In Singapore, the Land Transport Authority (LTA) is committed to greening Singapore's public transport. LTA will electrify half of the bus fleet by 2030 and achieve a 100% cleaner energy bus fleet by 2040. Electric buses have been identified as one of the earlier adopters in the electro-mobility space in Singapore due to their potential for emissions savings (CO_2, NO_x, PM). In order to enable electrification of the entire bus fleet, there is a growing need for understanding the complex interplay between vehicle characteristics, charging strategies, public transport demand, bus routes & traffic through research and trials in Singapore-specific conditions. In order to support LTA in the optimization of this transition, a Digital Twin of the (electric) bus system was developed using Urban Strategy, providing insight in the trade-offs between different solutions, technologies and operating strategies.

Another example of application Local Digital Twins for Sustainable Mobility is on the island of Curacao. Curaçao has taken major steps in making the energy system more sustainable. Nevertheless, the island is currently largely dependent on the import of fossil fuels for its energy supply. This is a vulnerable position from both a social and an economic perspective. Curaçao can and wants to reduce this dependency. The transition to energy management based on sustainably generated energy requires a system change within the entire chain from generation, conversion and storage to distribution and purchase of energy. Understanding the different parts within a chain is essential for controlled and affordable innovation and optimizing the energy system based on renewable sources. This is no different on Curaçao. In addition, the as yet untapped supply of sustainable energy from, among other things, sun, wind, waste and biomass on Curaçao offers opportunities for making Curaçao more sustainable. In order to initiate this transition, Netherlands and Curacao conjointly set up a Living Lab for a just mobility and energy transition. Essential part of this approach is knowledge transfer to the island. In this knowledge transfer, the Digital Twin Curacao plays a central role. The Digital Twin Curacao is operated by the University of CuracaoUoC. There has been intensive collaboration with the University of Curaçao to develop and maintain high-quality

Figure 3. Students of the University of Curacao (UoC) being educated in working with the Local Digital Twin.

knowledge on the island. Staff and students are being educated in technology that is needed to enable the transition in energy and mobility (see figure 3). This allows the interaction between the stakeholders of the Living Lab and the impact for the entire island to be simulated and predicted in real time. The Digital Twin Curaçao helps to make a good assessment based on different scenarios between different policy choices regarding the electrification of transportation, starting with e-busses and the generation of sustainable energy, starting with EV panels. The Local Digital Twin is used to estimate the effects thereof on various public and private interests (quality of life, accessibility, etc.) in 'triple helix' cooperation as described in Etzkowitz & Leydesdorff (1999).

Local Digital Twins for Sustainable Mobility and Livable Cities: Antwerp and Amsterdam

In 2018, imec, TNO, PTV and TomTom joined forces to build a Digital Twin of Antwerp (Belgium). In this digital 3D replica of the city combines noise pollution data with real-time sensor information from air quality and traffic, and computer models. It offers an up-to-date and predictive view of the situation in the city whereby the impact of planned measures can be simulated and tested.The digital twin was created on the basis of the simulation platform 'Urban Strategy' of the Dutch research institute TNO, on which imec builds a new interactive interface and provides sensor data to enable the real-time linking and enrichment of the models. (imec, 2018). Building upon this example, imec initiated the EU funded project Digital Urban European Twins (DUET) in which this Digital Twin technology is being elaborated and made applicable for cities throughout Europe.

The city of Amsterdam and TNO started a long term strategic cooperation to address the challenges of urban planning and integrated mobility planning with the support of Urban Strategy, to jointly identify new challenges and bottlenecks, and to develop and use Urban Strategy to assess, monitor and evaluate system interventions. In other words: close the "learning cycle" and validate assumptions with (real-time) data. Starting point of the cooperation was a collaboration between the municipal Chief Technology Officer (CTO) and the operational department for traffic and spatial planning (V&OR), supported by the elected leadership (vice mayor). The sustainability of this cooperation clearly proofs the added value of Local Digital Twins. Key factor is the success of the cooperation is the combination of applicability and the continuous innovation. One application of Urban Strategy in Amsterdam is to support the planning of the reconstruction of the "Zuid-As", the business district of Amsterdam. The challenge there: keep the accessibility and livability of the area up

to standards during the long period (10 years) of (re)construction. Another challenge is the urgent maintenance of the bridges and quays in the city. With Urban Strategy the city assesses the impact on traffic and accessibility of works on the 1,600 bridges, 600 kilometers of quays and banks, and 5 traffic tunnels. With the very high speed performance of the instrument, the city is able to optimize the planning in order to keep the city moving. The Municipality of Amsterdam and TNO explore options for shared mobility, determining optimal parameters, availability, spatial distribution, expected use of shared mobility and its effects (e.g. spatial gains). Aim of the municipality is to reduce car ownership and increase the share of sustainable and/or active modes of transportation such as public transport, walking and cycling. Free floating shared cars have been added as an additional modality in Urban Strategy. Data from shared mobility providers is used to validate the model. Various policy options (e.g. availability, pricing) have been modelled. Scenarios to implement shared mobility in the city of Amsterdam have been simulated in terms of number of cars, number of trips per car and impact on freeing up public space. Figure 4 shows an overview of noise due to road traffic in the Local Digital Twin of Amsterdam.

Directions of Future Work

To be able to simulate the impact of municipal policies, infrastructure investments and other interventions, it is essential to understand the choice behavior of travelers for existing modalities (public transport, car, bicycle) and to understand the adoption of new modalities and concepts (such as shared mobility, micro mobility, MaaS). Discrete choice modelsDCM that are used to predict choice behavior use utility functions that describe the generalized costs for different options. Research focuses, among other things, on: the utility functions of new forms of mobility (e.g. shared mobility and personal mobility devices) (Knapen et.al., 2021; Clercq et al., 2022) and active mobility (Borst et.al., 2009), the utility of not traveling (working from home) and the possibility to include

Figure 4. 3D representation of traffic noise in Amsterdam (Lden) in the Local Digital Twin

aspects other than time, costs, comfort, such as reliability or social status of a modality. Moreover we study the use of AI to predict and understand existing modality choices for trips in their city, baseduse a decision support system which uses a classifier to predict the modality that an individual chooses for a trip, based on trip properties as well as personal characteristics as described by Walraven et al., (2022).

Traditionally, mobility and infrastructure planning is focusing on the efficiency of the transportation system. Nowadays, more and more authorities tend to take other factors into considerations including the distribution of impact on communities. TNO has carried out an initial exploration commissioned by the Dutch Ministry of Infrastructure and Water Management on indicators for welfare in a broad sense in the mobility domain (Vonk Noordegraaf et.al., 2021). Next step is to make these indicators

applicable for ex-ante assessments. In addition, a further deepening of the possible impact is necessary by mapping the spatial and target group distributions of these indicators. One of the use-case currently being investigated together with the Free University of Amsterdam, is the impact of a zero emission zone in Amsterdam. Question is which target groups benefit from this measure and which target groups are left behind, not being able to afford the transition to electric mobility. This allows us, for example, to provide insight who will reap the benefits of an investment, and where, e.g. in terms of improved accessibility and -on the other hand, where the disadvantageous consequences will have an impact for instance due to extra environmental pressure.

Together with TU Delft, TNO starts the XCARCITY project to develop Local Digital Twins for low-car urban areas. These models will shed more light on the effects of different mobility solutions. These Local Digital Twins will be used to test various scenarios and interventions for addressing specific problems in the cities of Almere, Amsterdam, and Rotterdam. This helps the decision-making process of government agencies, regional developers and transport operators when striving for clean, accessible mobility in their cities (TU Delft, 2022). This project allow further development of knowledge, implemented in simulation models as well as enabling technologies to build the next generation Local Digital Predictive Twins.

Conclusion

Local Digital Twins, or Digital City Twins, gain growing popularity to help cities with their battle for space and challenges regarding transitions in mobility and energy. Challenges found regarding the use of Local Digital Twins are related to interoperability and practical value. This article provided an overview of how Urban Strategy technology allows cities and stakeholders to build and apply interactive, integral predictive digital twins of cities. The technology outline of

Urban Strategy, deals with challenges related to interoperability between silos and examples of applications demonstrate the added value of Local Digital Twins beyond the phase of the Proof-of-Concepts. Beside the technical solution, an important elements of successful and sustainable Digital Twin implementations are:

- Collaboration between city operations and innovation office, supported by elected leadership, ensuring daily use of the instrument, securing implementation of the technology in the workflow of the city, as demonstrated in the example of Amsterdam;
- Cooperation with local stakeholders (triple helix) to enable adaption of models to,- and practical applicability in the local context, requiring interoperability of data and software components as demonstrated in the Digital Twin Antwerp;
- Connection to (local) knowledge institutes (e.g. universities) to secure the exchange of knowledge, local capacity building and connection to the local eco-system as demonstrated in Curacao, Delhi and in the future in the XCARCITY project;

With these implementation principles, Local Digital Twins have proven to be valuable to support Sustainable Mobility and Livable Cities.

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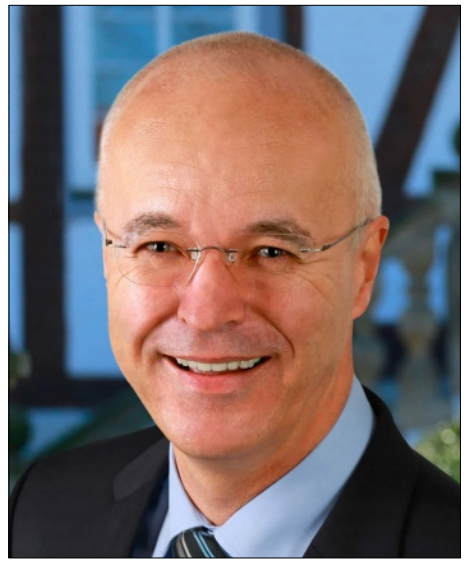
Open Source and Open Standards for Urban Competitiveness

도시 경쟁력을 위한
오픈소스와 오픈 스탠더드

Ulrich Ahle



Following his extensive experience in the industrial sector (including Vice President at Siemens and Atosin Germany), helping clients to digitize their business, Ulrich joined the FIWARE Foundation ias CEO in January 2017. In addition he is on the Board of the International Data Spaces Association and is one of the chairmen of the Smart City / Smart Region Domain within the German GAIA-X Hub.Since January 2017 Ulrich Ahle is Chief Executive Officer of the FIWARE Foundation headquartered in Berlin, Germany.

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ABSTRACT

Smart City realizations are driven by urgent and complex needs. Making a city "smart" means performing a more efficient and inclusive management of services and turning the city into an ICT enabler for innovation, economic growth and well-being. "Smartness" is also about using the right technology to exploit data purposefully, enabling better decisions and automating processes, to ultimately improve the daily life of citizens, ease business operations, and grow life and business opportunities. By adopting common standard interfaces and information models, and evolving their open data policies, cities can follow the steps of a digital transformation journey to achieve these objectives, minimizing efforts and costs, while maximizing impact. Teaming up with other cities and becoming part of powerful ecosystems in which they can connect, collaborate, co-create and co-invest. Ultimately, joining forces in such a way, can unlock additional values coming from the creation of a sustainable single digital market of interoperable and portable solutions that can be adapted and replicated according to the needs of each city. Cities adopting this open and forward-looking mindset have already proven to be quicker, less trial-anderror-driven and more efficient in their investment plans, as well as in the creation of higher citizens' satisfaction. Cities are increasingly adopting FIWARE to combine the power of data technology with inter-cities' collaborations. FIWARE, as a world-wide leading Open Source technology in the digitization market, has become the de-facto standard for Smart Cities, and as such, helps cities' decision makers and system integrators alike to incorporate standards for stronger interoperability, faster time-to-market, security of investment and replicability (portability). Avoiding island (or silo) solutions of just one single city or territory, prevents cities from losing out in innovation, best-practises and cost awareness. Together with its ecosystems of members, partners, iHubs, evangelists and academia, FIWARE also acts as an enabling force for inter-city and inter-country collaboration and co-creation.

KEYWORDS

Smart city, Open source, FIWARE, Open standards, Data spaces

초록

스마트시티 개념의 실현은 급박하고 복합적인 요구에 의해 추진되고 있다. 도시를 스마트하게 만든다는 말은 서비스 운영을 더 효율적이고 포괄적으로 실행함을 뜻하며, 도시를 혁신과 경제 성장, 웰빙을 가능하게 하는 정보통신기술ICT 조력자로 변신시킴을 의미한다. '스마트함'과 밀접한 활동은 또한 데이터를 목적에 따라 이용하기에 적합한 기술의 활용, 더 나은 의사결정의 지원, 과정 자동화이다. 이들 활동의 궁극적인 목적은 시민들의 일상적인 삶을 개선하고 사업 운영을 쉽게 해주며 삶과 사업의 기회를 성장시키는 것이다. 이들 목적을 달성하기 위해 도시들은 공통적인 스탠더드 인터페이스와 정보 모델을 채택하고 자기네 오픈 데이터 정책을 전개할 수 있고, 그럼으로써 노력과 비용을 최소화하고 효과는 최대화할 수 있다. 왜냐하면 개방형 솔루션은 상호운영과 이동이 가능하여 각 도시의 수요에 따라 채택되고 복제될 수 있기 때문이다. 이처럼 다른 도시들과 팀을 이루면 서로 연결하고 협력하고 함께 창조하고, 함께 투자하는 강력한 생태계의 일원이 될 수 있다. 이런 방식의 제휴는 궁극적으로 지속가능한 단일 디지털 시장의 창출에서 발생하는 추가 가치를 풀어놓을 수 있다. 개방적이고 전향적인 사고방식을 채택하는 도시들은 이미 투자계획에서 더 신속하며 시행착오가 적고 효율은 뛰어남을 보여주었다. 시민 만족도가 더 높음은 물론이다. 도시들은 점점 더 파이웨어의 채택을 늘리고 있는데, 이는 데이터 기술의 힘을 도시 간 협력과 결합하기 위해서이다. 파이웨어는 디지털화 시장을 선도하며 세계 전역에 걸쳐 활용되는 오픈소스 기술로서 사실상 스마트시티의 표준이 되었다. 파이웨어는 도시의 의사결정권자와 시스템 통합 책임자들로 하여금 더 강한 상호운영성과 더 빠른 시장 접근, 투자의 보안과 복제 가능성(이동 가능성)을 위해 표준을 제정하도록 한다. 한 도시나 지역만 활용하는 독립형(사일로) 솔루션을 피하면 혁신과 베스트 프랙티스, 비용 문제 인식에서 뒤처지지 않을 수 있다. 파이웨어는 구성원과 파트너, i허브iHub, 전도사들, 학계로 이루어진 생태계와 함께 도시 간, 국가 간의 협력과 공동 창조를 위해 조력자로 활동하고 있다.

키워드

스마트시티, 오픈소스, 파이웨어, 오픈 스탠더드, 데이터 공간

Introduction

There is no single definition of a Smart City, as every city incarnates a complex ecosystem by itself. In fact, while the challenges Cities face today could seem alike for all of them, each City will have to factor and respond to different social and economic priorities, environmental or historical constraints and the impact of these factors will drive possibly different responses from the political parties governing them.

Political pressure to make change happen has been increasing the stress on the city's operational organizations, with a strong demand to start addressing public services by implementing new technologies.

Global challenges are put on cities to create effective change. Challenges like the impact of climate change, the worsening of air quality, noise related stress from urban traffic or the actual COVID-19 pandemic and its limitations are some of the most discussed "reasons for change". From a social perspective, the need of assuring higher availability of affordable housing, quality education, social inclusion, public safety, economic stability and growth, shows how demanding it is, for local administrators and the political parties supporting them, to address policy-making in an environment that is showing increased complexity.

And while most reports on smart cities predict that the number of people living in cities will exponentially increase in 2030, the reality is that in most parts of the world the number of citizens moving from rural areas to live in urban areas today has already been growing at double digit rates since several years.

The real challenge is that all these people use the cities infrastructure with higher demand of

availability. Infrastructure that is already in use for decades, was not designed for and is not fit for a higher demand. And, as a simple example, investing in more buildings to stir up the economy, means that more people will need to travel to these working locations, will consume more energy, request more services, in summary adding more demand on the city's infrastructure, services and utility systems.

At the same time as all these social factors drive the need to rethink urban spaces and the way they are operated, the majority of "smart cities" definitions published so far seem to have one theme in common, highlighting "Data" as an enabler of change. Being able to leverage on vast amounts of data and process them into viable and relevant information, provides local politician with what is necessary to address policy making and promote the adoption of the relevant implementing measures.

The amount, quality and relevance of information have become the strongest assets of local administrations in promoting and pushing change supported by the digital transformation of public services.

But here is where things can easily go wrong. Technology itself is not the answer and, to prove that, recent history shows that early adopters focusing exclusively on technology, did not necessarily achieve the expected level and scope of changes they were targeting. Technology by itself might help create more efficiency, but a Smart City is not just more efficient, it needs to drive effective, relevant changes with tangible benefits for all its stakeholders and be able to address the challenges those key urban actors are called to face.

As a reaction to this state of things, the vast majority of cities (being them big or small) have decided to start "small" and thoroughly test and assess the real impact of new digital services and technologies.

As an additional, relevant trend, cities across the globe have been sharing the results of those assessments and their success stories, in order to help each other identify the most promising technologies and help technology providers improving them, assuring that services in need to be scaled to city-wide use (when proven effective) are really designed and deployed to do so.

Apart from understanding, scaling and tailoring technologies to their needs, cities need to embark on the complex processes necessary to accompany the changes that the digital transformation of public services pose to them. The impact of new technologies in the ways their workforce is called to interact with citizens and cities' assets is often disruptive and requires re-training and requalification, which are indispensable to embrace these new technologies and digital services, maximizing their benefits.

Smart Cities make effective change happen by putting the citizens at the center of their attention. If citizens are better informed on the impact of their decisions, change will definitely happen.

As a fact our new digital life will more and more gravitate around Context information describing what is happening, when, where, and why. Managing this information in a Digital Twin will provide us with capabilities to improve the quality of life of people living in cities or regions. At the same time, it will be possible to reduce the cost of operating a city. But today this data and Context Information are very often organized in silos without the chance to use them for other smart solutions. Open standards for APIs and data models have the capability to break down these silos. In combination with Open Source such approaches have the potential to also reduce the 'vendor-lock-in effect' and to provide the lowest cost of ownership to the end user. All of this needs to be operated based on a trusted environment.

Smart Cities: a transformation journey

Evolving business models are progressively reshaping the scope and structure of City services, with massive introduction of IoT paradigms and tight integration with the physical environment.

Market needs are already driving towards the creation of multi-domain and complex business chains, which undoubtedly bring more agility in service deployment and operation, but introduce additional security and privacy concerns that have not been addressed in a satisfactory way yet and new challenges inside the Cities.

To understand both Digital Transformation and the fact that cities are ecosystems which include both IoT and humans, in a largely human-built environmental context and that ecosystems have emergent technical properties that cannot easily be seen by simply looking at the different functional parts of a city: The whole is more than the sum of the parts.

Figure 1. The digital transformation journey (Source: FIWARE)

In the continuous collaboration between Cities, Open Source and Standard Data Models play today a major role in promoting the drafting of new Service Models, which are, more and more, supported and stimulated thanks to the use of core service platforms.

Several requirements forces such as the need for flexibility, agility and cost-effectiveness are now driving towards the creation of multi-domain and complex business chains for Cities and Human systems.

Cities are also increasingly developing their own smart city approaches and are finding ways to apply them to their respective situations, some of them in a practical way, others more conceptually. Thanks to Common Info and Data Models each city has its own special focuses. A basic system reflecting today's common practice was defined for each region or City.

When devices and software from different players are composed together in a business relationship, the trust and reliability of the overall end-to-end service is strictly dependent on safe and dependable operation in each administrative domain.

FIWARE and Digital Twins

FIWARE was created with the ultimate goal of creating an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards easing the development of smart solutions and supporting organizations in their transition into smart organizations. From a technical perspective, FIWARE brings a curated framework of Open Source software components which can be assembled together and combined with other third-party platform components to build platforms easing the development of smart solutions and smart organizations

in multiple application domains: cities, energy, mobility, utilities, etc. Since creation of the FIWARE Foundation in late 2016, a vibrant FIWARE Community has been formed with a true worldwide dimension, comprising more than 550 members, including large corporations, SMEs, technology centres and universities, and hundreds of in dividual members. Parallel to this growth the number of organizations adopting FIWARE has not stopped increasing. Any software architecture “powered by FIWARE” gravitates around management of a Digital Twin data representation of the real world. This Digital Twin data representation is built based on information gathered from many different sources, including sensors, cameras, information systems, social networks, end users through mobile devices, etc. It is constantly maintained and accessible in near real-time (“right-time” is the term also often used, reflecting that the interval between the instants of time at which some data is gathered and made accessible is enough short to allow a proper reaction). Applications constantly process and analyze this data (not only current values but also history generated over time) in order to automate certain tasks or bring support to smart decisions by end users. The collection of all Digital Twins modelling the real world that is managed is also referred to as Context and the data associated with attributes of Digital Twins is also referred to as context information.

Two critical elements need to be standardized in order to support an effective data integration: the API to get access to Digital Twin data and the data models describing the attributes and semantics associated with the different types of Digital Twins being considered. The FIWARE Community has driven and continues to drive standardization at both fronts:

- The NGSI API provides a simple yet powerful RESTful API for getting access to context / Digital Twin data. NGSI API specifications have evolved over time driven by feedback from developers and implementation experiences. A first mature version of the API was the NGSIv2 API, which was defined by members of the FIWARE Community and is currently used in many systems in production within multiple sectors. Evolution of the API has taken place within

the ETSI ISG CIM (Context Information Management Industry Specification Group), where members of the FIWARE Community and the FIWARE Foundation have led the definition of an evolved version of the API, known as the NGSI-LD API, whose specifications were first published by ETSI in 2019 and continue to evolve. The NGSI-LD API is used as the data integration API and is implemented by the core component of any "powered by FIWARE" architecture: the so-called Context Broker component. Different alternative Open Source implementations of a Context Broker are available within the FIWARE Community, namely the Orion-LD, Scorpio and Stellio products.

- The Smart Data Models initiative (website, github), launched by the FIWARE Foundation, provides a library of Data Models described in JSON/JSON-LD format which are compatible respectively with the NGSIv2/NGSI-LD APIs or would be useful for defining other RESTful interfaces for accessing Digital Twin data. Data models published under the initiative are compatible with schema.org and comply with other existing de-facto sectoral standards when they exist. They solve one major issue developers are facing, that is the fact that a given data model specification may be mapped into JSON/JSON-LD in many different ways, all of them valid. Thanks to the Smart Data Models initiative, developers can rely on concrete mappings into JSON/JSON-LD, compatible with the NGSIv2/NGSI-LD APIs, that are made available within this library, avoiding interoperability problems derived from alternative mappings. Since its creation, more than 500 data models have been published and the number of organizations contributing data model descriptions is constantly growing. Relevant organizations like TM Forum, OASC or IUDX are joining forces with the FIWARE Foundation bringing support to an open governance model for the initiative, following best Open Source practices.

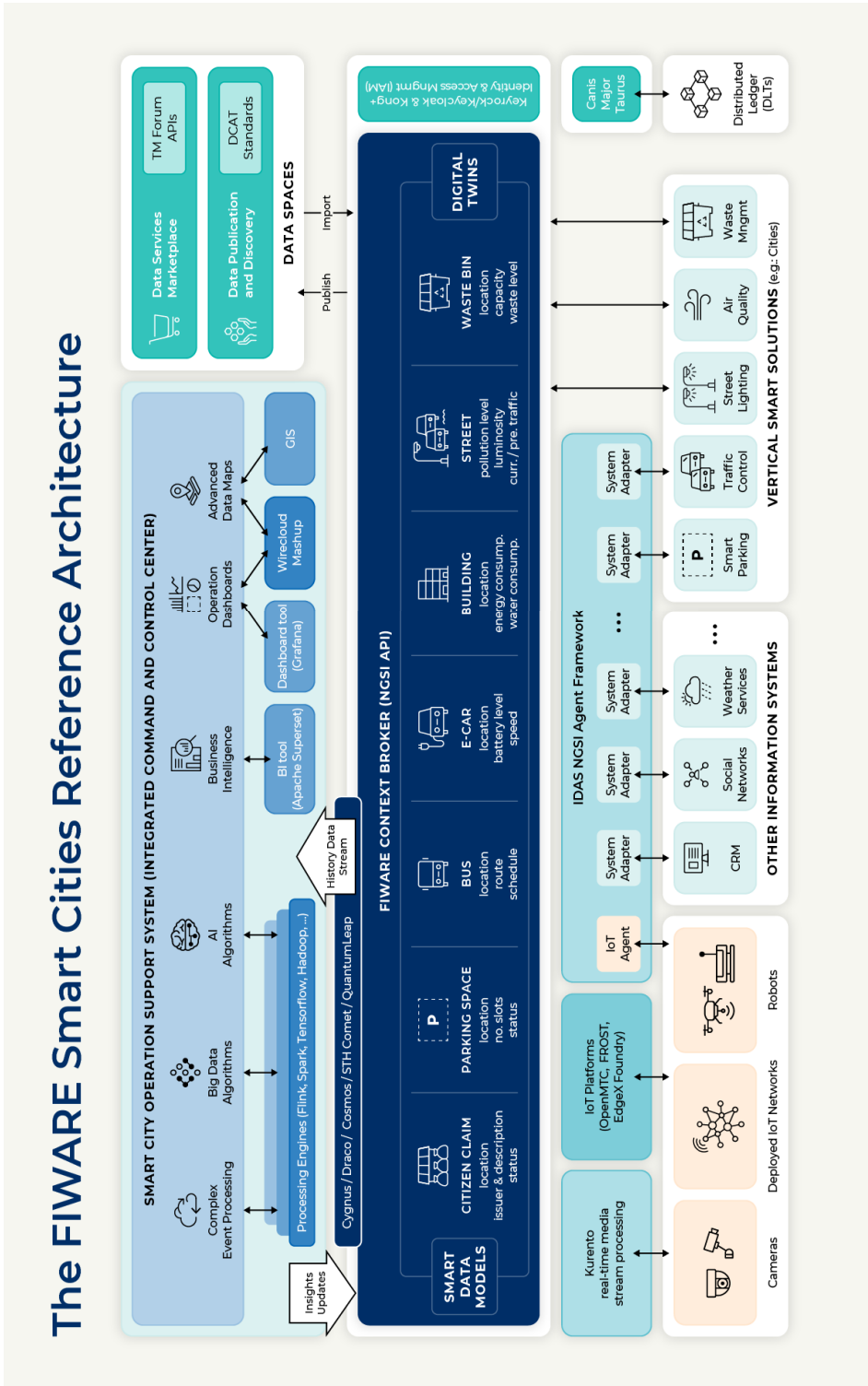

Figure 2. Smart City reference architecture (Source: FIWARE)

Smart Cities powered by FIWARE

FIWARE can help cities as well as rural areas to digitally transform themselves and become smart organizations, bringing support to the integration of the different systems within the organization following a system of systems approach. Figure 2 depicts the reference architecture of a smart city powered by FIWARE.

The Context Broker component is at the core of the architecture, holding a digital twin representation of the real world objects and concepts and describing what is going on in the city: streets, waste bins and containers, waste trucks, buses, electric vehicle chargers, buildings, events, citizen claims, etc. The different vertical smart solutions deployed in the city (e.g., Air Quality Monitoring, Smart Traffic Management, Smart Parking, Smart Waste Management) are connected to the Context Broker contributing the information they manage, which is relevant for creating a holistic Context / Digital Twin representation of the whole city, thereby breaking the information silos. Some of these vertical smart solutions may be powered by FIWARE (e.g., Traffic Control and Waste Management systems in the figure) in which case their interface with the global city-level Context Broker does not require any adaptation. Others may not be powered by FIWARE but this doesn't represent a major problem because creation of NGSI system adapters which translate from whatever API those systems export to NGSI-LD has proven not to be difficult. Last but not least, the city may deploy sensor/camera infrastructures through which valuable data is extracted. Exploiting the complete Context / Digital Twin representation of the city, the Smart City Governance System (or City Operation Center) can be developed. Real-time Big Data processing tools can be used relying on data coming from multiple sources, extracting more valuable insights for the support of decisions. Similarly, monitoring tools can leverage this holistic Context / Digital Twin representation of the city. Completing the picture, FIWARE brings components which provide the means for tracing digital twin data transactions. This provides the basis for a number of important functions, from identification of the provenance

of data to audit-proof logging of certain transactions. For those organizations with strong requirements on transparency and certification, FIWARE brings components (i.e., Canis Major) that ease recording of transaction logs into different Distributed Ledgers / Blockchains.

An example from India

This is a use case which contains many lessons learned that could be applied around the world. When Prime Minister Modi was elected for the first time back in 2014, he soon started the '100 Smart Cities program' in India. 13 billion US$ were allocated to this program. Several of the large global consulting companies guided the cities in creating their Smart City strategy, brought first tenders to the market and observed the implementation of the first platforms and projects. Back in 2019, the responsible Ministry for Housing and Urban Affairs in India identified that each city had built its own silo, that there were only limited synergies between the cities and that the wheel had been re-invented several times using public funding. This led to a strategy change in the public funding program and to the creation of the India Urban Data ExchangeIUDX platform. The FIWARE Foundation, together with partners of its ecosystem like Trigyn from India, NEC from Japan and HOPU from Spain, supported the IUDX program together with the India Institute of Science in Bangalore from its inception in 2019. A standard reference architecture was developed which includes the standard interface generated within the FIWARE ecosystem called NGSI-LD and the FIWARE Standard Data Models. Subsequently, a standard smart city platform for India was developed using open-source software building blocks from FIWARE and other parties. The platform is provided as Open Source and was implemented in the meantime within the first 30 cities in India. There are two main benefit areas for Indian cities. First is the opportunity to benefit from the cost and flexibility advantages of cloud-based services. Second is the reduction of vendor lock in when creating solutions based on Open Source and open standards for interfaces and data models which

in total reduces the total cost of ownership and increases the replicability of solutions between cities not only on national level.

Data Spaces powered by FIWARE

To further increase the competitiveness of cities and regions it is important not to rely just on local data but also to utilize national and even global data. Data spaces are the enablers for this approach. A Data Space can be defined as a decentralized data ecosystem built around commonly agreed Building Blocks enabling an effective and trusted sharing of data among participants. From a technical perspective, a number of technology Building Blocks are required ensuring:

- Data interoperability. Data Spaces should provide a solid framework for an efficient exchange of data among participants, supporting full decoupling of data providers and consumers. This requires the adoption of a "common lingua" every participant uses, materialized in the adoption of common APIs for the data exchange, and the definition of common data models. Common mechanisms for traceability of data exchange transactions and data provenance, are also required.
- Data sovereignty and trust. Data Spaces should bring technical means for guaranteeing that participants in a Data Space can trust each other and exercise sovereignty over data they share. This requires the adoption of common standards for managing the identity of participants, the verification of their truthfulness and the enforcement of policies agreed upon data access and usage control.
- Data value creation. Data Spaces should provide support for the creation of multi-sided markets where participants can generate value out of sharing data (i.e., creating data value chains). This requires the adoption of common mechanisms enabling the definition of terms and conditions

(including pricing) linked to data offerings, the publication and discovery of such offerings and the management of all the necessary steps supporting the lifecycle of contracts that are established when a given participant acquires the rights to access and use data.

Besides the adoption of a common technology foundation, Data Spaces also require governance, that is the adoption of a number of business, operational and organizational agreements among participants. Business agreements, for example, specify what kind of terms and conditions can regulate the sharing of data between participants and the legal framework supporting contracts established through the Data Space. Operational agreements, on the other hand, regulate policies that have to be enforced during Data Space operation. They may also comprise the definition of tools that operators of cloud infrastructures or global services supporting Data Spaces must implement, enabling auditing of certain processes or the adoption of cyber-security practices. Last but not least, organizational agreements establish the governance bodies (very much like ICANN for the Internet). They deal with the identification of concrete specifications that products implementing technology Building Blocks in a Data Space should comply with, as well as the business and operational agreements to be adopted. The complete taxonomy of Building Blocks required for creating Data Spaces is illustrated in Figure 3.

Sharing of data within a given Data Space should not be limited to a single domain. This would severely limit the creation of new innovative services since individuals and organizations usually act in multiple domains at the same time and many opportunities will flourish when data generated within organizations operating in certain domain (management of traffic in cities, for example) is shared for its exploitation in processes relevant to other domains (continuing with the example, logistics). Therefore, technology Building Blocks for Data Spaces must be domain-agnostic. On the other hand, they should rely on open standards, allowing multiple infrastructure and global service providers to emerge and support Data Spaces, without getting locked by any particular provider.

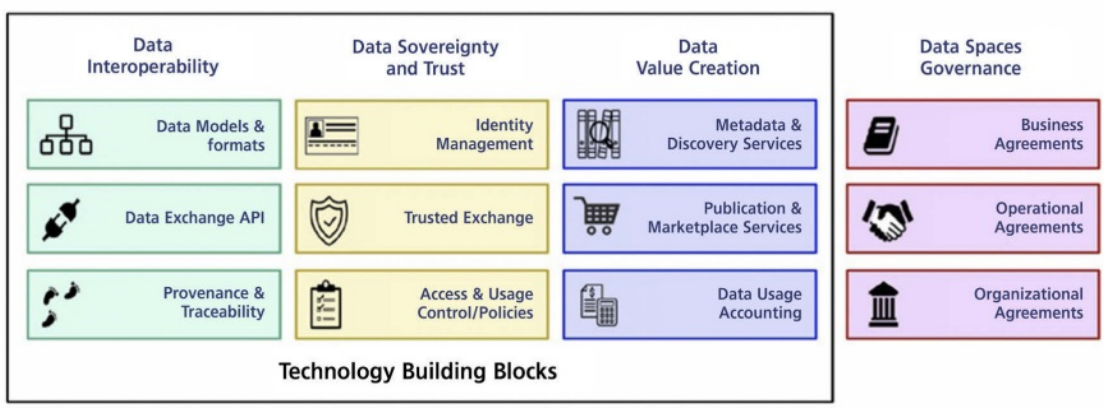

Figure 3. Building Blocks in a Data Spaces (Source: FIWARE)

Given this, while making things work in living labs and pilots is relatively easy, the main challenge towards definition of successful Data Spaces is the decision of what concrete standards and design principles are adopted, since they have to be accepted by all participants. The following sections elaborate on the different components FIWARE brings materializing the different technical Building Blocks required for creation of Data Spaces.

Cities as Enablers of the Data Economy through Data Spaces

A new Data Economy is emerging, as technological advancements are transforming supply chains into complex mesh ecosystems. Not only as data producers, but also providing the means for third parties to publish their data in data marketplaces they run, cities are called to play an increasingly important role in this Data Economy. They are increasingly becoming the platforms for end users and businesses requiring near real-time contextualized data. Based on FIWARE's core capabilities cities become platforms for the publication of the required Context Data

being a combination of pieces of information originating from multiple (and new) sources. Due to the rise in data availability and new data driven insights, more and more data can be exchanged within and among cities and companies. This will spawn a new Data Economy built upon using data to generate value, ensuring that only owners of the right pieces of information will have the power to drive decisions. With FIWARE, users in diverse domains can effectively share and exploit data relevant in other domains thanks to domain-agnostic common APIs, security schemas for data exchange and Smart Data Models. Furthermore, they can share data under concrete terms and conditions, including pricing or data/usage control policies. This paves the way for the creation of innovative services and business models. FIWARE brings all the necessary technology Building Blocks for the creation of data spaces. FIWARE brings new economic opportunities to the city, helping solution providers and system integrators to create platform models that connect consumers and producers, enabling a federated publication of context data, allowing app builders to find and use data from city and third party sources while preserving Data Sovereignty. User rights acquisition processes and revenue-sharing APIs enable these “consumers and producers” to buy and sell context / Digital Twin data, building the basis for the new local Data Economy. Data value creation is enabling participants to collaborate in the development of multi-sided markets where they can generate value out of data sharing (i.e. creating data value chains). A data space can be defined as a decentralized data ecosystem built around commonly agreed building blocks enabling an effective and trusted sharing of data among participants. Creation of data spaces will drive the development of the Data Economy and increase urban copetitiveness. Cities connecting to Data Spaces powered by FIWARE can benefit from the data services offered by third-parties and, at the same time, provide data services that will fuel the development of innovative services.

About the FIWARE Foundation

The FIWARE Foundation is managing a global Open Source community which is providing Open Source software building blocks as well as standards for our smart digital future. More than 550 members from all over the world are members of the FIWARE Foundation which is headquartered in Berlin, Germany. In the meantime, FIWARE is adopted in different verticals like energy or agriculture and is the globally leading Open Source technology for Smart Cities implemented in more than 300 cities and 30 countries.

FIWARE was born in a Public Private Partnership of the European Commission with a large group of companies from the market and organizations from research. Picture 4 shows the history and future vision of FIWARE.

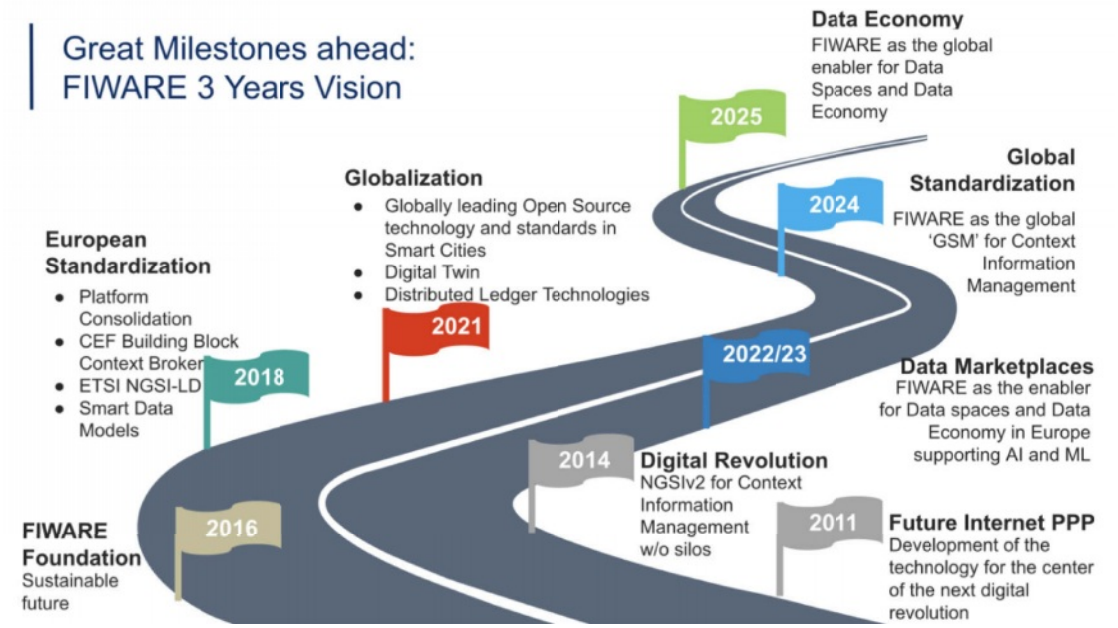

Figure 4. FIWARE 3 years vison (Source: FIWARE)

Conclusion

Open Source and open standards are the basis for architecting smart solutions for urban competitiveness. FIWARE brings core aspects to enable this approach, namely the interface to be used for management of data describing what's happening around us, and the definition of common data models. This way, solutions based on Open Source and open standards will be fully interoperable and portable across platforms. The open source nature of FIWARE guarantees that users of such solutions will not be locked-in to any particular vendor. In addition, the FIWARE ecosystem has proven the ability to create standards which are accepted and adapted in the meantime on a global scale. Actually, solution providers and end users in the Americas, in Africa, in India or in Asia are building their smart solutions based on FIWARE standards and technologies.

Developing Government as a Platform in Korea

한국의 디지털플랫폼정부 추진 방향

Koh, Jean

Koh, Jean who served as the head of Digital Platform Government Task Force of the Presidential Transition Committee, is now leading the Presidential Committee of Digital Platform Government launched in September 2022 as a chairman with a goal of realizing Digital Platform Government where people, businesses and the government work together to solve social challenges and create new values. Mr. Koh graduated from the Department of Electronic Engineering at Seoul National University and obtained a PhD in Computer Science from Syracuse University, the USA. He commercialized world's first mobile VOD services using fully domestic technology at Varo Vision he founded in 1994. Since then, he served as the chairman of the ICT and Convergence Expert Committee of the National Science and Technology Council, and a member of the Presidential Committee on the 4th Industrial Revolution. In the capacity of the president of the Korea Mobile Internet Business Association and the Korea Metaverse Industry Association (K-META), Mr. Koh is committed to reinforcing the global competitiveness of the nation's smart content and mobile app industry.

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ABSTRACT

Digital Transformation and the COVID-19 pandemic made the Korean government realize that it, too must change in order to survive. Current issues ranging from silos among ministries, limited data openness, experience-based, rule of thumb policy decisions to public services that fall short of people's expectations call for a completely new approach different from the one we have seen so far. The solution presented by Yoon Suk Yeol government is Digital Platform Government, a government where people, business, and the government work together to solve social problems and create new values on a digital platform where all data is connected. It represents a completely new model where the government collaborates with the private sector and becomes an innovation partner, instead of unilaterally providing services to citizens. The Korean government's plan is to open data and services hitherto blocked by silos and work together with the private sector on the digital platform, which will translate into better services for the public, improvement in the way the government works and new opportunities for business to create values. The close collaboration between the public and private on the Digital Platform Government is expected to take Korea's digital government - which is already world-class, to the next level, accomplishing historical achievements as a global leader.

KEYWORDS

Digital platform, Digital government, e-Government, Data openness, Innovate the way the government works, National innovation strategy

초록

디지털 대전환, 코로나19 사태 등을 겪으며 한국 정부는 정부도 변해야만 살아남을 수 있다는 것을 체감하였다. 부처 간 칸막이, 데이터 개방 부족, 경험에 의존한 주먹구구식 정책 결정, 국민의 눈높이에 미치지 못하는 서비스 등 현재의 문제를 타파하기 위해서는 지금까지와는 완전히 다른 새로운 접근 방식이 필요하다. 윤석열 정부가 제시하는 해법은 디지털플랫폼정부로, 모든 데이터가 연결되는 디지털 플랫폼 위에서 국민, 기업, 정부가 함께 사회문제를 해결하고 새로운 가치를 창출하는 정부를 말한다. 지금까지와는 완전히 다르게, 정부가 일방적으로 서비스를 제공하는 공급자에서 벗어나 민간과 협업하고 혁신의 동반자가 되는 새로운 모델이다. 한국 정부는 그동안 칸막이에 막혀 있던 데이터와 서비스를 개방하고, 디지털 플랫폼을 통해 민간과 협업함으로써 국민에겐 더 좋은 서비스를 제공하고, 정부는 더 똑똑하게 일하며, 기업은 새로운 사업 기회와 가치를 창출해 나갈 수 있게 지원한다는 계획이다. 디지털플랫폼정부를 통해 민관이 서로 머리를 맞대고 협업한다면 이미 세계 최고 수준의 한국 디지털정부가 한 단계 더 도약하여 세계를 선도하는 역사적 성과를 만들어 갈 것이라고 기대한다.

키워드

디지털 플랫폼, 디지털정부, 전자정부, 데이터 개방, 정부 일하는 방식 혁신, 국가 혁신 전략

Why
Digital Platform Government now?

Today digital technologies change so fast that we don't even feel the pace of their change. On top of that, unpredictable crises, and disasters such as the COVID-19, the US-China conflict and Russian invasion of Ukraine occur concurrently. In a time of great transformation like this, the approach where the government singlehandedly leads and solves challenges is no longer valid. The pandemic clearly showed us first-hand that the government alone was no longer able to address problems. The government's existing systems proved useless when it came to quickly handling emergency situations such as the mask shortage crisis, vaccine reservation system crashes, and disbursement of emergency relief funds. All this brought the government to the realization that sticking to the status quo would leave them with no answer.

People's expectations have also become very high. They are already accustomed to innovative services from various private platforms. Popular portals and online shopping malls allow users to search for what they want at one go and make recommendations for them based on their preferences. With just a single click, the product you ordered will be delivered to your front door. All of this is possible with a smartphone and authentication and payment are easy, too. The government's services have not yet met these high expectations of people. Even eligible citizens miss out on benefits because they don't know about them, and it takes several visits to different places with multiple payments for people to just use a single public service. For instance, if you want to register property ownership transfer, you have to visit three(3) agencies offline and nine(9) Internet sites with four(4) online payments. No wonder why the public is frustrated with government services. The government also needs a big change in sync with the Great Digital Transformation.

The paths the Korean government has taken so far

The Korean government has also made great efforts until now. It built world's best e-Government by actively introducing technologies in response to the needs of different times from the computer era, internet era to mobile era. As a result, Korea came in second in the UN e-Government Development Index published in 2020 while it has ranked first in data openness assessment by the OECD for the third time in a row.

However, the informatization implemented with the fragmented division of roles within the existing institutional framework has rather deteriorated silos between ministries and hindered data sharing and collaboration within the government. It gets in the way of innovating the way the government works and delivering integrated services that citizens want. Under these circumstances, any attempts to solve issues within the current framework will provide us with no solution. It is time to break away from the existing framework and find a new path forward.

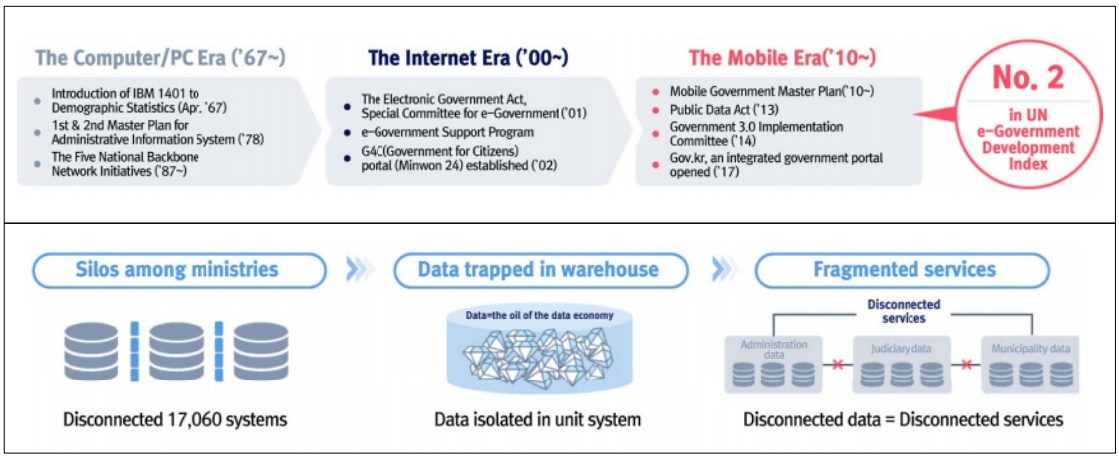

Figure 1.
Top- Korea's e-Government Journey
Bottom- The Limitations of the Current e-Government System

A new paradigm of Digital Platform Government

To address these challenges and take the nation to the next level, Yoon Suk Yeol government presents Digital Platform Government. It can be defined as a government where people, business, and the government work together to solve social problems and create new values on a digital platform where all data is connected. The Digital Platform Government represents a new paradigm with government's commitment to offering a platform on which people, business and the government create new values going beyond simply delivering information and services.

The Digital Platform Government will lead a new future for Korea under the principle of connection, openness, and collaboration. Ministry-specific systems and data hitherto trapped in silos will be connected and opened up to complete one platform for collaboration.

Once the digital platform is completed, data sharing and integration will create new values while more up-to-date and timely services brought by cloud will lead to increase in value. The cost required for building and operating the system will be based on a pay-for-use subscription model, bringing down the overall cost of the information system. As shown in Figure 2, the effect will

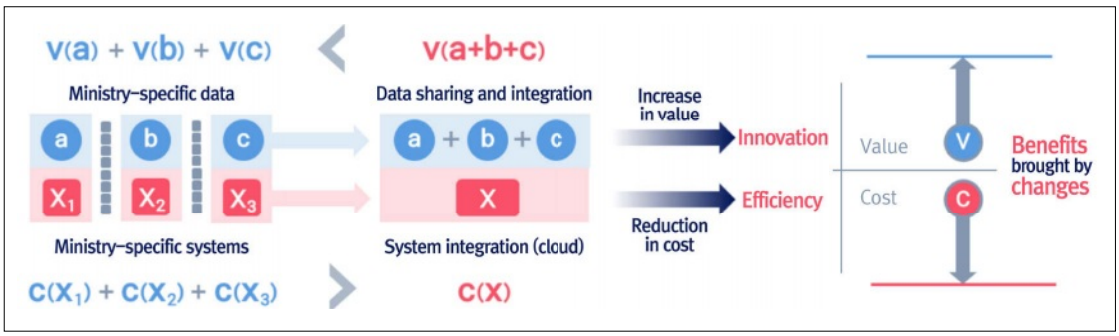

Figure 2. Innovation Formula for Digital Platform Government

be doubled by the increase in value and reduction in cost, thus delivering much greater benefits to people.

Priorities of Digital Platform Government

The Korean government will focus on implementing the following priorities to deploy a world's leading Digital Platform Government where all data is connected.

First, the government plans to build an innovative infrastructure of the Digital Platform Government for private-public collaboration and delivery of integrated services. First of all, integrating existing systems will be implemented from an integration point of view and then designing and building a new innovative infrastructure in line with the philosophy of the Digital Platform Government will follow. In the process, the government will actively adopt state-of-the-art technologies from the private sector including cloud and hyperscale AI to create an environment capable of delivering services that satisfy the expectations of citizens.

Second, the government plans to fully open up the high-quality data people want and promote their use. To this end, it will eliminates regulations and systems that impede data openness and use and implement policies for data standardization, Mydata and promotion of pseudonymous data for more value-added data use.

Third, the government intends to innovate the way it works by fully embracing AI and data technologies. It will facilitate collaboration between private and public sectors, between ministries and between the central and local governments, moving away from individual ministries working

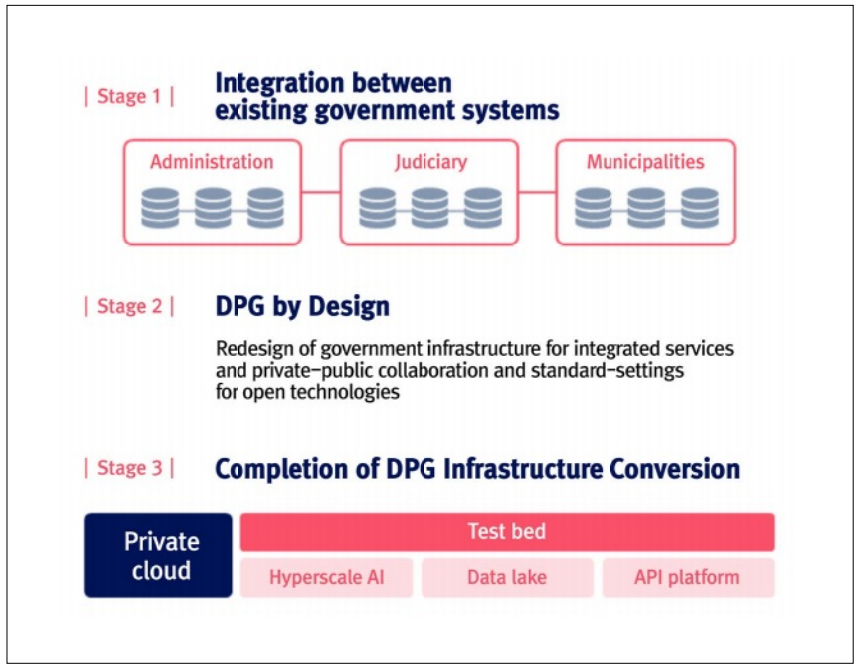

Figure 3. Implementation Strategy by Stages of Innovative Infrastructure of Digital Platform Government

alone while creating a culture of working based on data and science instead of practices and experiences. In addition, it plans to significantly expand digital capability trainings to help government employees adjust to the new way of working based on AI and data.

Lastly, the government plans to create a trusted information security environment to ensure all citizens securely access and use the Digital Platform Government. A system will be put in place that can verify access and use of personal information in a transparent manner to address people's concerns about data breach and abuse. Adoption of cutting-edge security technologies including blockchain, Artificial Intelligence and quantum cryptography communication will help citizens securely use the Digital Platform Government with trust.

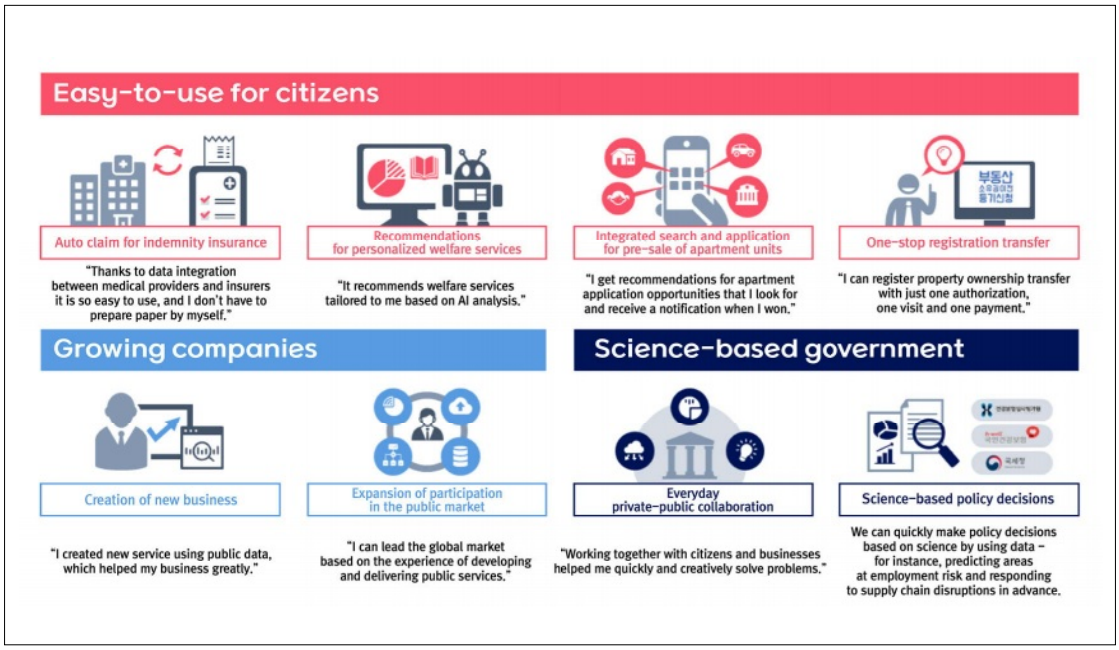

Figure 4. New Korea Transformed by Digital Platform Government

Digital Platform Government, a steppingstone for hegemony in the digital economy

Simply breaking down the walls between ministries and creating a single platform won't mean the completion of the Digital Platform Government. This single platform that connects countless objects will serve as an online test bed where new services are planned and verified. It will be a magnet for start-ups with creative ideas and strong capabilities which will grow their way into next gen unicorns by making use of open data. The innovative companies born out of the platform will drive the growth of the digital economy, helping Korea leapfrog into a country with hegemony in the digital economy.

When the Digital Platform Government is completed, citizens will no longer miss out on benefits

because they don't know about them. They won't have to visit multiple public agencies and submit same paper over and over, in order to get a public service. "Government services will come to citizens first" by predicting what they want in advance. In addition, companies will be able to create new business by leveraging on high-quality data opened up by the government and their experiences and growth in the public sector will help them expand into the global market. For the government, collaboration with the private sector will become a part of their day-to-day activities. It will be able to work scientifically and transparently based on data, gaining trust from the public and companies.

Deployment of the Digital Platform Government represents a paradigm shift in running the government so it cannot be achieved overnight and requires a significant time for it to be fully mature. However, the Yoon Suk Yeol government recognizes the seriousness of the issues such as silos among ministries, limited data openness, experience-based policy making and public services falling short of people's expectations. In addition, President Yoon puts a top priority on the Digital Platform Government initiative, with a plan to implement it with unprecedently strong drive. Successful collaboration between the government and the private sector on this initiative is expected to advance Korea's digital government - which is already one of the world's best - into even a higher level, making a historical feat as a global leader.

Korea's Smart City Empirical Study and Prospects for Expansion

한국의 스마트시티 실증 연구와 확산 전망

Lee, Kabjae

At present, he works for the Korea Agency for Infrastructure Technology Advancement (KAIA) as the head of the National Strategic Smart City Program and previously served as a member of the Ministry of Land, Infrastructure and Transport's New City Advisory Committee and the Working Committee on the National Intelligent Transportation. He received a PhD in electrical engineering from Hanyang University and has been recognized for his outstanding research works - for instance he won the IR52 Jang Young Shil Award for researching motors for hybrid and electrical vehicles at the Mabook-Ri Research Institute of Hyundai Heavy Industries. At the KAIA, he previously held such positions as the head of Industry Promotion Division and Transportation Business Division where he built his expertise on policies, planning and research management for national R&D projects and contributed to setting national R&D policies as a member of the Operation and Specific Evaluation of the Technology Level Evaluation of the Ministry of Science and ICT.

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ABSTRACT

Countries around the world including Korea have put great efforts into building and demonstrating smart cities. Nevertheless, such efforts have so far failed to lead to data standardization while smart city services designed to solve urban problems and make the lives of citizens better are independently provided through individual platforms. Data collected and managed by individual platforms lacks compatibility. In addition, Internet of ThingsIoT and network technologies for data collection also lack standardization and the collection costs are high.

In order to solve these problems and build a smart city standard model, the National Strategic Smart City Program was launched as a national R&D project. Daegu City and Siheung City were chosen for demonstration where data hubs were built and smart city services for mobility, the environment, etc. were developed and verified. This paper will introduce the results of the smart city demonstration and present the way forward for expanding data-based smart cities in Korea.

KEYWORDS

Data hub, Living lab, Citizen participation, Smart city standard model, Service demonstration, Mobility, Parking sharing, City safety, Emergency rescue, Facility, Energy, Prediction of air quality, The elderly living alone, People with disabilities

초록

대한민국을 비롯하여 세계 각국은 스마트시티 개발과 실증을 위해 많은 노력을 기울여 왔다. 그럼에도 불구하고 데이터 표준은 정립되지 않았고, 도시문제 해결과 시민 편의를 도모하기 위한 스마트시티 서비스는 독립적인 개별플랫폼으로 운영되고 있다. 데이터는 플랫폼별로 수집 및 관리되어 데이터의 상호호환성이 갖추어지지 않았다. 또한 데이터를 수집하는 사물인터넷IoT 및 네트워크 기술 등도 표준 제정이 미흡하였고 수집 비용도 많이 든다.

이러한 문제들을 해결하고 스마트시티 표준 모델을 구축하기 위해 국가 R&D사업으로 스마트시티 혁신성장동력 프로젝트를 추진하였다. 대구시와 시흥시를 실증도시로 선정하여 데이터허브 구축과 모빌리티, 환경 등 스마트시티 서비스 개발 및 실증을 진행하였다. 본 원고를 통해 스마트시티 실증 결과를 소개하고 대한민국의 데이터 기반 스마트시티 보급 방향을 소개하고자 한다.

키워드

데이터허브, 리빙랩, 시민참여, 스마트시티 표준 모델, 서비스 실증, 모빌리티, 주차공유, 도시안전, 긴급구난, 시설물, 에너지, 대기환경 예측, 독거노인, 장애인 이동성

Smart City R&D Trends in Korea

From ancient times to today, cities have been the center of the lives of people, politics, society and culture. Urban space preserves history and provides the foundation for a rich life where people experience civilization, culture and arts. People are flocking to cities for better living conditions and over half of the world's population now live in cities. In addition, the world's population continues to increase with urbanization accelerating. Concentration of population in cities and urbanization have given rise to a array of social challenges related to energy, environment, transportation, crime, and so on. These combined with climate change like global warming threaten the life of human beings.

In the early 2000s, Korea resorted to science and technology to solve urban problems. The case in point is Ubiquitous-City (U-City) program. Urban data collected from sensors and CCTV cameras was analyzed and utilized for city management while new cities were developed with the U-City concept. Song-do is one of U-City examples. Since then, the U-City has evolved into smart city as it combined with advanced technologies and ICT such as AI, Big Data, IoT, and 5G. A smart city is designed to improve the quality of life of citizens by solving urban problems, make cities sustainable with active response to climate change by reducing CO_2 emissions, and lay the basis for a business ecosystem through data collection, analysis, and provision.

Since 2018 Korea has been active in implementing smart city policies and programs. Sejong and Busan selected as pilot cities for a national smart city project by the Ministry of Land, Infrastructure and Transport are now being developed with a smart city concept while 60 municipalities across the nation were selected as recipients for smart city solutions that fit their urban characteristics. In addition, the government selected smart city for a national strategic program and to this end, it launched a R&D project jointly supported by the Ministry of Land, Infrastructure and Transport and the Ministry of Science and ICT in 2018.

Data-Based Smart City Model

The objectives of the National Strategic Smart City R&D Program are to build a data hub that can systematically collect, store, analyze and utilize a variety of city data, connect urban-problem solving to smart city services that address the needs of residents, and establish a smart city model that supports decision-making in city administration. Smart cities built at home and abroad mostly have platforms providing independent services with each platform having its own system to collect and operate data. That is why data is scattered across different information systems and incompatible with each other. The volume of data is exponentially growing as cities grow into mega cities and more complexities are added to society. Therefore, the data operating system with a silo structure has to be corrected to enable cross-domain analysis for efficient management of data and complex problem-solving. To this end, the National Strategic Smart City ProgramNSSCP introduced a concept of Data-Based Smart City Model descried below.

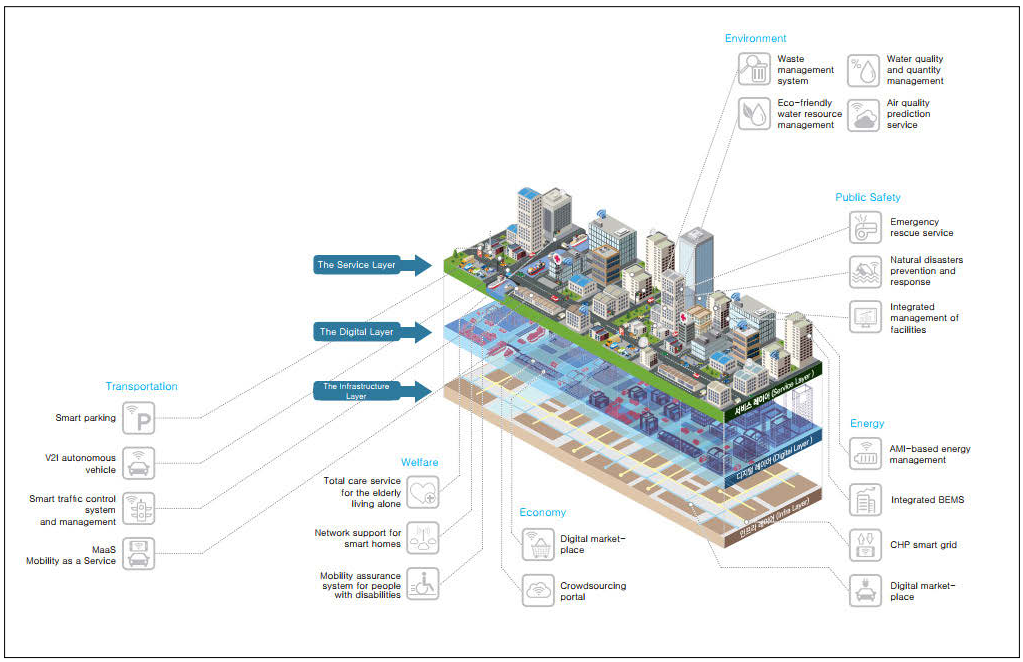

Figure 1. Data-Based Smart City Model Concept

Conceptually, the Data-Based Smart City is composed of three layers: an infrastructure layer, a digital layer, and a service layer. The infrastructure layer provides the basis for smart city infrastructure, such as IoT sensors that collect data from objects and communication networks. The digital layer represents a data hub domain responsible for distribution and reproduction of data such as collection, storage, analysis and utilization of urban data while the service layer exchanges data with the data hub, provides services to citizens through analysis and helps city administrators with decision-making.

The Data Hub for Integrated Analysis and Connected Cities

In the past smart city demonstration and pilot projects, area-specific urban services were individually developed and operated. For instance, transportation services provided only transportation services by collecting data from the transport infrastructure in the city. Even though the concepts of convergence technology and services existed before, systems in cities were divided by different areas of services and who is in charge of their operation and management. Therefore, there were few cases where data collection was integrated in one place for cross-domain analysis.

The Smart City Data Hub connects numerous information systems in cities from a system perspective and provides the foundation for storage, conversion and cross-domain analysis of data. Thus, it enables availability of combined services for instance, of transportation and energy where charging is triggered when electric rates are cheap or of transportation and environment that control traffic in connection with the levels of fine dust.

There are already many systems that utilize data in cities. A wide-range of data generated in

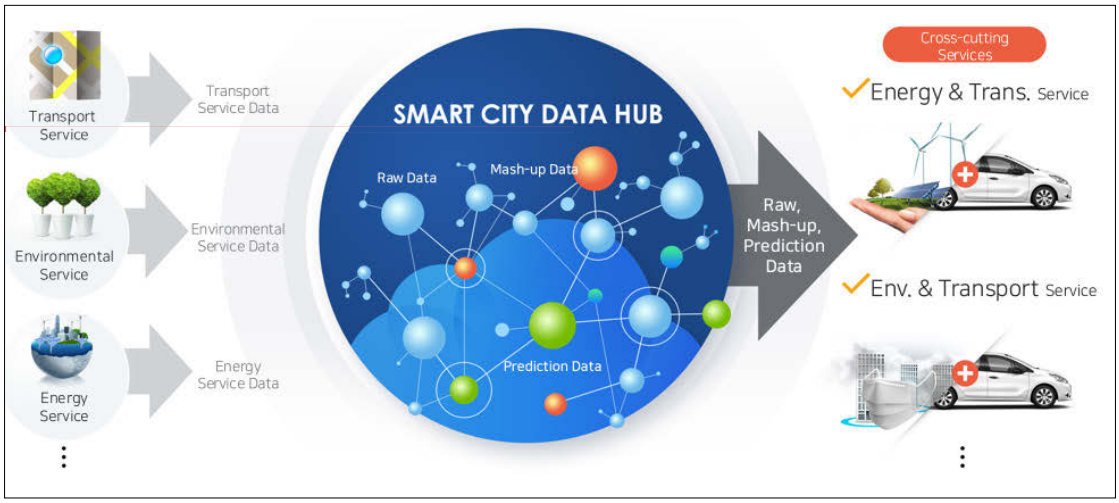

Figure 2. Combined Services based on the Smart City Data Hub

cities is being collected from IoT platforms, Big Data platforms, U-City integrated platforms, and many administration systems and is individually utilized. The beauty of the Smart City Data Hub is to collect data dotted across different systems and integrate and manage it for use in various services. It converts raw data to fit in a highly utilized common data model and saves it so that it can be used in services of different areas while supporting data search and utilization with a standard interface. It also adopted a hub & spoke concept to a city data platform.

The hub & spoke can be understood as a model connecting existing data systems in cities to the Data Hub for integrated management. For instance, city data from public data portals and oneM2M platforms corresponding to the spoke is collected to the Data Hub where it is used for integrated analysis. In addition, this hub & spoke model can be expanded to between the Data Hubs - i.e. the integrated Data Hub model between local and provincial governments or data integration and utilization among adjacent municipalities. For instance, river data and wide-area traffic data can be a good candidate for integrated utilization by different municipalities.

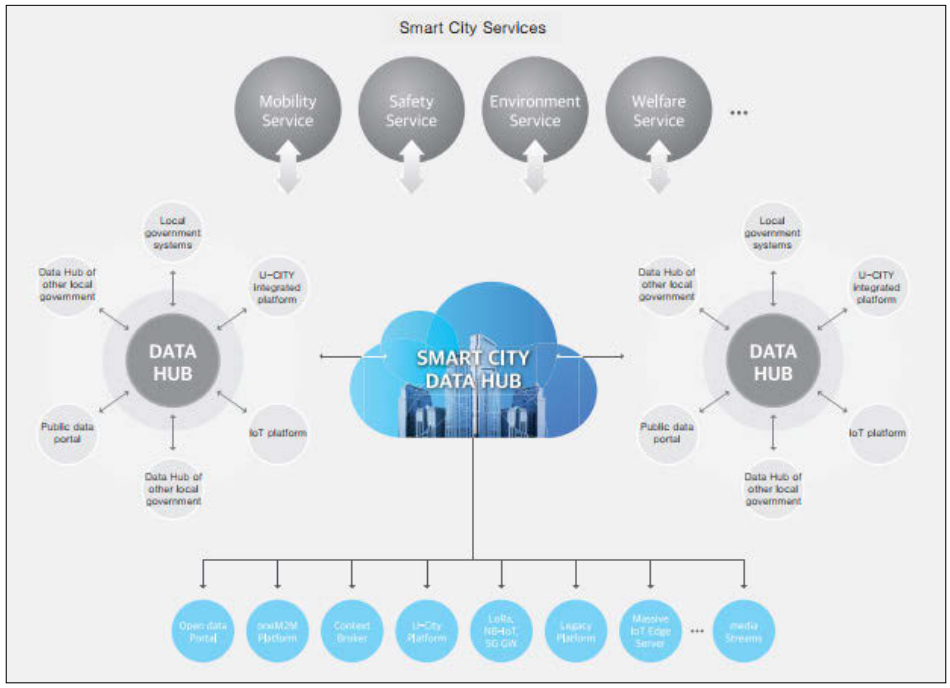

Figure 3. City Connection & System Integration Using the Data Hub

Standard for Integrated Analysis and Open Platform that Supports Linked Data

The Smart City Data Hub Platform designed to efficiently collect and process urban data was developed with open source codes which were then provided to private companies and municipalities, the users of the data. The Data Hub was verified by the Telecommunications Technology AssociationTTA for its completeness including interface suitability and data model suitability and its technology was used to build data hubs in Daegu and Siheung.

The Smart City Data Hub applied NGSI-LD standard interface developed by the European Telecommunications Standards InstituteETSI to develop features such as data storage and inquiry.

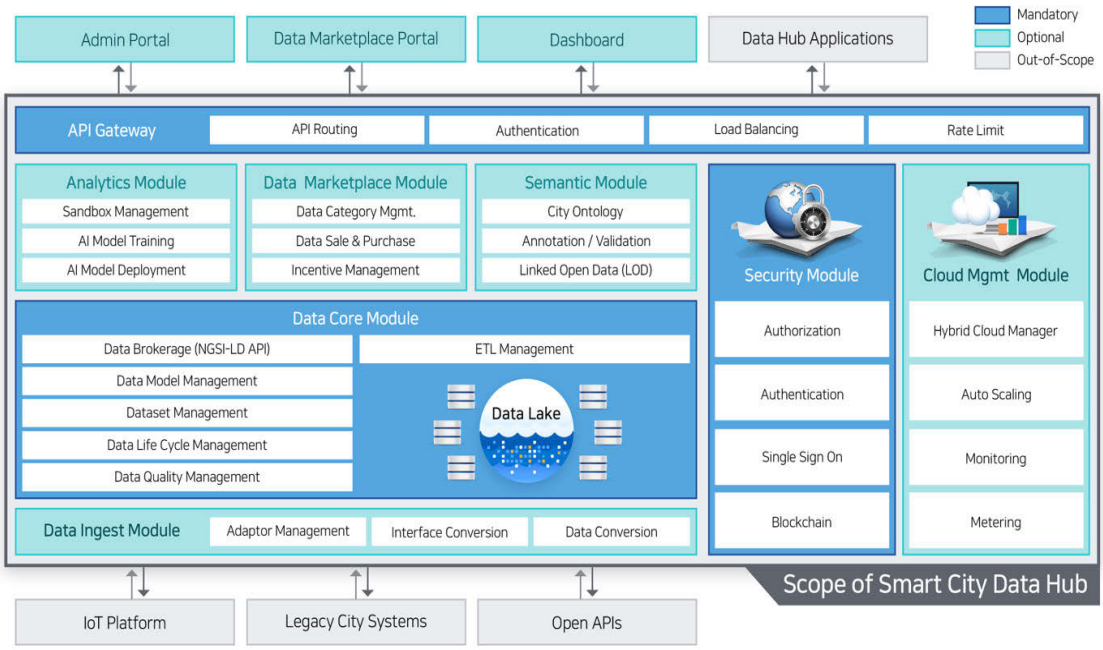

Figure 4. Open Data Hub Standard Architecture of Smart City

NGSI-LD is a standard for integrated management of data at a level higher than IoT and public data platforms that generate and collect data. The Data Hub implemented with the NGSI-LD standard is interoperable with other Korean and foreign solutions using the NGSI-LD standard. The urban services with NGSI-LD interface used in the Smart City Data Hub Platform can be linked to other data hubs. Further integration can be expected as many software programs using NGSI-LD are being developed not only in Korea but also in overseas through FIWARE.

NGSI-LD supports linked data as the name indicates. Urban data shown as entity in the NGSI-LD standard has URI(Uniform Resource Identifier) and can represent not only the various attribute values (e.g. the number of currently available parking spaces) of data (e.g. parking lot) but also the relationship with other data (e.g. parking space entity in the parking lot). The relationship between data can be added to represent linked data, which can be understood as convergence between different data. For instance, real-time parking data of public parking lots in Yatap-dong, Seongnam-si can be linked to

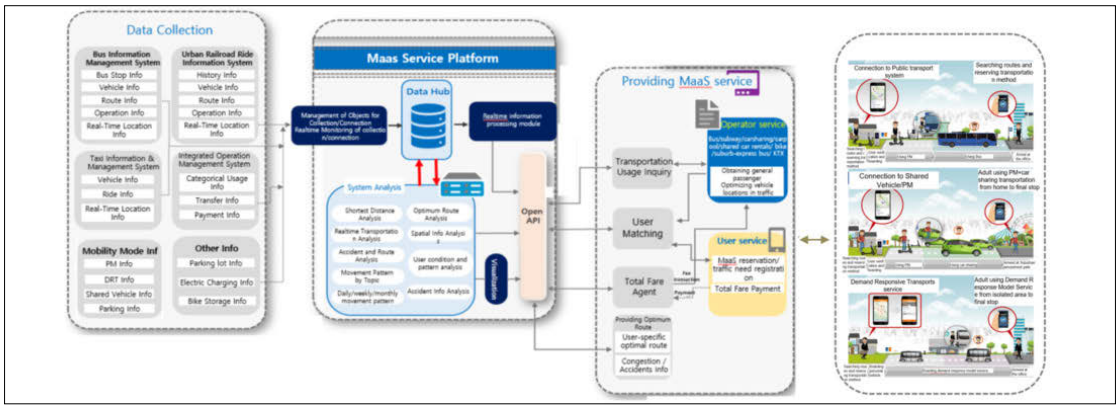

Figure 5. Conceptual Diagram of Smart Mobility Service

weather observation and forecast data of Seongnam-si. The real-time data on the available parking spaces combined with weather observation data can be used to train a machine learning model to offer services that predict the available parking spaces based on weather forecast.

Daegu Smart City Data Hub & Its Service Verification

Under the strategy of Smart City for Happy People, Daegu City built a data hub and verified smart city services including Smart Mobility, Parking Sharing, City Safety, Emergency Rescue, Urban Facility Management, Social Crowdsourcing and Citizen Participation Portal. In addition, to build a data-driven sustainable smart city and provide high-quality services with impacts on its citizens, the city linked the existing urban data it already holds to the data collected from the Smart City Data Hub Platform.

Users can search for and save the best route from a starting point to the destination along with means of transportation and book a ride using this integration mobility application. The single app

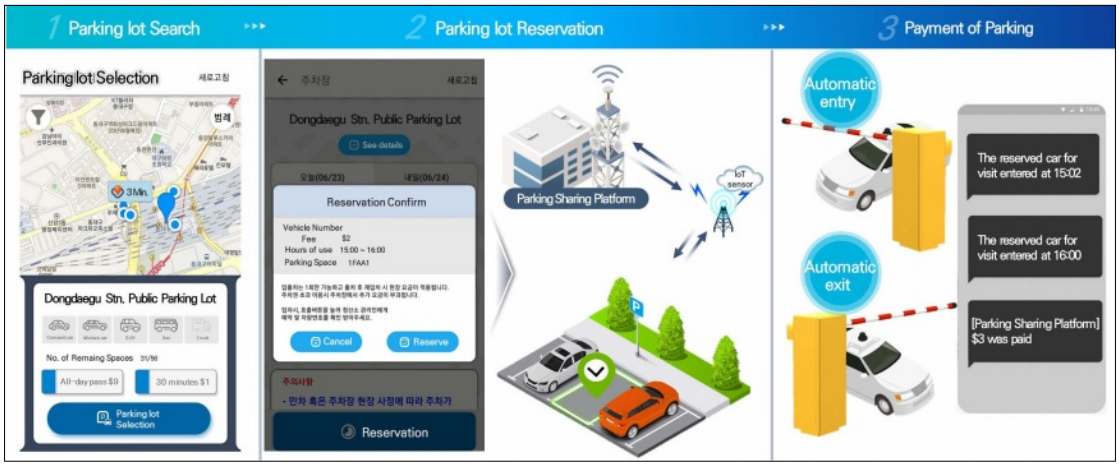

Figure 6. Parking Sharing Service Scenario

gives users access to different modes of transportation with payment features.

Using this service is expected to shorten travel time by about 30%, thereby improving people's convenience and satisfaction with urban transportation and reducing CO_2 emissions as more people choose for public transport.

Parking Sharing that collects data on public and private parking lots, and integrates the information on available parking spaces in the city shares parking space information in real-time with users who then book and make the payment for the chosen space. Citizens who use this service that maximizes efficiency can save about 10% of their time required for parking for greater convenience and satisfaction. The service also helps to reduce and disperse cars driving around to find a parking spot, thus contributing to easing traffic congestion in the city center.

Smart Mobility, a flagship service in the sector of transportation represents a new integrated mobility service that combines different modes of transportation including personal mobility, shared vehicles, and Demand Responsive Transit with a focus on public transportation for convenience of people.

Figure 7. City Safety Service Scenario

City Safety is a service that provides detailed location-based warnings by disaster types to citizens and local governments as it observes water disasters including floods, landslides, and heat waves in real-time and produces forecast. During a disaster, it is critical to let citizens to actively respond to the situation through real-time data collection and dissemination. The information provided by the Korea Meteorological Administration (KMA) is not detailed enough to derive real-time information and forecast on flooding and heat waves for small and specific areas. Here enters the City Safety service that makes predictions about flooded areas and areas at risk of landslides in real-time from rainfall data, and provides specific location-based forecasts and warnings to citizens in units of 100m based on its predicted values on top of the KMA's warnings at administration district levels of eup/myeon/dong. The verification results show over 80% forecast accuracy of water disasters with up to 20% savings in damage to life and property. In addition, the service allows people to secure 30 minutes for emergency evacuation, contributing to protecting people's lives and reducing damage to property while its real-time remote control capability improves the local government'

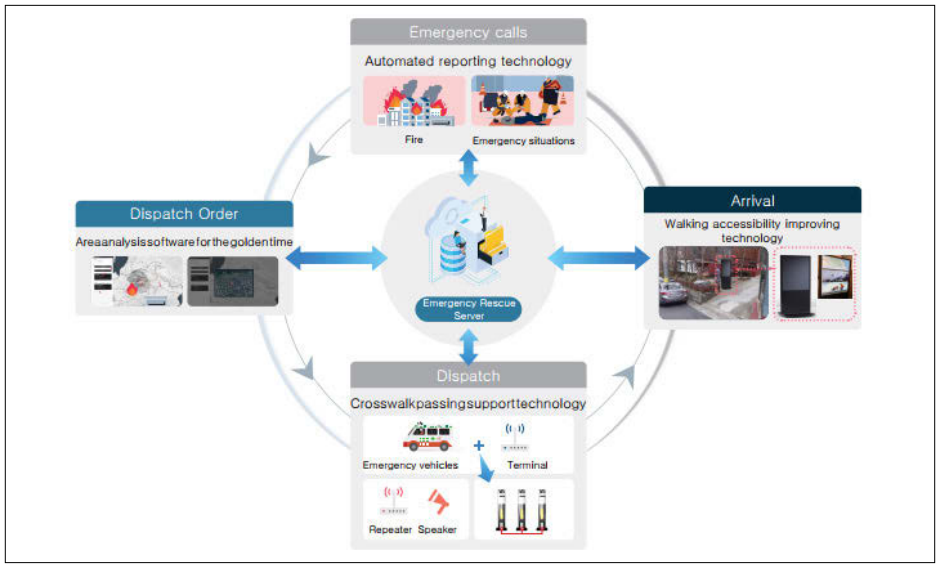

Figure 8. Emergency Rescue Service Scenario

efficiency in city management.

Emergency Rescue service collects and analyzes the information on fire detector locations, the crisis alert level management system and real-time traffic. When an emergency occurs, the service

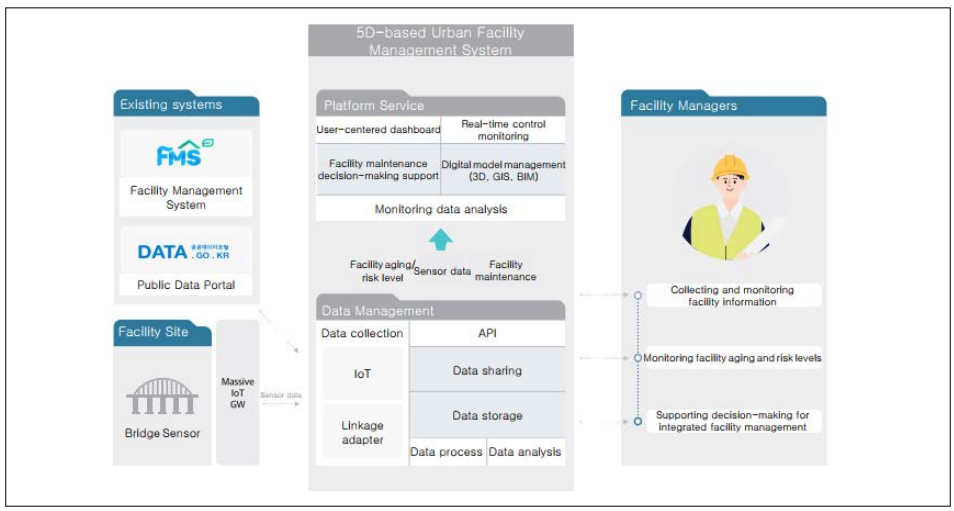

Figure 9. 5D Integrated Facility Management Service Scenario

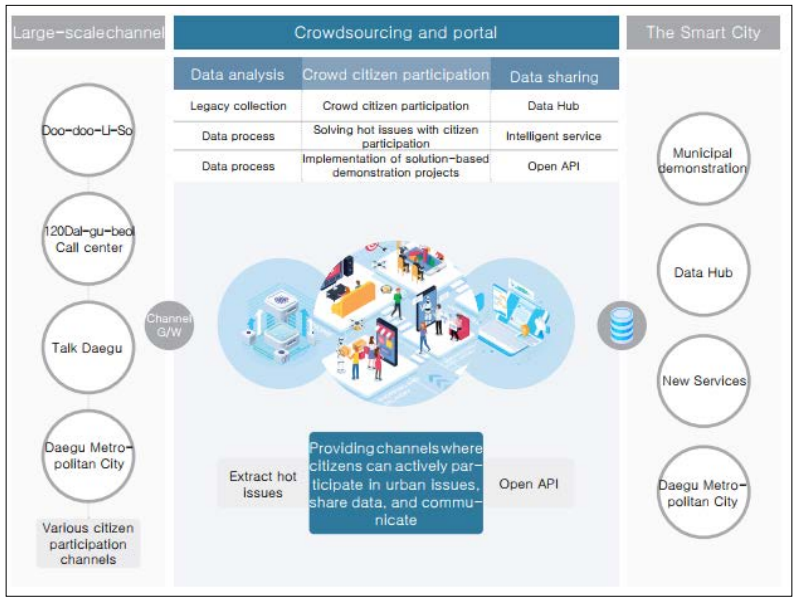

Figure 10. Social Crowdsourcing & Citizen Participation Portal

immediately notifies the situation, selects ambulances to be dispatched and guides the route for the ambulances with a goal of protecting people's safety with prompt response. The demonstration confirmed the Emergency Rescue service helped to secure the life-saving golden hour by reducing the arrival time of the paramedics by 5% from the city's previous average.

Urban Facility Management is a low-cost and high-efficiency maintenance service that calculates the aging and risk levels of urban facilities such as buildings and bridges and helps facility operators to decide on repair and reinforcement based on 5D (3D spatial information + time + cost) by analyzing data collected through the interface with the existing Facility Management System and IoT sensors. This service is expected to make people safer by managing the aging and safety of facilities and enhance the management efficiency of the local government with real-time remote control.

Social Crowdsourcing and Citizen Participation Portal is aimed at creatively solving urban challenges by engaging people. It provides a digital space for discussion to different stakeholders

(citizens, businesses and local governments). The Crowdsourcing platform service encourages people to objectively solve urban issues with data-based analysis. It is expected to serve as an interactive communication channel for people-led urban problem solving as it provides opportunities for citizens to present their ideas and actively engage.

Siheung Smart City Data Hub & Service Verification

Siheung Smart City pursues a strategy of building a citizen-participating smart city ecosystem and to this end, the city built a data hub and demonstrated a number of smart city services

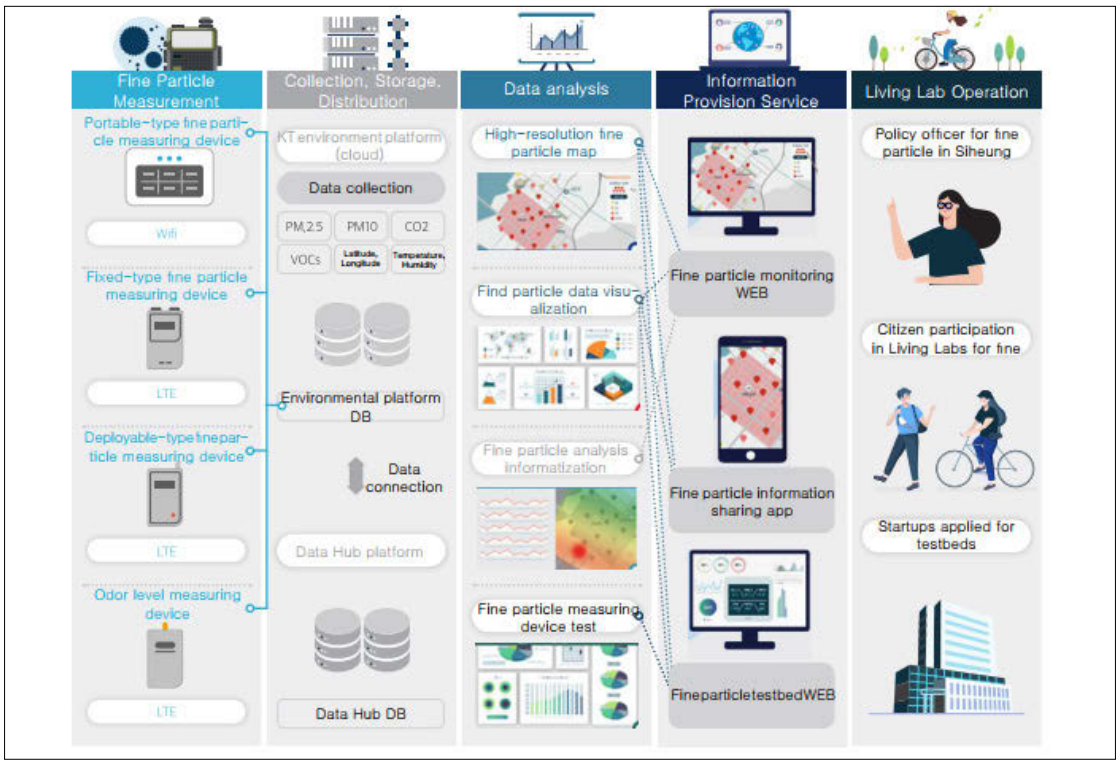

Figure 11. Measurement and Prediction of Air Quality Service Scenario

including Measurement and Prediction of Air Quality, Urban Energy Management, Total Care for the Elderly Living Alone, and Mobility Assurance for People with Disabilities. The Siheung Data Hub built with open source codes collects the data closely related to the life of its residents as well as from Siheung City and major public data. The collected data then goes through standard data modeling and is provided as a service in the form of API. This Data Hub provides data set API aimed at solving urban problems in real-time, improving the life and welfare of citizens and creating new businesses. It provides high-quality data to its citizens, who then improve the value of data by using it with a potential of creating new combined data.

The objective of the Measurement and Prediction of Air Quality is to improve the quality of life of citizens by providing the distribution and prediction of fine dust of the city in high-resolution through

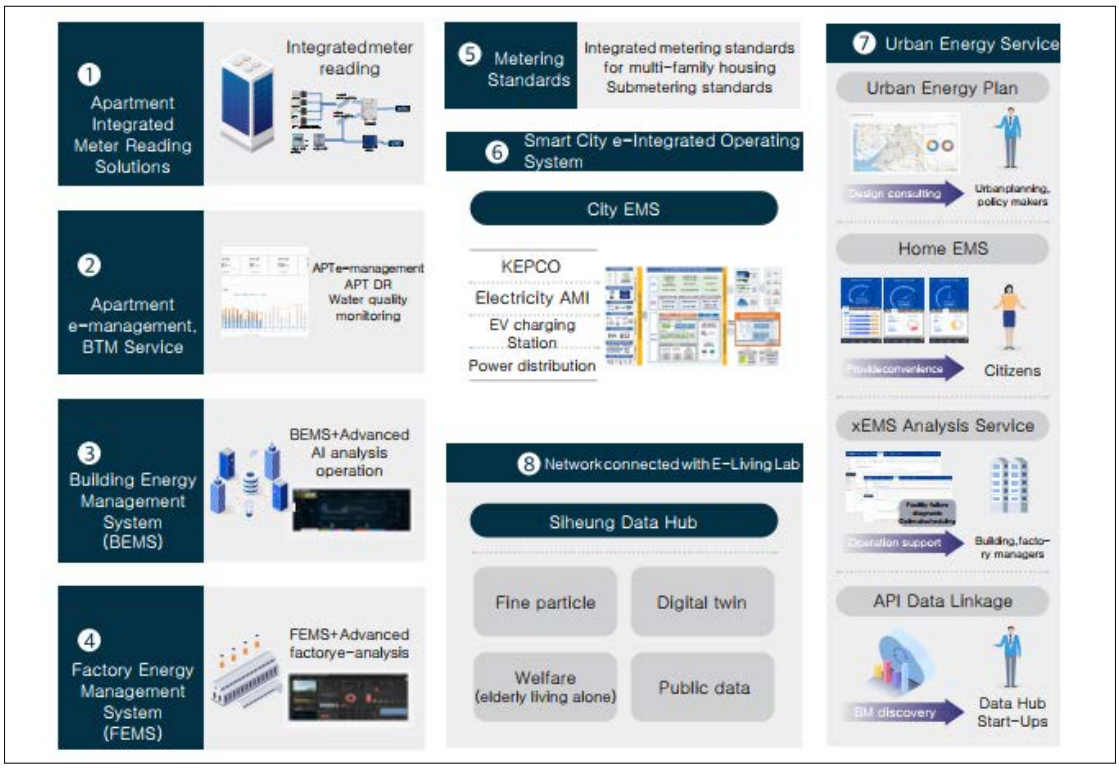

Figure 12. Urban Energy Management Service Scenario

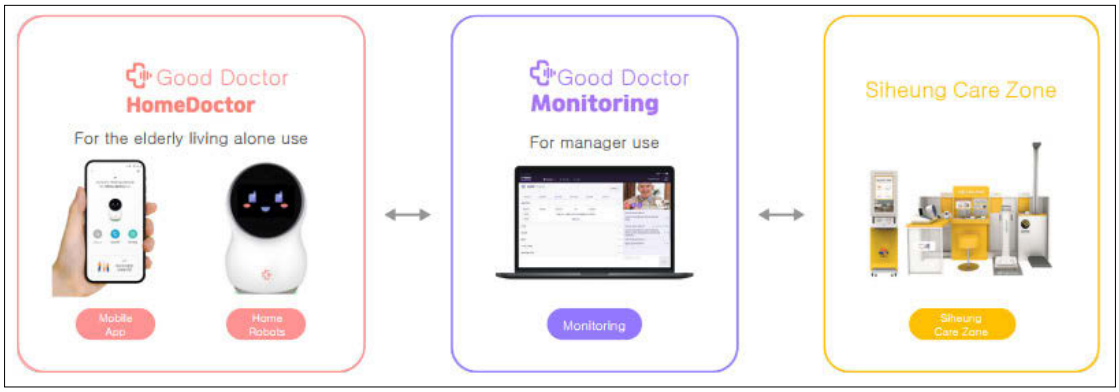

Figure 13. The Total Care for the Elderly Living Along Service Scenario

the crowdsourcing-based measurement and analysis of fine dust and ultra fine dust. The National Air Quality Measuring Network of the city has only two measuring equipment not enough to measure and forecast fine dust. In the service demonstration, 65 measuring tools and 100 portable measuring devices of citizens were used with an observation resolution of 500m,2 improving the accuracy of the prediction model. The demonstration results provided the expectation that the service would help to enhance a happiness index of people by ensuring a pleasant and clean space and enhancing cleanliness of urban areas with a control of pollutant emissions in the city. Furthermore, the Living Lab-based service ensuring direct engagement of citizens with portable measuring devices boosts citizenship while providing a test bed to start-ups, which will help to promote an ecosystem of measuring device development and analysis.

Urban Energy Management collects and analyzes the energy consumption data of homes, buildings, factories and public facilities and provides the analysis results to users and administrators for efficient use of energy. The service demonstration also included building an integrated management system for urban energy and laying the basis for cross-domain services by utilizing the system. The service that makes people more aware of their energy consumption patterns can lead to 8% energy savings for buildings and 1% for factories with increased energy efficiency.

Figure 14. Mobility Assurance for People with Disabilities Scenario

The service called Total Care for the Elderly Living Alone collects living data from AI home robots, life log data using smart bands, and biometric data from Siheung Care Zone and then analyzes the collected data to send emergency alarms when an abnormal situation is detected from its data analysis. The service is anticipated to provide a solution that helps to deal with the aging population and ease the burden of caring for the elderly.

Mobility Assurance for People with Disabilities is aimed at improving the quality of life for the disabled by developing smart maps and a mobile app equipped with travel route search, and route guidance features with a crowdsourcing-based information collection system to help the disabled to move from A to B with ease. The service collects and analyzes the mobility information of the disabled based on crowdsourcing that involves citizens, the disabled and their care givers, provides information on the occurrence of events and updates the maps. It also provides information on optimal means of transportation, recommended and detour routes through the mobile app. In addition, shortest and safest routes to the destination and the surrounding environment information are also available based on analysis in integration with various external data such as real-time weather and construction information.

Deployment and Prospects of Data-based Smart City Model

The data-based smart city model in Korea aims to be a platform that systematically collects urban data from different sectors of the city with standardization of data processing and AI-based integration analysis capability. A data hub lies at the center of this platform. Empirical study that connects the data held by local governments to smart city services was carried out in the two cities. The Ministry of Land, Infrastructure and Transport plans to deploy the Data Hub, the outcome of the empirical study to 17 metropolitan cities and provinces across the nation by 2023. Although it will take some time before the Data Hub can provide smart services that suit each city, meet the needs of its citizens and link to the data at the primary local government level, its deployment is believed to lay the foundation to build data-based smart cities. It is world's first of its kind system for urban data collection and AI-based integrated analysis among heterogeneous data.

Just as semiconductors are a key component of advanced technology, data is an essential component of AI analysis. Although technical integration of Digital Twins and Metaverse to smart cities has been active of late, its implementation can not be done without urban data and will work properly only when it is linked to data-based smart cities. This highlights the importance of deploying the data-based smart city model whose empirical study was completed.

The smart city services verified through the R&D project were mainly identified from the perspective of the state and the public sector to solve urban challenges and make our cities sustainable. When data is disclosed through the Data Hub and the marketplace function gets activated, it will attract ideas, start-ups and companies from the private sector, thereby leading to expansion into new businesses. Therefore, the data-based smart city model is believed to be a must for cities growing

into Meta City as more people, objects and technologies gather in the space, declining due to low birth rates and aging of the population or transitioning to a low-carbon economy in response to climate change.

Acknowledges

The paper is written based on the research results of the National Strategic Smart City ProgramNSSCP jointly supported by the Ministry of Land, Infrastructure and Transport and Ministry of Science and ICT. The NSSCP is a large-scale demonstration R&D program aimed at finding growth engines for the nation with a total expenditure of KRW 135.4 billion over a five- year period. The technologies developed from R&D were applied to 26 smart city services across six sectors including transportation, safety, urban administration, environment, energy and living welfare for verification in Daegu and Siheung selected as demonstration cities. 155 research institutions were involved during the course of the program. I would like to take this opportunity to thank the Ministry of Land, Infrastructure and Transport and the Ministry of Science and ICT for their generous support for successful implementation of the program and thank the Korea Agency for Infrastructure Technology AdvancementKAIA for the strong support in running the program team. My appreciation also goes to Daegu City and Siheung City, two demonstration cities, their citizens who participated in identification of urban challenges and service demonstration as well as researchers and colleagues who directly involved in the program.

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Eco Delta Smart Village;

The First Residential Test Bed for Water, Energy, and City Nexus & its Living Lab

Eco Delta Smart Village:
물, 에너지, 도시 연계를 위한 최초의 주거 테스트베드
& 그 리빙랩

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Kim, Dokyoon

Kim, Jin, head of Smart City Development Department at K-water has led the planning aspect of the Eco Delta Smart City Project in Busan from January 2018 when pilot cities for the national smart city project were selected including the master plan of Busan Eco Delta Smart City, Smart Village planning, and an application plan for smart water standards.
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Kim, Dokyoon, general manager of Smart City Development Department is responsible for operating Smart Village, a living lab test bed for the pilot city of the national smart city project with overall responsibilities for introducing and operating innovative technologies for Smart Village, attracting innovative companies to the Urban Tech House and creating an innovative ecosystem and running a platform-based living lab.
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ABSTRACT

Growth-oriented urban development brought about a new set of issues to modern cities such as environmental degradation and pollution of water resources as it caused erosion of the natural environment and excessive consumption of energy. Environmental challenges that transcend national borders have led to a drive to build smart cities to enable sustainable growth where nature and the city co-exist and to solve urban challenges by utilizing modern ICT.

The Korean government selected Sejong and Busan as pilot cities for a national smart city project, implemented bold regulatory reforms like a regulatory sandbox to facilitate private investment and provided the pilot cities with strong, multifaceted support such as government R&D investment, allocation of policy budget, and promotion of citizen engagement while K-water built Smart Village to expand people's participation and minimize the risks of the smart city project.

Smart Village which consists of 56 residential units is located in Myeongji-dong, Gangseo-gu, Busan. All units were occupied as of January, 2022 in the zero-energy residential complex where 41 innovative technologies(services) were deployed including a smart water purification plant built using K-water's technology. The Smart Village was created with a Living Lab concept to collect feedback from residents on the innovative technologies(services) they use and experience in the complex. The outcome of the Living Lab to be accumulated over the next five years is expected to help to build a sustainable innovation ecosystem of smart cities, thereby ultimately contributing to realizing the nexus of water, energy and city.

KEYWORDS

Smart city, National pilot city, Smart village, Living lab and water, energy and city nexus

초록

경제성장 논리에 치중한 도시 개발은 자연환경의 잠식과 에너지 과소비를 유발하면서 환경파괴, 수자원 오염 등 현대 도시의 새로운 도시 문제를 유발하였다. 환경문제가 글로벌 이슈로 등장하면서 자연과 도시가 공생하는 지속가능한 성장이 가능하고, 첨단 정보통신기술을 활용하여 도시문제를 해결하기 위해 스마트시티를 추진하였다.

대한민국 정부는 세종과 부산을 스마트시티 국가시범도시로 지정하여 규제샌드박스 등 과감한 규제개혁을 통해 민간투자 활성화와 정부 R&D 및 정책예산 투자, 시민참여 활성화 등 다방면으로 지원하고. K-water는 시민참여를 확대하고 스마트시티 사업의 리스크를 최소화하기 위해 스마트빌리지를 조성하였다.

부산시 강서구 명지동 일대에 총 56세대 주택단지로 조성된 스마트빌리지는 2022년 1월까지 전 세대가 입주를 완료하였고, K-water 물 특화기술인 스마트정수장과 제로에너지 주택단지 조성 등 41개 혁신기술(서비스)을 도입하여 입주민들이 체험하고 피드백할 수 있는 리빙랩 실증 환경을 마련하여 운영 중이다. 5년간의 리빙랩 성과 데이터를 토대로 지속가능한 스마트시티 혁신생태계 조성을 통해 물-에너지-도시 넥서스 실현을 기대하고 있다.

키워드

스마트시티, 국가시범도시, 스마트빌리지, 리빙랩, 물-에너지-도시 넥서스

Change In Paradigm of Urban Problem-Solving

Growth-oriented urban development in industrial and modern cities which caused degradation of the natural environment and excessive consumption of energy resulted in a new set of urban challenges including environmental destruction, water pollution, and increase in the scale and frequency of natural disasters.

Consequently, as environmental issues turned into a global challenge the world saw sustainable growth emerging as a new paradigm in urban development for co-existence between the nature and city. However, global adoption of this new paradigm was limited because carbon regulations held back the economic development of countries which grew their way by consuming carbon. Along with environment challenges, inherent urban issues such as reckless development, “doughnut effect,” and traffic congestion brought by rapid population growths and urbanization have also become severe. The past provider-centered approach addressing these issues by building more roads and other infrastructure failed to gain buy-in from citizens and only caused another set of problems.

Against this backdrop, smart city, a concept that leverages ICT to efficiently solve urban issues and make the city sustainable emerged. And the world enthusiastically embraced this new urban model for solving their chronic urban problems. In addition, smart city started to attract more interest as a space to realize the 4th Industrial Revolution highlighted by the World Economic Forum held in January 2016. Today countries around the world have either announced or are implementing initiatives at central government levels to build smart cities and related technologies. This move combined with the demand for urban development in developing countries is rapidly gaining momentum.

Korea implemented projects for Ubiquitous City or U-City, a concept similar to smart city before the latter came to light. U-City projects implemented from the mid 2000s were designed to solve urban issues that reached the limits and ensure sustainability led by the public sector by building state-of-the-art infrastructure. However, the projects had only limited issues and could not take hold as they targeted just new cities with a focus on building infrastructure without the engagement of citizens (users) and private companies (providers). Later based on the lessons learned from the previous projects, a relevant law centering on supplying infrastructure (the Act on Construction etc. of Ubiquitous Cities) was amended and the Presidential Committee on the 4th Industrial Revolution was established to drive smart city as a national strategy. Now the paradigm in urban development is evolving toward a people-centered smart city that embraces inclusive(balanced) growth beyond economic development of the city and enhances quality of life for people through 4th Industrial Revolution based smart services and expansion of project participants (including citizens, private companies, and public partnerships).

Eco Delta Smart City or EDC & Smart Village in Busan

The Presidential Committee on the 4th Industrial Revolution announced Smart City Strategy in 2018. The main objective of this strategy is to create a sustainable city for innovative growth and people-centered sustainable smart city that engages private companies, citizens, and other users. The key initiative that lies at the center of the strategy is to build a national pilot smart city with an aim of establishing a world-class role model for a smart city. The smart city national pilot initiative starts from scratch with an objective of building a world's leading smart city in five years. This initiative facilitates private investment through bold regulation reforms such as the regulatory sandbox and provides an array of support including government R&D investment and allocation of policy budget, review of infrastructure creation for a smart city, and promotion of citizen participation.

Two sites – Sejong 5-1 living zone and Busan Eco Delta City(herein after Busan EDC) were chosen for the pilot city. Busan EDC is a planned city to be built by K-Water in a site of some 11.77km²(about 3.6 million pyeong) in Gangseo-gu, Busan. To be exact, a site of 2.8km²(about 0.84 million pyeong) near Semulmeori district at the center of EDC is where a pilot smart city will be built. To expand citizen participation and minimize the risk of the smart city project, K-water created Smart Village, a residential test bed where innovative technologies to be deployed to the smart city are first evaluated. Proven technologies will be deployed across the entire complexes of the smart city. The 21,000m²(about 6,300 pyeong) Smart Village located in Myeongji-dong, Gangseo-gu, Busan is a residential complex composed of 56 units of which 54 were occupied between December 2021 and January 2022 excluding those units allocated for a “experience” purpose.

The Smart Village features 41 innovative technologies and services in the areas from water, energy, robots, healthcare to living amenities for their residents who experience them and give feedback on them. The data created from these technologies and services are being collected via Smart Village integrated platform with some 300 types of data collected, analyzed, and managed.

Water Technology for Sustainability

K-water, a Korean public water corporation and Busan EDC developer is creating a Korean water-centered urban model for this project with introduction of smart water management technologies and services throughout the entire water cycle of the city (from rain fall, river, purification to water friendliness). Busan Smart City plans to build Urban Water Disaster Management System linked to small precipitation radars to make it safe from climate change and establish a building-type Smart Purification Plant near the Smart Village to supply freshly produced purified water.

Figure 1. Water Technologies Introduced to Busan Smart City and Smart Village

In addition, the smart water management capability it introduced enables people to check the quantity and quality of water in real-time. Another piece that completes the water-specialized city picture is Water Friendliness Platform that provides various water and environment related information to the residents.

K-water has implemented development and demonstration projects for element technologies across the water circulation system to build a water-specialized city. However, most water technologies developed from the past projects focusing on a project developer rather than the needs of citizens could not go further than a demonstration stage as they failed to respond to the opinions and demands from citizens. Recognizing this, Busan Smart City engaged citizens and private companies from a planning stage to incorporate their inputs in an implementation plan. It is committed to establishing an advanced water circulation system featuring water technologies that impact people's lives and improving the quality-of-life step by step together with citizens.

Energy Innovation Technology for Sustainability

As a result of the Ministerial Meeting on Science and Technology in October 2019, Busan EDC Smart City was selected as a test bed for developing low carbon, energy-efficient construction

technologies among R&D initiatives of the Ministry of Land, Infrastructure and Transport and in November of the same year a trilateral agreement was reached between K-water, the Korea Institute of Energy Research and GS E&C to make the Smart Village a zero- energy rating 1 pilot housing complex. Accordingly, the Smart Village aimed at being an energy independent complex with passive and active housing design and techniques, and a series of consultations took place with relevant institutions to employ latest innovative energy technologies from the initial design stage.

Passive techniques including high airtight and exterior insulation construction, thermal bridge blocking materials, exterior blinds, and heat recovery ventilators were applied to residential and public buildings in the Smart Village to minimize the loss of heating and cooling energy. Buildings with passive techniques were designed to maintain the chilly air for a long time with a fan coil unit operating when the indoor temperature drops to a certain level during summer like a thermos. Solar panels with a capacity of 503kW were installed on the roofs of residential buildings and smart corridors and the walls of the platform center and LWP community center to meet the power demand.

In addition to solar energy, Korea's first hydrothermal and geothermal combined system was built to save electricity required for heating and cooling and make more use of thermal energy much underutilized in Korea compared to the advanced nations in Europe. Water from Pyeonggang River near the complex is taken to produce thermal energy through heat exchange. 1,600 tons of water per day is taken from the river and additional 1,600 tons are withdrawn to be mixed with the water used for hydrothermal energy when it is discharged to keep the temperature change in the river water to the minimum. Geothermal energy is produced from a vertical ground heat exchanger installed in the ground below residential buildings of the Smart Village. The thermal energy from the water and the ground is stored in the form of hot and cold water in the heat storage tank inside the machine room in the basement of the platform center of the Smart Village. This means that cooling and heating in the house is provided from FCUs and geothermal boilers not from air conditioners and gas boilers.

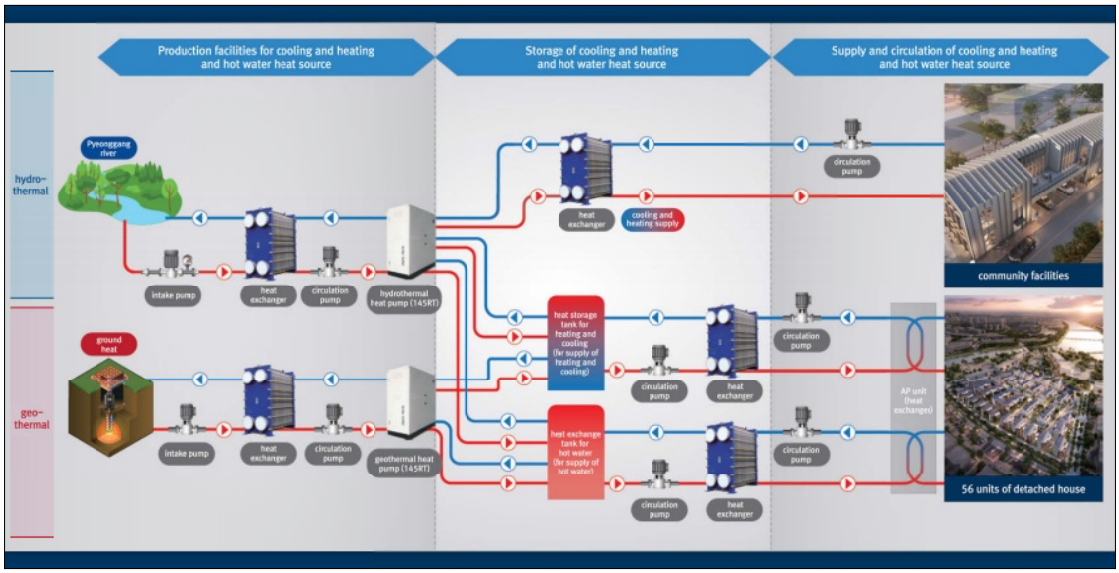

Figure 2. Heat Source Flow Chart of Busan Smart Village

Solar power generation is the most efficient thanks to a lot of sunlight during the daytime, but households consume energy mainly in the evening hours. Lightings and electronics at home as well as hydrothermal and geothermal heat pumps for cooling and heating use electrical energy. As most residents are at work, school or out during the daytime, less power is consumed than produced, resulting in surplus power. When a heat pump is operated during the evening hours when the demand for heat is high, even if people use the same amount of electricity as during the day, electricity bills go higher due to different rates applied to different times of the day. To reduce electricity bills, thermal energy is stored in a heat storage tank by running heat pumps during the late-night hours and is supplied to home during the daytime and evening hours.

The Smart Village is introducing the Energy Storage System or the ESS to resolve this intermittent issue and use solar energy more efficiently. It plans to use the ESS based on energy consumption patterns of the residents, storing the surplus power generated during the day in the ESS and supplying it to homes during peak load in the evening. Considering resource re-circulation, the ESS deployed in

the Smart Village is made of EV's used batteries which are expected to increase sharply as EV penetration increases over the time. The ESS in the Smart Village has 400kWh battery and 180kW PCS.

Thanks to these technologies and efforts, the Smart Village was certified as Building Energy Efficiency Rating 1+++ and Zero Energy Building Rating 1 in March 2022. Residential buildings were rated to have an energy independence rate of 109.8% and that of public buildings was rated to be 104.5%. This outcome makes the Smart Village an ideal candidate as a reference model in meeting the mandatory Zero Energy Building Standards scheduled to be extended to the private sector by 2030. It can be also used as a precedent to determine validity for making relevant policies.

Figure 3. Innovative Energy Technologies deployed at Busan Smart Village

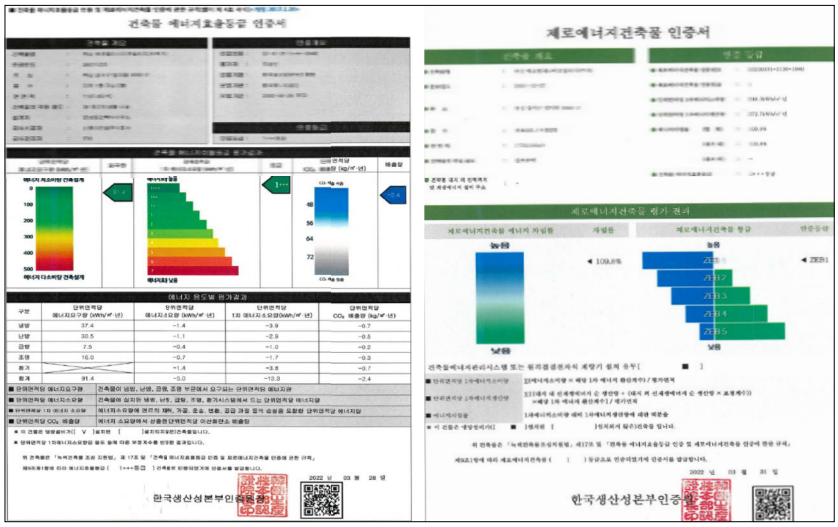

Figure 4. Energy Certificates of Busan Smart Village

Participatory Living Lab of the Smart Village

The Smart Village was built with a concept of data-based, citizen-participatory Living Lab where residents experience futuristic technologies in advance which are then further advanced for user-friendliness based on their feedback. The citizen-participatory Living Lab represents a bottom-up policy methodology that engages citizens and the private sector, breaking away from a project developer-led, top-down urban development policy of the past. This methodology has been fully embraced in creating and running the Smart City. The idea of the participatory Living Lab is to advance innovative technologies in the areas of water, energy, healthcare, robotics and living amenities applicable across the city as the residents and private companies directly evaluate them and provide feedback on them in the Smart Village, a residential test bed of Eco Delta City, Busan. It aims at achieving sustainable growth of innovative technologies by sharing the outcome, enhancing and combining services through the Smart Village community based on the partnership between the public, private and residents while enhancing trust and people's satisfaction in the process

of introducing innovative technologies to the Busan Smart City.

The key tasks of the Smart Village Living Lab are to run the Living Lab based on resident participation, assess innovative technologies based on data, and utilize and spread policies/technologies. Residents are at the center of running the Living Lab from raising problems all the way through their resolution. Innovative technologies are evaluated not only through the issues raised by the residents but also based on the usage data to identify their shortcomings and make further advancement. Utilizing and spreading policies/technologies is about further deploying innovative technologies across the Smart City as they are proven and advanced. These activities are aimed at making the Living Lab a leading model to be incorporated in smart city policies/technologies and spreading its outcome at home and abroad.

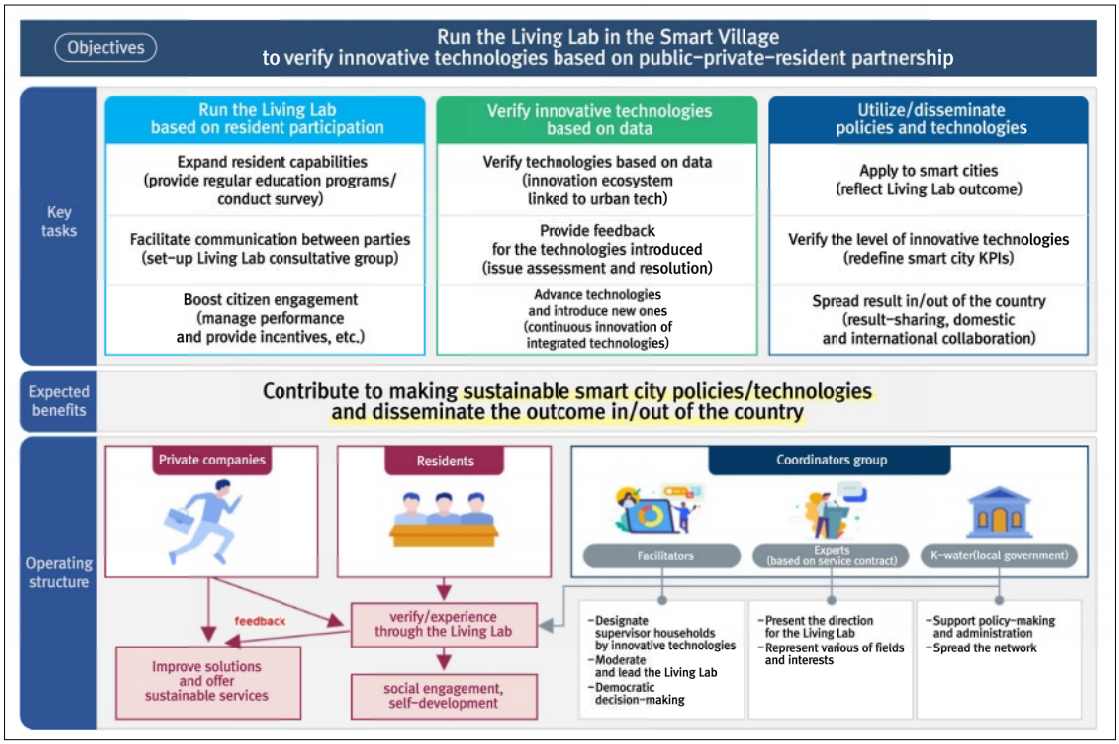

Figure 5. Smart Village Living Lab Operation Plan

To comprise the residents of the Smart Village across generations and classes, the size of a house and the age distribution of householders were considered to ensure optimal operation of the Living Lab. People wishing to experience and give feedback on smart functions and features were selected through a public competition instead of selling the units through a pre-sale process to allow them to serve as a litmus test for policies designed to solve urban issues. The selected people for 56 units are required to participate in Living Lab programs to experience and give feedback on innovative technologies applied to the complex for five years(2022 to 2026). Education programs were provided for to-be residents before they moved in the Smart Village to help them understand the concept of smart city and Living Lab so that they won't have any difficulty carrying out Living Lab activities. After moving in, a survey on people's satisfaction with innovative technologies and areas of improvement was conducted and Living Lab operational guidelines established led by supervisor households along with residents are in operation. In addition, to ensure continuity in the future operation of the Living Lab, research on its operation and planning was commissioned to gain sustainability.

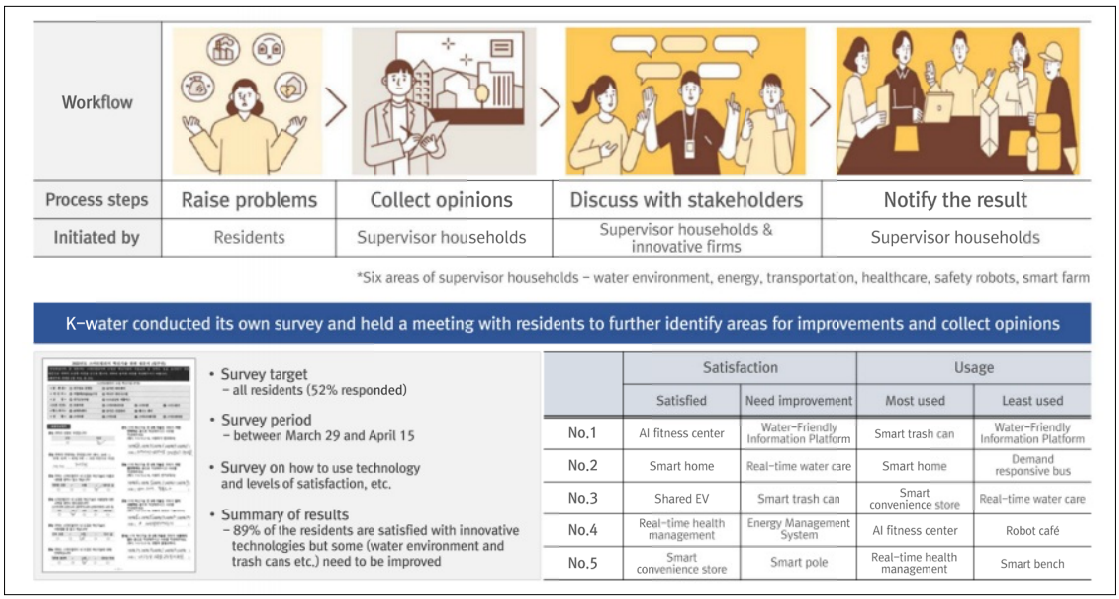

Figure 6. Supervisor Household - Centered Living Lab Operation Structure and Resident Survey Results

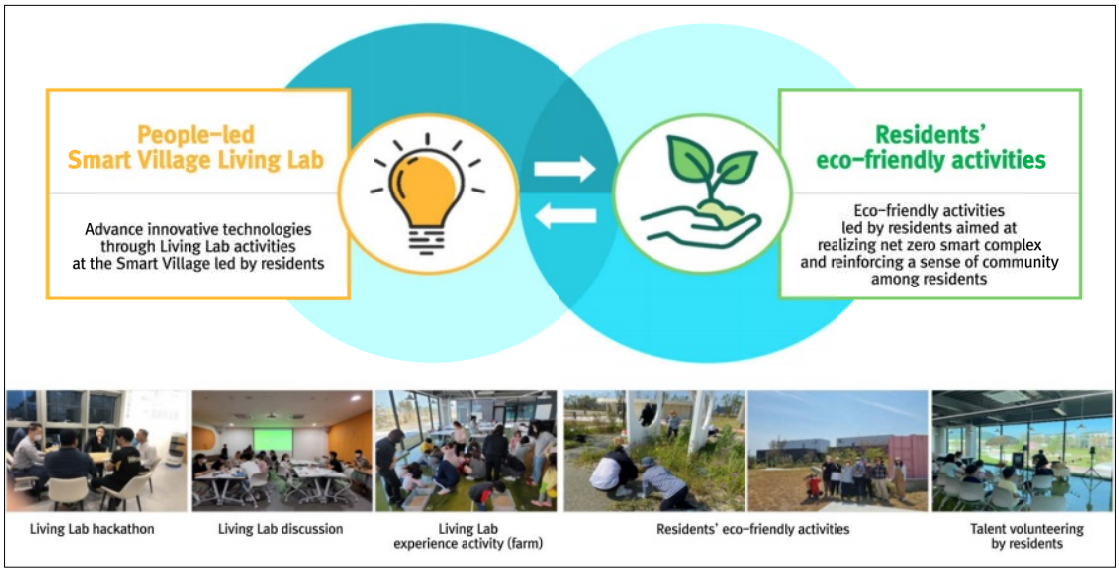

Figure 7. Public-Private-People Partnership Activities through Smart Village Living Lab

The Living Lab is run based on data coming from various innovative technologies deployed at the Smart Village. It is also designed for the companies to identify the opportunities for improvement and make enhancements along with the issues raised by the residents. In addition, a shared office near the Urban Tech House is provided to 19 innovative companies related to the Smart City to help them quickly improve technologies and services through the Living Lab, and launch new, combined services, forming an industry ecosystem for quick feedback on the site. As such the raison d'etre of the Smart Village is to realize smart city through the two-track Living Lab based on public-private and people partnership and achieve sustainability.

Next Steps

People in charge of different fields in the Smart Village work hard to make life more convenient for the residents based on their feedback. Generally, apartment complexes enter a maintenance

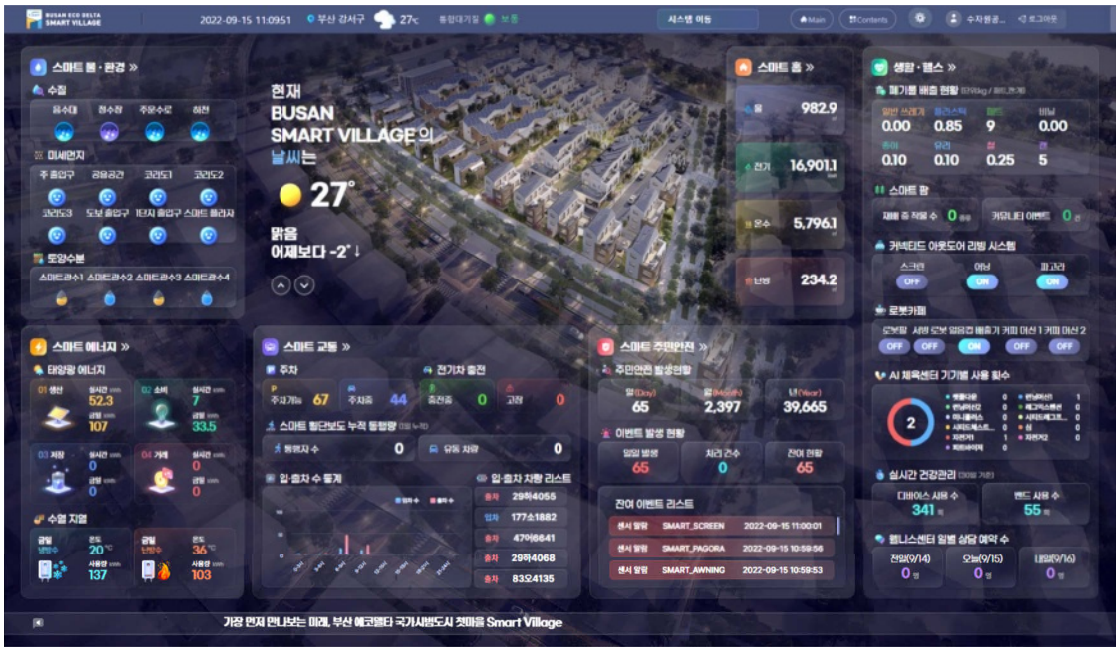

Figure 8. Smart Village Living Lab-Based Data Platform (Example)

mode once all units are occupied but the technologies of the Smart Village keep evolving as they continue to be monitored and advanced for further deployment across the Smart City when they are proven useful.

The Interpersonal Energy Sharing & Trading Platform to be introduced in the Smart Village is highly anticipated as a driver for expanding into a carbon-neutral city. Using Big Data and blockchain technology, the Korea Institute of Energy Research and the Advanced Institutes of Convergence Technology are currently building the platform. For energy sharing and trading, five types of meters (electricity, water, heating & cooling and hot water) with a remote reading capability were installed at the units during construction. K-water gives the right to use to the household for the energy produced from the solar panel installed on its house. If the household consumes less electricity than it produced form the solar panel, the surplus will be shared and traded with neighbors, K-water, and even other nearby residential complexes in the future, getting one step closer to achieving net zero.

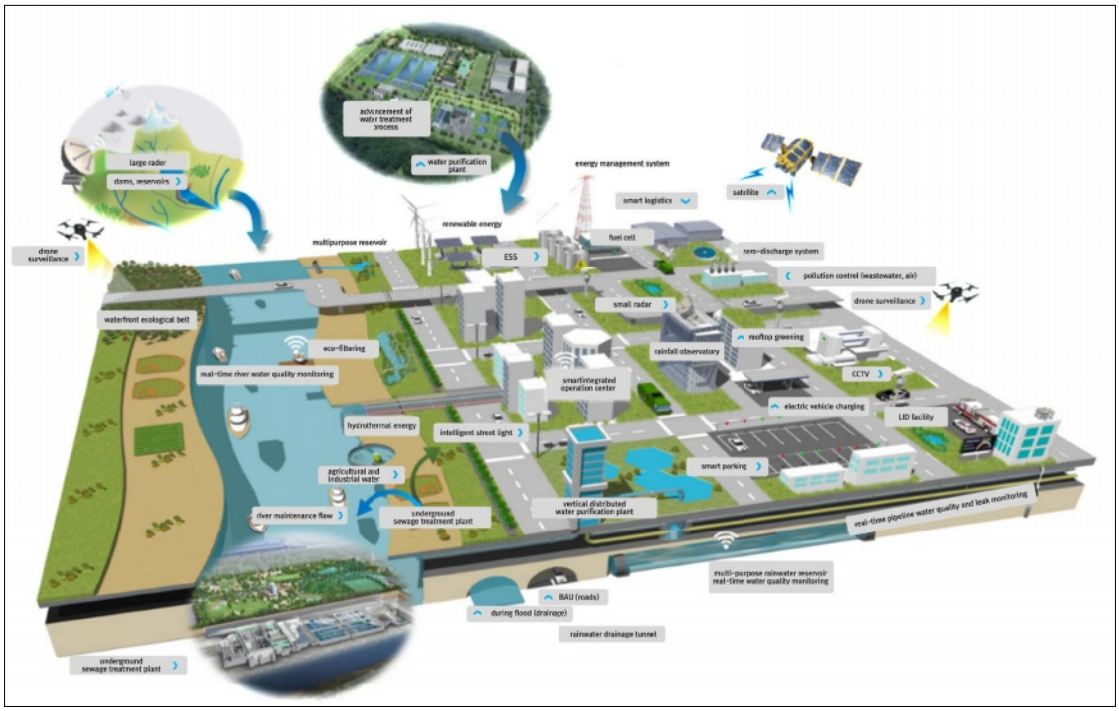

Figure 9. Draft Plan of Water-Specialized Smart City with Water – Energy – City Nexus Realized (example)

When the Energy Sharing & Trading Platform is up and running in the Smart Village and is proved to be useful, it is expected to expand across the city, helping it to achieve energy independence. A sustainable smart city innovation ecosystem can be created if we find ways to make use of the data generated from innovative technologies and collected on the Smart Village integrated platform and share the final verified outcome with public institutions, the academia, and private companies to enhance technologies and create new services. Then, water-energy-city nexus will become a reality.

Climate Crisis and Sustainable Cities

기후위기와 지속가능한 도시

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ABSTRACT

As urban areas account for 70% of global greenhouse gases, urbanization and subsequent industrialization have been considered as the main culprit for carbon emissions. Buildings and transportation are main sources of carbon emissions in urban areas. In other words, the way we live, and travel has great impacts on carbon emissions. To reduce carbon emissions by improving city's energy efficiency, urban areas should be developed for high-density, mixed-use purposes. It is necessary to achieve an optimal density that can efficiently provide public transportation and energy and establish an urban structure that reduces overall mobility demand with compact land use and rational distribution of functions for proximity of jobs and housing. The transportation system should be built in a way to enable different means of transport that people use to move in and out of the city to co-exist. A right level of density and well-conceived transportation network planning will encourage the use of eco-friendly means of transportation to reduce the use of private cars. In addition, well-preserved green spaces in cities in harmony with developed areas can be used as resources for carbon absorption that contributes to the transition toward a sustainable net zero city. Lastly, cities should give a priority to carbon zero energy independence in setting the goal of smart services. A long-term energy supply and management plan needs to be developed by simulating energy production and consumption at the city level. City-level renewable energy supply and smart grid planning will help to shed light on how to achieve economic sustainability of new energy.

KEYWORDS

Urbanization, Climate crisis, Carbon neutrality scenarios, Sustainable urban development

초록

도시 지역에서 전 세계 온실가스의 70%를 배출하기 때문에 도시화에 따른 산업화가 탄소 배출의 주범으로 여겨져 왔다. 도시 지역에서 배출되는 탄소의 주요 발생원은 건물과 수송 분야이다. 다시 말하면 우리가 생활하고 이동하는 생활환경이 탄소 배출에 큰 영향을 미친다는 의미이다. 도시의 에너지 효율을 높여 탄소 배출을 줄이기 위해서 도시 지역은 고밀도 복합용도 지역으로 개발해야 한다. 대중교통과 에너지를 효과적으로 제공할 수 있는 적정 밀도를 달성하고, 압축적인 토지 이용과 직주근접을 위한 합리적 기능 배분을 통해 전반적인 이동 수요를 줄이는 도시 구조를 확보해야 한다. 교통 시스템은 도시 안팎의 이동을 위한 다양한 교통수단이 공존할 수 있도록 만들어져야 한다. 적절한 밀도와 교통망 계획을 통해 친환경 교통수단 활용을 유도하여 개인 승용차의 이용을 줄여 나가야 한다. 또한 도시의 녹지를 보존하여 개발 지역과 조화를 이루는 녹지를 탄소 흡수의 자원으로 활용하여 지속가능한 탄소중립도시로의 전환에 이바지해야 할 것이다. 마지막으로 도시에서 우선하여 고려할 스마트 서비스의 목표는 탄소제로 에너지 자립으로 볼 수 있다. 도시 단위의 에너지 생산과 소모 시뮬레이션을 통해 장기적인 에너지 공급과 관리 계획이 수립되어야 한다. 도시 단위의 재생에너지 공급과 스마트 그리드 계획을 통해 신 에너지의 경제적 지속가능성을 확보하는 방안을 마련해야 할 것이다.

키워드

도시화, 기후위기, 탄소중립 시나리오, 지속가능한 도시개발

Urbanization and Climate Crisis

In Korea with over 90% of urbanization, the majority of people live in cities. Why do so many people choose to live in the city despite its array of problems? The fundamental strength of a city comes from its density. Many people living together means more contacts to be made among people and more jobs to be created with unexpected opportunities. Concentration of population and industry which creates economy of scale enhances the efficiency of providing resources integral to city operation such as energy, urban infrastructure, transportation system and cultural infrastructure. However, the side-effects caused by overcrowded cities are undeniable. Chronic urban issues like environmental pollution, crimes, lack of green spaces and a deteriorating residential environment stubbornly remain as longstanding challenges for the government and urban planners.

As cities grow the increase in urban density has brought about a range of side-effects. The cities created within the confines of mobility limitations of walking and carriages since the Middle Ages, had a high density with a close mix of jobs and housing. The rapid urban migration from rural areas triggered by the Industrial Revolution led to overcrowding in existing cities. Many people in crowded cities suffered from poor living conditions such as lack of area, ventilation, and lighting while cities were impacted by environmental pollution and lack of green spaces.

The growth of suburbs emerged as relatively high-income groups moved out of cities to avoid urban problems. In suburban areas housing was affordable and spacious with abundant greenery. The development of transportation made it possible for the residents in suburbs to commute to the city center. With more advancement of private transportation, and development of infrastructure like highways, suburbs grew exponentially, causing a new urban problem called sprawl, a phenomenon that refers to spreading of low-density urban areas in an uncoordinated manner. Sprawl entails development of excessive green spaces and inefficient use of resources to provide basic urban

services like electricity, heating and cooling and roads for low-density development. In addition, heavy dependance on private cars in suburban areas due to lack of public transportation has resulted in excessive waste of energy including electricity, gas and gasoline with aggravating traffic congestion and air pollution. This carbon-based urbanization and reckless expansion of development are seen as one of the fundamental causes of the severe climate crisis faced by the world now.

In response to this, New Urbanism, Smart Growth, Transit-oriented DevelopmentTOD and Compact City have emerged that pursues high-density, mixed-use, and public transit-focused development and now The 15-Minute City concept is being discussed. This trend illustrates that growth and development are heading in the direction that maintains the advantages of high-density cities while mitigating the side-effects. This idea can be extended to the question raised by Ebenezer Howard's garden city: Where will people live? Town, country, or town-country? To put it differently, how can we build a sustainable city that keeps a balance between urbanity and nature?

Smart City which has been actively promoted of late aims at efficient management and operation of a city using ICT technology. Emergence of Smart City concept represents a shift of the paradigm from "how to build?" to "how to operate?" In other words, development- and growth-oriented urban development is transitioning to sustainable ecological city operation and management.

Climate Crisis and Carbon Neutrality by 2050

The international community faced by ever-increasing damage caused by climate change has become serious about how to mitigate climate change. Korea also declared a national vision of achieving carbon neutrality by 2050 in October 2020 to minimize damage from climate change in

the nation and join the world in combating the climate change as a responsible member of the international society and subsequently launched the Carbon Neutrality Commission in May 2021. The commission announced two 2050 Carbon Neutrality Scenarios in November 2021 after gathering inputs for the draft released in August of the same year.

The vision of the 2050 Carbon Neutrality Scenarios is to build 'sustainable carbon neutral society safe from the climate crisis' and includes transition targets by sectors to achieve carbon neutrality and how the future holds when carbon neutrality is achieved in 2050. Therefore, the scenarios provide the decision-making framework for sector-specific policy directions and transition speeds. Both of the scenarios aim to reduce domestic net emissions to zero. Scenario A focusing on reducing carbon emissions as much as possible entails complete elimination of thermal power generation. Scenario B actively utilizes carbon removal technologies including CCUSCarbon Capture, Usage and Storage while maintaining the sources of carbon including LNG power generation at a certain level. Two scenarios are not presented to choose one or the other. Rather the goal is to depict various futures by factoring in different levels of technologies (The Ministry of Environment A).

The Carbon Neutrality Scenarios are mainly divided into two parts: emission and absorption. Main sectors contributing to emissions include energy transformation, industries, buildings, transportation, agriculture, livestock and fisheries, and waste. In both scenarios, energy transformation discontinues coal power generation and dramatically increases the share of renewable energy power generation. Industries introduce green process technologies including HyREXHydrogen Reduction Steelmaking that emit no carbon and make a transition to renewable fuels and raw materials. Buildings introduce zero-energy buildings and green remodeling for energy efficiency enhancements. Transportation expands public transit to reduce private car traffic and increases the penetration rate of zero emission vehicles to over 85% or 97%. Agriculture, livestock, and fisheries expand low-carbon farming while waste reduces waste volume, expands recycling, and utilizes biogas

energy. Lastly, the absorption part includes expansion of carbon sinks like greenery and introduction of CCUS and DACDirect Air Capture (The Ministry of Environment B).

Cities and Carbon Neutrality Scenarios

One needs to understand carbon emissions trends by city to successfully implement 2050 Carbon Neutrality Scenarios. As urban areas account for 70% of global greenhouse gases, urbanization and subsequent industrialization have been considered as the main culprit for carbon emissions (IEA, 2012). Also, according to a recent study, 25 megacities are responsible for 52% of the world's greenhouse gases (Ting et al., 2021). This implies that the goal of carbon neutrality can be efficiently reached only when greenhouse gases are reduced in urban areas.

Then, how do we reduce carbon emissions in our city? The main sources of carbon emissions in urban areas are buildings and transportation (Burgelman). In other words, the way we live, and travel has great impacts on carbon emissions. To understand the relationship between the living environment and greenhouse gas emissions one should consider both city's total carbon emissions and its carbon emissions per capita. As mentioned earlier, megacities tend to account for half of the world's greenhouse gas emissions. According to the analysis by a research team at the Norwegian University of Science and Technology carried out using carbon emission estimates by city, New York's total carbon emissions are overwhelmingly higher than those of other major cities in the United States, but its carbon emissions per capita are at a moderate level (Moran). On the other hand, the total carbon emissions of New Orleans are low but its carbon emissions per capita are the highest in the United States (Figure 1). Similar patterns are found in Korea, too (Figure 2). Seoul emits overwhelmingly more carbon than other cities in the nation, but its carbon emissions per capita

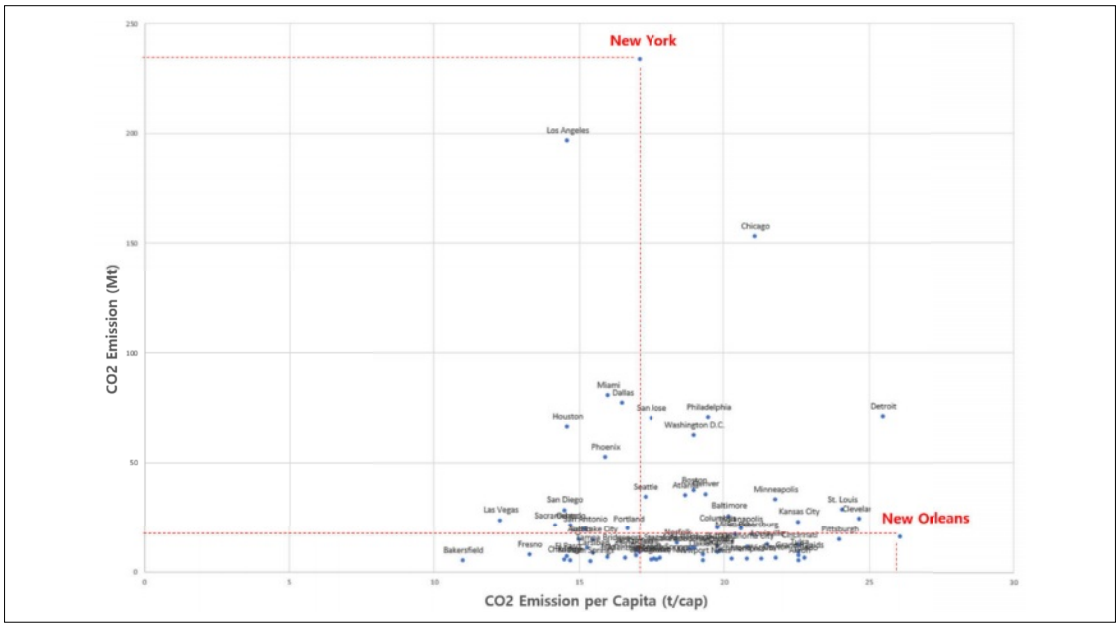

Figure 1. CO_2 Emissions and CO_2 Emissions per Capital of Major Cities in the United States

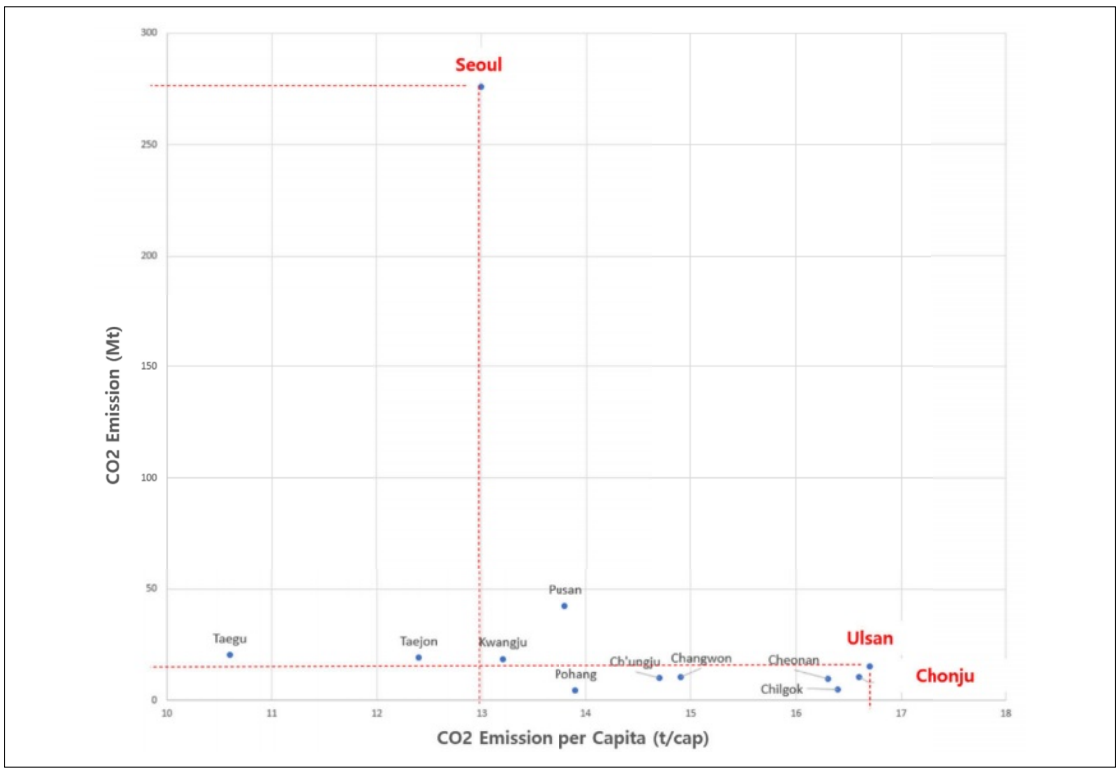

Figure 2. CO_2 Emissions and CO_2 Emissions per Capital of Major Cities in Korea

are moderate. On the other hand, although the total carbon emissions of Jeonju are low, its carbon emissions per capita are the highest.

Sustainable Urban Development

These patterns of carbon emissions by city are the result of urban density and aggregation of activities. The concentration of population and activities in cities leads to economy of scale and efficiency. In buildings the energy efficiency of apartments tends to be higher than that of detached houses. This is because apartments with less area exposed to the atmosphere by individual units are better for insulation with more efficient supply of energy. In transportation, big cities with better access to public transportation can be in a better position in reducing carbon emissions per capita than cities with heavy dependence on private cars. In terms of land use, compact land use that limits the development area while preserving green spaces is a better approach when it comes to carbon sinks than development of a large area with low-density.

This means to reduce carbon emissions by improving energy efficiency, urban areas should be developed for high-density, mixed-use purposes. It is necessary to achieve an optimal density that can efficiently provide public transportation and energy and establish an urban structure that reduces overall mobility demand with compact land use and rational distribution of functions for proximity of jobs and housing. A right level of density enabling efficient provision of basic urban services helps to ensure efficiency in providing basic infrastructure by the public sector and at the same time it is also conducive to creating a market big enough to attract commercial and cultural activities of the private sector. In addition, the mixture of urban functions that do not conflict with each other enhances the density and diversity of activities. When the functions of shelter, commerce, culture, and production are well-mixed together, it will reduce unnecessary travel and encourage synergy

effects arising from diversity collision.

In addition, a transportation system should be built in a way to enable different means of transport that people use to move in and out of the city to co-exist. In modern cities we cannot rule out the use of private cars. However, a compact city enhances the activities of public transportation, personal mobility, and walking, which are classified as environmentally-friendly means of transportation. Therefore, it is imperative to encourage the use of green transportation means to reduce the use of private cars with a right level of density and transportation network planning.

To this end, transportation system planning should be well harmonized with living area planning. Living infrastructure required for day-to-day life should be built in an area reachable within walking distance. Generally speaking, a distance of up to 400m (1/4mile) can be considered walkable. It takes about 15 minutes on average for an adult to walk 400m and most adults won't have any problem walking this distance. For this reason, 400m or 15 minutes is an important criterion in TOD and Paris, The 15-minute City. Satisfactory living infrastructure built within this living zone will contribute to creating a walking- and personal mobility-oriented environment with a road network and public transit system to move around between different living zones.

Pedestrian-oriented streets bring in vitality in a living zone. However, pedestrian-oriented streets do not necessarily have to be pedestrian-only. Rather, being connected and open to the streets by allocating lower floors of buildings to commercial and cultural purposes frequently used by people and securing enough space for people's activities, matters more than anything else. Also, buildings, pedestrian paths and green spaces that create uniqueness and individuality to the streets should be in harmony.

In addition, cities should become sustainable and carbon neutral by preserving greenery in urban

areas and utilizing green areas in harmony with the developed area as resources for carbon sinks. We must respect nature, create green infrastructure, and develop and grow cities in a way to make use of the amenities Mother Nature provides to us. Here, Emerald Necklace, one of important pillars of Boston's growth provides important implications for the role of urban parks.

Sustainable Smart City

People rather than technology should come first in planning sustainable smart city. Smart services require deployment of additional technologies and facilities along with long-term maintenance. This means we need to first think about why smart services should be introduced and keep monitoring their performance once they are introduced. It is necessary to set the target levels of the environment that can be provided by smart city to citizens over the long-term using smart city KPIs (Key Performance Indicators) with evaluation and updates on a regular basis. Therefore, a smart city initiative must include a long-term management plan to create a sustainable urban environment.

Considering climate change mitigation and ecological sustainability smart city aspires to achieve, cities should give a priority to carbon zero energy independence in setting the goal of smart services. Already there are residential, business, and industrial buildings certified as zero-energy. A long-term energy supply and management plan should be developed in smart city through simulation of energy production and consumption at a city-level. City-level renewable energy supply and smart grid planning will help to shed light on how to achieve economic sustainability of new energy.

Although many smart city services are currently under development around the world, a smart industry ecosystem must be built to make smart services sustainable. Smart services that can

survive only when subsidized by the nation cannot be sustainable over a long-term. The services whose sustainability can be subsidized are restricted to only those with strong public nature indispensable to citizens, even if it means injecting taxpayer's money. In order for a wide-range of smart services to firmly take hold, an autonomous ecosystem should be in place where smart service innovation accepted by the market attracts active private participation. The public sector can encourage innovation by providing incentives and urban infrastructure to support the private sector.

When this industrial ecosystem is up and running, a smart garden city will be able to gather people. A city without industry is bound to end up being a bed town, no matter how good the environment is. A smart garden city should attract low-carbon green growth-related industries first and encourage creation of green jobs. Over the long-term, it can lead a green industry ecosystem by attracting companies trying to make a transition from traditional industries to green areas. This will help smart city to change an urban paradigm and present a new model in urban development when the world is faced by climate change and still reeling from implications of COVID 19 pandemic.

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The Future After Digital Transformation Smart City Trends in 2023

디지털 전환 이후 미래 2023 스마트시티 동향

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ABSTRACT

Urban resilience has attracted great attention from cities around the globe over the past two years in the post-pandemic period as they try to return to the old way of living. At the same time, services based on new technologies such as Artificial Intelligence, drones, robots, and Metaverse have emerged in different parts of urban spaces, accelerating the transition to smart cities.

This paper will look into in which direction smart cities around the world are heading from a policy perspective in preparation for the era of digital transformation and faced by the new internal and external environment and what are their main characteristics based on smart cities index data. Main trends discussed in this paper are: first, citizen-centric digital inclusion policies and services to narrow down the digital divide between different classes of society, second, emergence of Smart Resilience, an approach designed to implement data-based policies and services as to how to overcome and respond from a perspective of urban resilience, third, urban intelligence and democratization of innovation to cooperate in different areas and advance together from a view point of intelligent technology and innovativeness in the city, and lastly, the emerging concept of City Logging through Meta - Twin transformation, what are the key elements of new, emerging virtual reality technology and how these elements have converged and developed. In addition, main issues will be discussed to shed light on the way forward for smart cities.

KEYWORDS

Smart cities index, Digital transformation, Urban resilience, Digital inclusion and innovativeness, and Urban intelligence

초록

세계 각국의 도시에서는 지난 2년간 팬데믹 이후 도시의 회복성Urban Resilience에 집중하며 예전의 생활 방식으로 돌아가기 위한 노력을 하고 있다. 동시에 인공지능, 드론, 로봇, 메타버스 등 새로운 기술 기반의 서비스들이 발전하면서 다양한 도시 공간에 나타나고 스마트시티로의 전환이 가속화되고 있는 추세이다.

본고에서는 스마트시티 구현을 위해 디지털 전환 시대 및 새로운 대내외 환경에 대비하여 향후 세계 스마트시티들은 정책적으로 어떠한 방향으로 나아가고 있는지, 주요 특징은 무엇인지 스마트시티 인덱스 자료를 기반으로 논하고자 한다. 그중 대표적인 동향으로 분석된 것이 첫째, 도시 내 전 계층의 디지털 격차를 감소시키기 위한 시민 중심의 디지털 포용 정책 및 서비스들에 대한 내용 소개, 둘째, 도시의 회복 탄력성 관점에서 어떻게 극복하고 대응하고 있는지 데이터 기반 정책 및 서비스들을 추진하는 '스마트 리질리언스 등장'에 대한 소개, 셋째, 도시 내 지능화 기술 및 혁신성 관점에서 어떻게 다양한 영역들에서 협력을 진행하고 상호 발전하기 위한 도시 지능화 및 혁신성의 '민주화' 에 대한 내용 소개, 마지막 넷째, 최근 부상하고 있는 가상현실의 기술들은 어떤 주요 요소로 있으며 이 요소들 간에도 어떤 융합 및 발전 형태가 이어져 옴으로써 추진되고 있는지 메타트윈 트랜스포메이션을 통한 'City Logging' 대두의 개념에 대한 소개가 있다. 그리고 대표적인 이슈들을 통해 향후 스마트시티의 발전 방향에 대한 논의를 진행하고자 한다.

키워드

스마트시티 인덱스, 디지털 전환, 도시 회복성, 디지털 포용, 혁신성, 도시 지능화

The History of Smart Cities Index

The Center for DT(Digital Transformation) Technology Management · Information Systems Intelligence Lab at Yonsei University has published a report describing the overall picture of global smart cities since 2017 every other year. The Smart Cities Index Report 2022, the most recent 3rd edition jointly published with IfM Engage (Institute for Manufacturing) of University of Cambridge examined 31 cities in the world including Seoul from the perspective of smart city strategies and policies as well as various smart city services, infrastructure and innovation projects implemented through those strategies and policies. Based on the sector-specific Index indicators, 1,489 apps/web services, 514 smart infrastructure-based services, 1,088 innovation projects related to smart cities, 206 living labs and 52,338 data sets currently publicly available in the 31 cities were analyzed in eight areas of assessment: Service Innovation, Urban Openness, Urban Innovation, Collaborative Partnership, Urban Intelligence, Urban Sustainability, Infrastructure Integration and Smart City Governance.

Figure 1. Smart Cities Report by Year

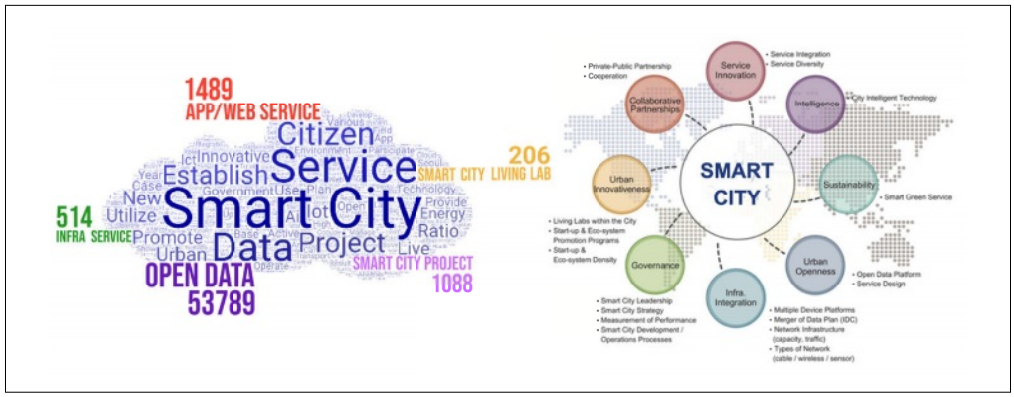

Figure 2. Eight Dimensions of Smart Cities 2022 shown in Word Cloud

Main Trends of Smart Cities

Smart cities around the world are busy with implementing wide range of policies, strategies, and services to adapt to digital transformation and changes emerging in the internal and external environment. The four major trends witnessed are: citizen-centric digital inclusion, data-driven Smart Resilience, democratization of urban intelligence and City Logging of Meta-Twin transformation.

Trend 1: Citizen-Centric Digital Inclusion

Digital inclusion means everyone has access to digital devices and services in any situation and at the same time can improve the quality of life by empowering digital capabilities. Smart cities have continued to launch services related to digital inclusion for vulnerable groups including the elderly, people with disabilities and low-income families as well as for the youth, the future leader of cities while targeting for all members of society. The main objectives of those services include giving digital access, providing digital devices, protecting the underprivileged and offering education opportunities. Cities in Europe are mainly implementing services aimed

Figure 3. Digital Inclusion Services in Europe

at protecting the underprivileged and offering education opportunities for digital empowerment. For example, NaviLens and ddTags, app services for the visually impaired in Barcelona, Spain make public transport more accessible for users by providing voice guidance when they simply scanning QR codes.

In Helsinki, Finland Digital Counseling is available for everyone that solves digital issues and offers online as well as offline counseling. Digital Society School in Amsterdam, Netherlands provides a variety of training programs to enhance citizens' capabilities for digital transformation and runs sessions to address social issues.

Trend 2: Emergence of Data-Based Smart Resilience Model

Urban resilience mentioned at the outset refers to the capacity of a city to nimbly respond to, recover and rebuild from internal and external changes and shocks. Prevention, response, and recovery are important concepts when it comes to urban resilience and different policies and services are integrated and provided for prevention, response, and recovery. Urban resilience is implemented in such areas as renewable energy, prevention of social and natural disasters, access to urban services, urban reforestation, and urban governance. Services in those areas tend to rely on data-based prediction systems for prevention, response, and recovery with over 51 % using IoT and 41 % utilizing AI and virtual reality technology.

For example, bush fires in Australia which caught world's attention with unprecedented intensity about three years ago are considered as a major issue that hits the nation every year with huge impacts. Thus, the CSIRO(Commonwealth Scientific and Industrial Research Organization) has been pursuing policies and services targeting cities in the southeastern region to help them better respond to wild fires. It studies ways of response by detecting signs of bush fires, convert them into data and keep monitoring them through evenly distributed hotspots equipped with sensors in key points of the mountain range near the cities. Cities in California, USA prone to seismic activities have implemented smart services to brace for earthquakes. For instance, MyShake is an app that delivers ShakeAlert across California based on seismic data and the LA Times started to write articles using AI-driven system called Quakebot in the event of an earthquake in 2014 to deliver the news to the public.

Starting from Daegu and Busan, Korea uses a rainfall forecast system with a real-time monitoring capability to send alerts to people when the water level reaches a dangerous point to keep them safe against floods.

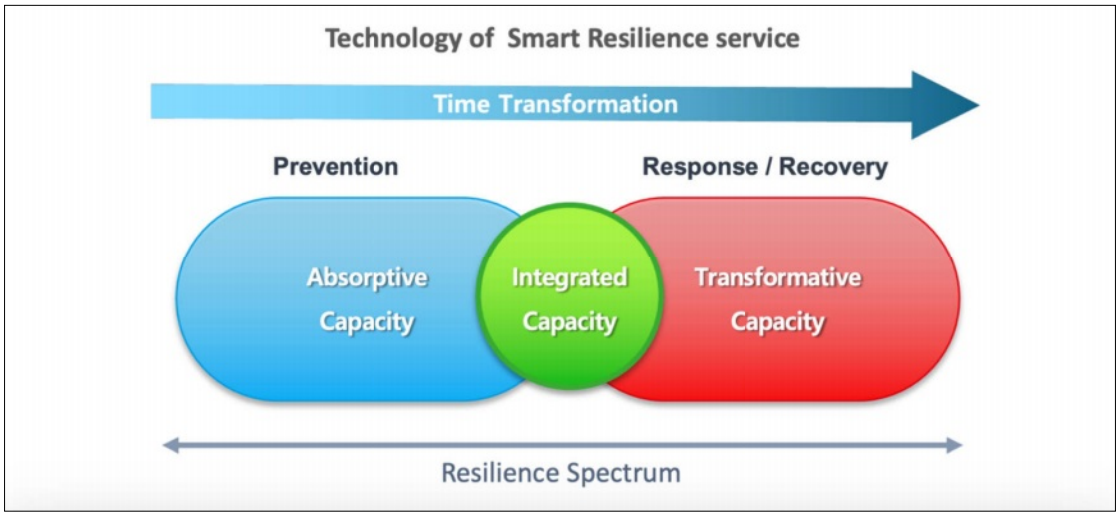

Figure 4. Concept of Smart Resilience Model

Trend 3: Urban Intelligence and Democratization of Innovation

Intelligent and innovative capabilities in smart cities are empowering cities through public and private projects as well as people-led projects centering on living labs. Such projects are being implemented in various fields and at the same time the ways to verify intelligent technologies and enhance the quality of an urban life are jointly sought after through collaboration. About 30% of smart city projects are innovation projects designed to create jobs, ICT R&D/business models, and clusters, with 50.3% led by companies and the rest 49.7% led by living labs. Among them, 65% are in the process of verifying AI, blockchain and virtual reality, and 22% Big Data and IoT technologies. A relevant example city is Helsinki where Nordic District Innovation Labs are

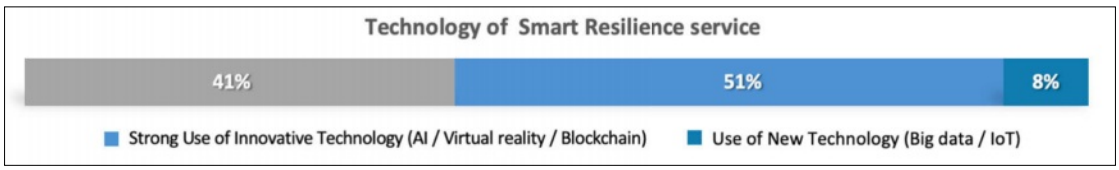

Figure 5. Technology Distribution of Smart Resilience Services

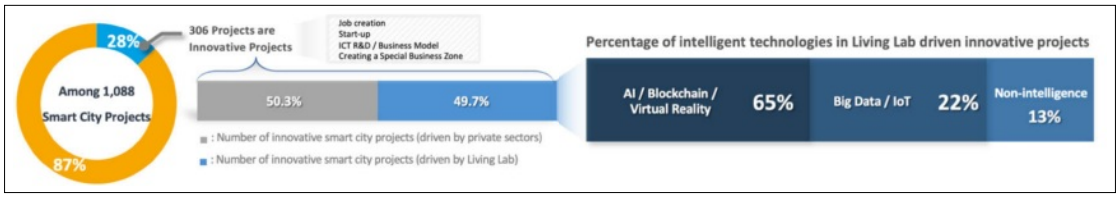

Figure 6. Status of Smart City Projects and Technology Utilization in Living Labs

operated mainly led by Kalasatama test bed with Green Kalasatama project underway to create an environment-friendly ecosystem. As part of the project, regular workshops are held to develop education content using AR by engaging citizens, experience new spaces to be built and share opinions among different stakeholders.

Trend 4: Emergence of City Logging through Meta -Twin Transformation

Today, smart cities are increasingly relying on VR-based Metaverse and Digital Twin to predict what changes and effects may occur in the city by computer simulating situations that may take place in the real world and use it to effectively implement policies. In doing so, the harmony between ICT-based infrastructure, data infrastructure and data utilization elements takes a different form from one city to another along with discussions on how to store and utilize urban data. ICT-based infrastructure elements include deployment and reach of public WiFi, and mobile networks. The examples of data infrastructure elements are public cloud, and open data portals

Figure 7. Example of Democratization in Urban Intelligence, Helsinki

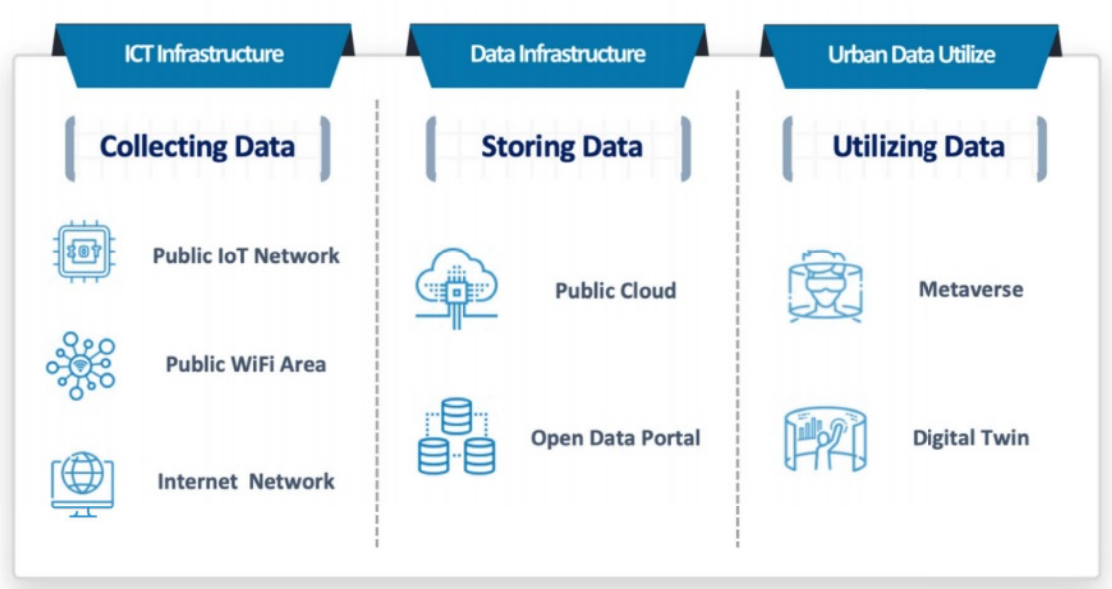

Figure 8. Key Elements of Metaverse and Digital Twin

while data utilization elements include Metaverse and Digital Twin technologies.

Singapore and Barcelona continue to collect data to create city's overall landscapes by using Digital Twin while Seoul and Dubai have embraced Metaverse technology to develop smart office and tourist landmarks that create new spatial value. As more cities apply Metaverse and Digital Twin technologies to various settings, the concept of City Logging will be established where an entire city is connected both online and offline and efficiently advances capitalizing on smooth flows of data, leading to emergence of relevant services.

Conclusion: Continuous Evolution As Smart City Platform

Recent trends in smart cities show that more advanced smart services are emerging driven by internal and external changes such as Digital Transformation and climate change. Collaboration and convergence in many different fields is pushed forward to lay a stable foundation for technologies to move beyond a demonstration stage to commercialization with more policy efforts put in to make citizens the main users of the smart services. More testbeds are required to make intelligent technologies an integral part of city operation and create new innovative values out of them. In addition, access to smart services should be inclusive so that no one is left behind. Lastly, we can expect sustainable development of a smart city ecosystem and enhancement of the quality of life of people in the coming era, only when cities share their local knowhow and work together.

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