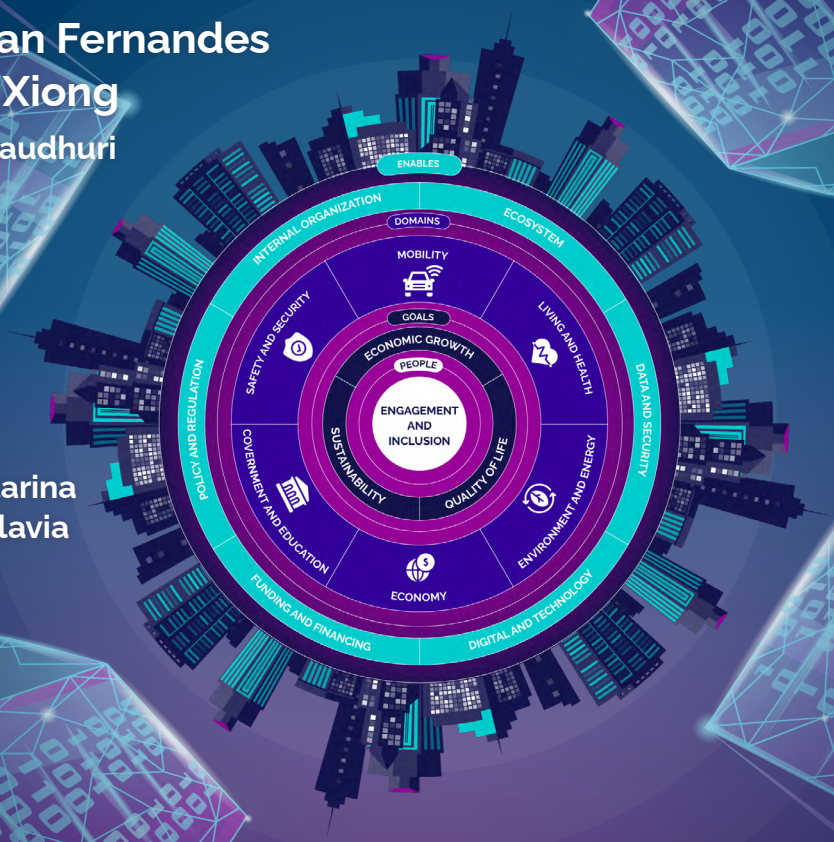
Blueprint for Smart Cities

A Social Contract

Professor Kiran Fernandes
Professor Yu Xiong
with Dr. Atanu Chaudhuri and Ashish Kakar



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Foreword
HRH Princess Katarina de Silva of Yugoslavia and Serbia

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for Smart Cities

A Social Contract


ENABLES
INTERNAL ORGANIZATION
ECOSYSTEM
DATA AND SECURITY
DIGITAL AND TECHNOLOGY
FUNDING AND FINANCING
POLICY AND REGULATION
DOMAINS
MOBILITY
LIVING AND HEALTH
ENVIRONMENT AND ENERGY
ECONOMY
GOVERNMENT AND EDUCATION
SAFETY AND SECURITY
GOALS
ECONOMIC GROWTH
QUALITY OF LIFE
SUSTAINABILITY
PEOPLE
ENGAGEMENT AND INCLUSION

Blueprint for Smart Cities

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Foreword

Her Royal Highness, Princess Katarina de Silva of Yugoslavia and Serbia

I recently chaired the World Smart City Leaders Summit, where I set out a simple vision for Smart Cities. In my keynote speech, I argued that the environment, society, politics and economy must come together to create cities with a clear focus on humans. While there are different definitions of the smart city based on different views, my personal perspective is that the smart city does not simply mean "smart plus city", but emphasises who is leading the city. This means developing a city by the people, for the people, where the goal is to create a human-centric ecosystem.

I am therefore delighted that this report, entitled "Blueprint for Smart Cities – A Social Contract for Smart Cities", has made the human-centric ecosystem a central tenet of a smart city's blueprint. The report's central message is that the four key stakeholders (university, business, government, environment) must work together to create a smart city ecosystem.

As industrialisation progresses at an unprecedented rate, cities are facing major Social, Environmental, Political and Economic (SEPC) challenges. For example, challenges with traffic congestion, air and water pollution, noise, safety due to crime and disasters, population growth and decline, ageing, and unemployment are present across the world. To solve these problems, it is necessary to think about how to make a city safe and sustainable with human-friendly spaces. In particular, I would like to emphasise the importance of education, democratisation of society, civic participation, intergenerational relationships, value pursuit, welfare, Circular Economy (CE) and Corporate Social Responsibility (CSR) as details that should not be overlooked. This also means that a city of true humanity can be created only when the efforts of all stakeholders of the city take place at the same time.

It is important to note that our future is not just about technology. Our future is about our children and the citizens that inhabit this earth. In my experience as a global humanitarian, I realise that people often complicate things by not seeing the world as a whole, but by focusing on smaller aspects that affect our daily lives. A smart city must have a bottom-up approach – where the needs of individual citizens are connected with technological advances to develop a humane and environmentally friendly ecosystem. It is clear that technologies like artificial intelligence, blockchains, etc. are important, but these do not hold significant meaning without focusing on the people who are going to use them. Our smart city should be for the people, not just for large corporations or governments. Therefore, education is central to any smart city ecosystem.

This report provides an approach to developing a human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes. Finally, as the International Ambassador for the World Smart City Forum, I am honoured to represent the global community with an interest in Smart Cities.

HRH Princess Katarina de Silva
of Yugoslavia and Serbia

Smart Cities Blueprint

A Blueprint to build Smart Cities

By Dinis Guarda – Founder of citiesabc.com / citiesabc indexdna, FreedomX.com / ztudium group

Cities are all about people's lives, and thanks to 4IR (Fourth Industrial Revolution) technologies such as Blockchain, AI and IoT, Smart Cities have become the heartbeat of humanity.

"Men come together in cities in order to live:
they remain together in order to live the good life." — Aristotle

"What is the city but the people?" — William Shakespeare

"Urbanization, one of humankind's most successful and ambitious programs, is the triumph of the unnatural over the natural, the grid over the organic… Underway on a scale never before witnessed, one side effect of urbanization is the liberation of vast depopulated territories for the efficient production of 'nature'." — Bruce Mau

"A smart city is an intelligent town that provides enormous possibilities for human growth through art, culture, social, architectural, economic, political, environmental, and scientific flowering with the optimal mix of nature, technology, humanity, and arts." — Amit Ray

Cities are all about people's lives; about large, often complex social groups living and collaborating together.

Cities as diverse as London, New York, Singapore, Tokyo, Beijing, Shanghai, Shenzhen, and Barcelona offer advances and opportunities that are unique in their intent to serve millions of people through smart technologies, which identifies them as leaders of the smart city movement. Smart Cities play host to the world's most intelligent minds and the technologies which they create, offering a forum for innovation in order to tackle both global and local challenges, such as the organisation of society, access to innovation and technology, and the uses of data. Smart Cities centralise these concerns in order to provide groundbreaking solutions. The definition of a smart city is still in flux but can broadly be defined as an urban area that uses different types of 4IR technology, namely: blockchain, artificial intelligence, and the Internet of Things (IoT) through electronic sensors that collect data and generate insights to manage assets, resources and services more efficiently.

Smart Cities, like the city states in the past, embed the highest hopes of humanity through the promise of harnessing the innovative technologies of 4IR for better lives and social harmony. However, it is important that we remember the people at the heart of these Smart Cities and avoid them becoming embodiments of a dystopian future where human lives are governed by machines. Artificial Intelligence, IoT, automation and blockchain will no doubt disrupt our lives; but with smart, intelligent urban governance, we can make sure that they disrupt them for the better.

The research led below by Professor Kiran Fernandes and his team, together with citiesabc.com, looks at the urgency of the situation and explores the best ways to create a social contract for the development of Smart Cities.

Dinis Guarda
Founder CEO citiesabc.com
part of techabc ztudium group

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This report is the product of nearly 18 months of dedicated work of our project team. It has involved the collaboration of experts from universities, governments and industry. We thank all the individuals named on this page for their expertise, dedication, energy and generosity.

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Executive Summary

Citizens, industry, policy makers and society need to act together to create a human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental change.

The 17 Sustainable Development Goals (SDGs), adopted by United Nations Member States in 2015, provide a blueprint of how we can build a better and more sustainable future for all. These 17 challenges are set within a global context where the rate and pace of technical and societal change have profound implications for life, work, travel, and the growth of our communities. Most importantly, these changes will have a significant impact on the urban population, which is expected to be around seven billion by 2050. Living in such highly dense cities is a new phenomenon for humankind and brings about several opportunities, but also some tensions: the individual against the collective; the regional against the global; privacy against open systems; economic growth while maintaining zero carbon emissions.

There are two key challenges to be addressed in such highly dense cities:

1. Promoting inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG8);

2. Making cities and human settlements inclusive, safe, resilient and sustainable (SDG 11).

SDGs 8 and 11 are critical for allowing urbanisation to contribute to sustainable growth where inclusivity, productivity and innovation can emerge. We call this the *circularity challenge*. The circularity challenge refers to the process of collaboratively developing citizen-centric ecosystems, where SEPC challenges can be achieved by connecting physical and cyberspace systems. This must be done within the context of a zero-carbon environment and inclusive innovation systems.

This circularity challenge is particularly urgent and, given the speed and scale of urbanisation, which has been compounded by the COVID19 pandemic, brings large-scale challenges that are not easy to resolve. For example, policy makers have to accelerate demand for affordable housing and transport systems while ensuring that zero carbon targets are also met at the same time. Other issues like homelessness, informal settlements and conflicts are on the rise. The UN estimates that there are over one billion slum dwellers living in urban cities.

Cities play an important role in tackling climate change due to human population and the ever-growing pressure on energy usage. Cities are currently under huge pressure due to the COVID19 pandemic, which is not only impacting public health but also the economy and social wellbeing of

citizens. Building cities that are inclusive, safe, resilient and sustainable requires extensive coordination between policy makers, universities, industry and citizens (also called quadruple stakeholders in our report). This report outlines a response to the circularity challenge by proposing a social contract model to engage the quadruple stakeholders in developing inclusive, safe, resilient and sustainable cities – which contributes directly to SDGs 8 & 11. We identify the following eight factors that are essential to this social contract and are detailed in this report: Innovation & Technology, People & Human Resources, Wellness, Health, Education & Liveability, Financial Funding, Leadership & Governance, Business Professional ESR, Circular Economy and Energy Net Neutrality.

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and Ashish Kakar

Professor Kiran Fernandes
University of Durham

01.

Smart Cities–State of Play

We have conducted an extensive and systematic literature review of Smart Cities publications from 1999 to 2022. The aim of this comprehensive review was to understand the key debates and issues that have been identified by the plethora of research studies conducted in the area of "Smart Cities". Analysing over 61,554 peer-reviewed studies shows that there is no universally acceptable definition of "Smart Cities". While many studies have used synonymous terms like *intelligent*, *sustainable*, *digital*, *ubiquitous*, *artificial intelligence cities*, there is a need for clearly articulated definitions of Smart Cities.

Our review seeks to address the following two questions:

1. What are the key developments in smart city research?

2. What are the major thematic areas of smart city research?

As can be seen in Figure 1, there has been an overwhelming interest in the area of Smart Cities since 2005. The number of studies that have researched this topic has grown exponentially.

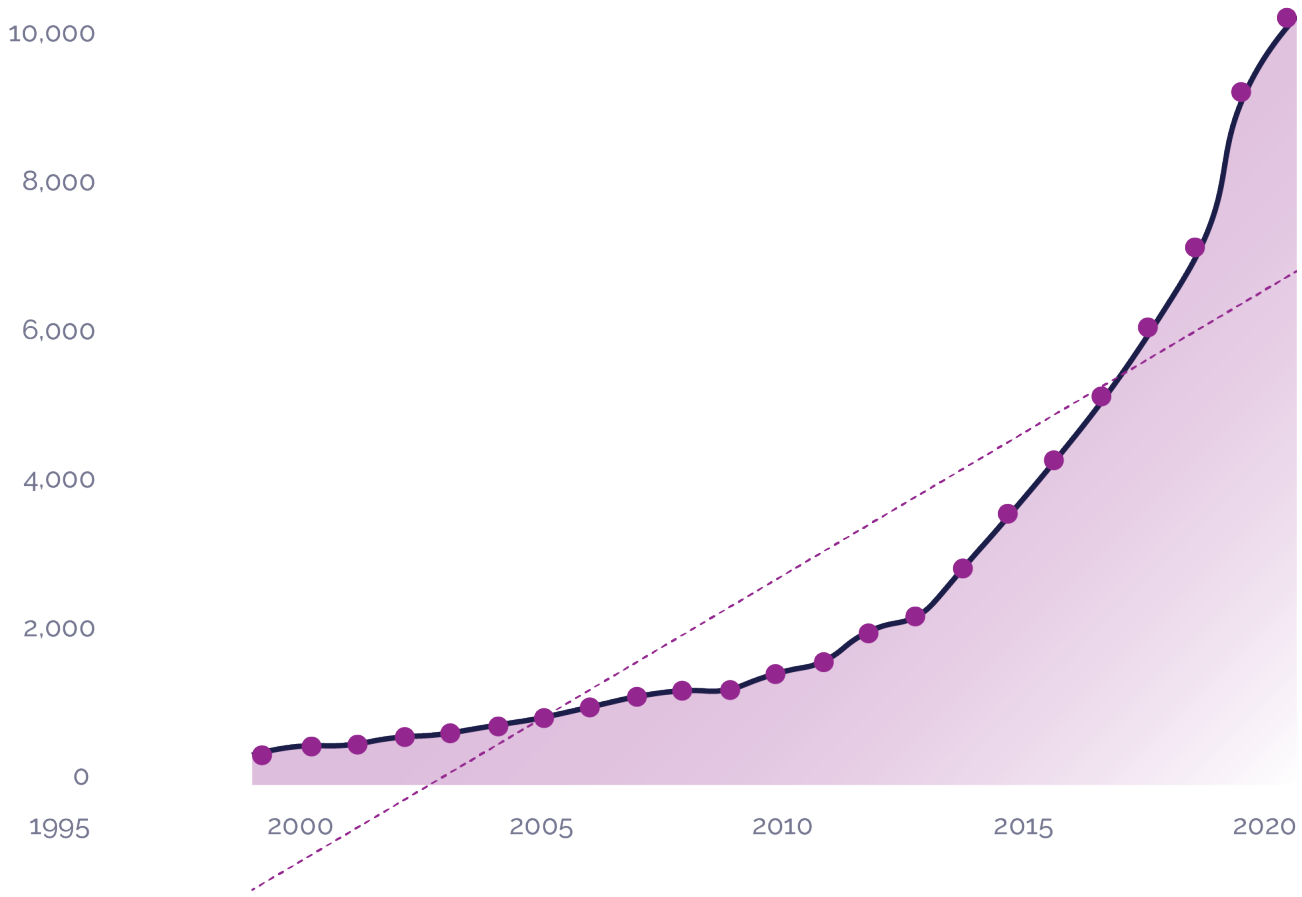


Figure 1. Number of studies in the area of Smart Cities since 1995

Engineering, Social Sciences & Computer Science as a discipline seems to be the most active research discipline in the area of Smart Cities, as can be seen in Figure 2.

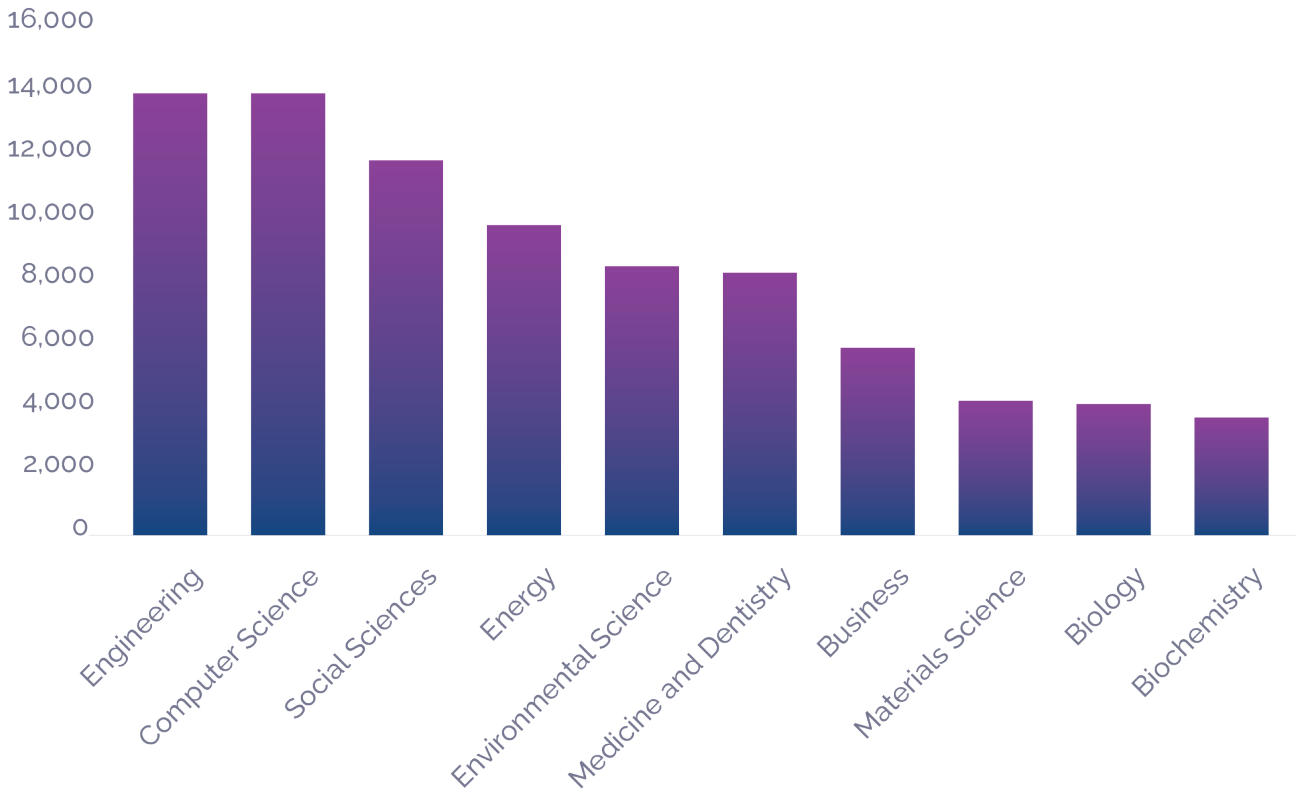
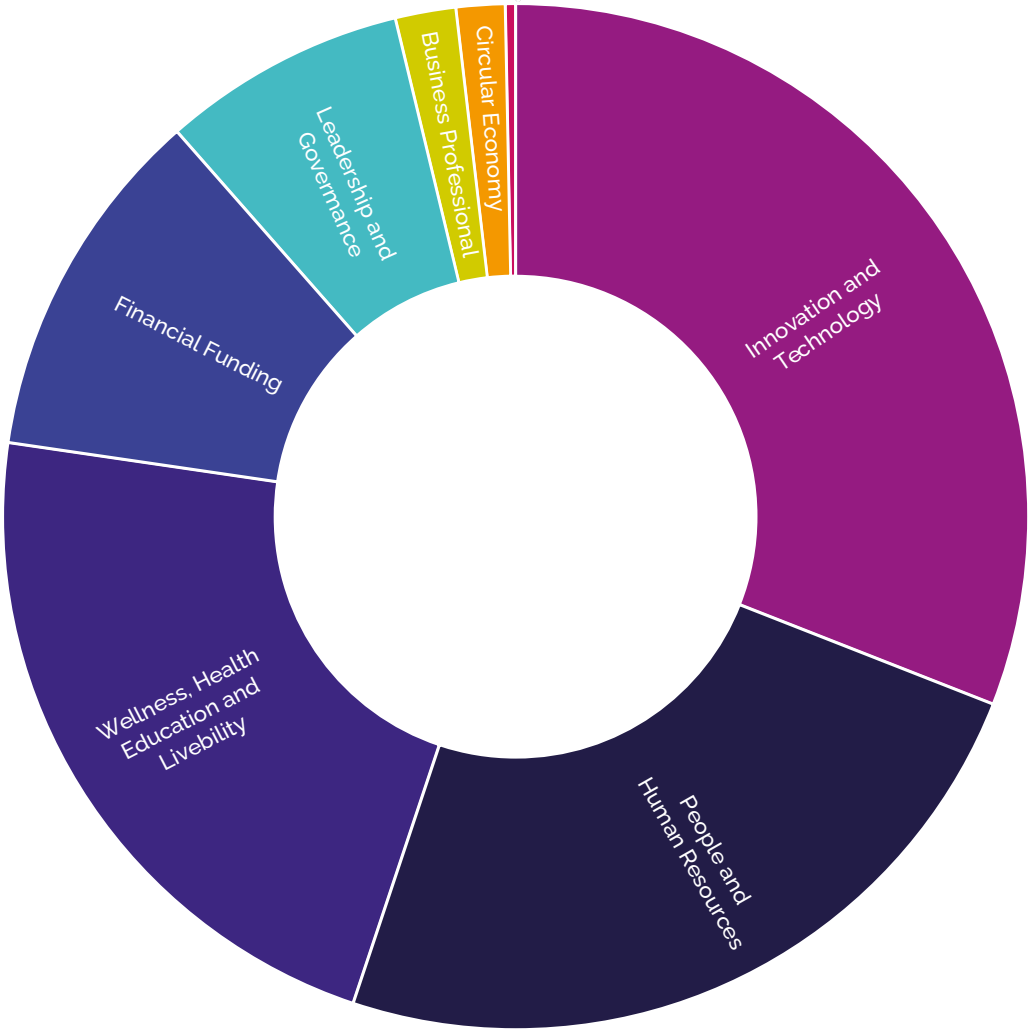


Figure 2. Studies in the area of Smart Cities by discipline since 1995

To explore the relationships among themes and gain insight into studies in the area of Smart Cities, we clustered research themes based on keywords from publications. We used a data extraction software to extract papers from "ScienceDirect". ScienceDirect is the world's leading source for scientific, technical and medical research. We looked at data from 1995 (to date), which had a total of over 200,000 scientific outputs listing the keyword "Smart Cities". The scientific output included research articles, book chapters, review articles, short communications, discussions, editorials, conference abstracts, news, book reviews, correspondence, data articles, product reviews, case reports, patent reports and software publications. A team of experts (see list of authors) used manual methods to cleanse data. Scientific output with missing or non-relevant information were excluded in this study. For example, papers without key words, those for editorial comments, academic conference notices, etc. were excluded. A total of 166,455 scientific outputs were considered for further analysis.

The second stage in our analysis was to create a symmetrical co-word matrix based on the original data by calculating the co-occurrence between the two key words. We were able to group all the relevant scientific output into eight clusters.



Innovation and Technology	51,775	Leadership and Governance	12,495
People and Human Resources	39,811	Business Professional ESR	3,536
Wellness, Health, Education and Liveability	36,674	Circular Economy	2,493
Financial Funding	19,176	Energy Net Neutrality	495

Figure 3. Major themes of studies in the area of Smart Cities since 1995

Given the fact that there is no universally acceptable definition of Smart Cities, we take a holistic, citizen-centric approach to Smart Cities, where we define a smart city as a "humancentric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes". We take the view that smart city services (e.g., interaction between citizens and service systems) is an outcome, rather than the core proposition of a smart city.

02.

Globally Connected Cities –The Need


ENABLES
INTERNAL ORGANIZATION
ECOSYSTEM
DOMAINS
MOBILITY
LIVING AND HEALTH
ENVIRONMENT AND ENERGY
ECONOMY
COVERNMENT AND EDUCATION
SAFETY AND SECURITY
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QUALITY OF LIFE
SUSTAINABILITY
PEOPLE
ENGAGEMENT AND INCLUSION
POLICY AND REGULATION
DATA AND SECURITY
FUNDING AND FINANCING
DIGITAL AND TECHNOLOGY

Cities are estimated to generate 80% of all economic growth and produce approximately 72% of all greenhouse gas emissions, despite covering only 3% of the land. Urban city regions account for more than 50% of the total global population and are expected to be around 70% by 2050. This unprecedented drive to urbanisation is growing at an exponential rate and is projected to be as high as 90% in some countries – notably in Asia and Africa-by 2050 (UN).

Governments have been reactive to this migration trend and are experimenting with emerging and established technologies to provide services and solutions to this unprecedented urbanisation. Many cities are taking proactive steps to make their cities "digitised" or "smarter". Such initiatives are called 'smart city' initiatives and are primarily focused on using a collection of technologies to provide timely and effective services to citizens.

The term "smart city"has several predecessors like "intelligent city" (N. Komninos, 2007), "digital city" (N. Leach, 2009) or "ubiquitous city" (L. Anthopoulos and P. Fitsilis, 2010). While there are differences in these terms, the fundamental proposition in all these definitions is the use of information and communications technology (ICT) to provide services and support to citizens. The three positions adopted in the literature range in focus from technology to citizens to governance. This focus has resulted in terms like "smart" being used synonymously with terms like "intelligent", "sustainable", "digital" and "ubiquitous" – even the concept of "artificial intelligence cities" has been raised (Ullah, Al-Turjman, Mostarda and Gagliardi, 2020). There is no universally accepted definition for a smart city. We represent some of the key definitions and terminologies used to describe the concept of "Smart Cities" and give our position on the definition.

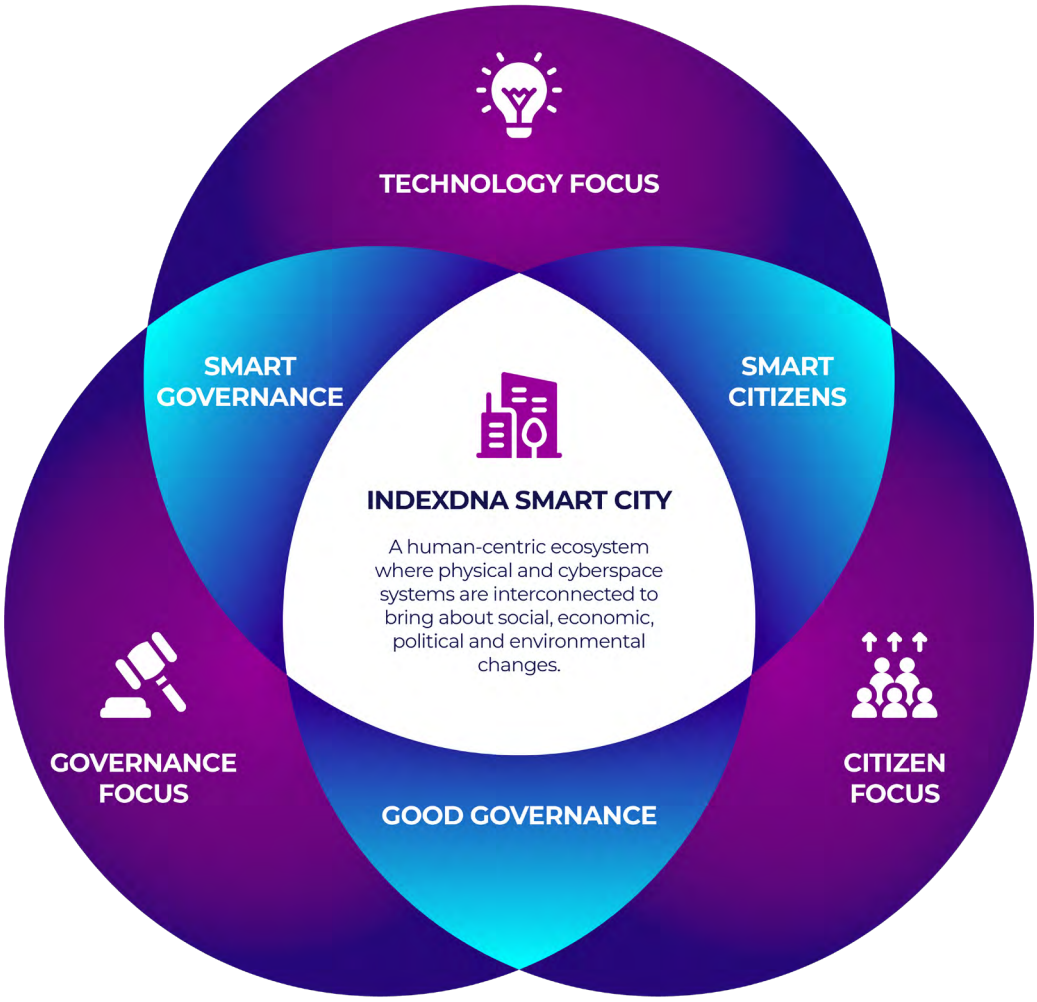


Figure 4. Definitions and perspectives of Smart Cities

03.

The Need to Define Smart Cities

Cities are complex urban systems that have a number of heterogeneous agents (e.g., citizens, policy makers, etc.) where each agent makes decisions about how they act and behave in such a system. These decisions evolve over time and often become routines in systems. Cities are self-organising networks where holistic patterns are formed through human interaction via feedback systems. Therefore, to understand such a complex adaptive system, we need to take a holistic view of a city. We therefore advocate the use of a dynamic technology platform to better "understand" a city: a key aspect missing in most other indexes. These fall short in the following respects:

- Lacking a balanced distribution of indicators.
- Using assessment tools that fail to engage local and regional stakeholders in their development and implementation, and, in the same vein, fail to consider locally specific conditions.
- Failing to consider the feasibility of smart city initiatives and operations. Relativism is needed when it comes to developing countries, which face additional challenges such as digital divide, lack of infrastructure, insufficient funds and political instability.
- Failing to provide concrete, tangible recommendations on linking results to action plans. In this area especially, citiesabc pulls ahead of other indexes.

Examples

The metrics adopted by the China Urban Sustainability Index (2016) exemplify a typical lack of capaciousness: "Society" and "Environment" each account for 33% of the overall weighting, while "Economy" and "Resources" each account for 17%. Streamlining individual criteria under such broad headings runs the risk of being reductive; a high GDP cancels out the shortcomings of significant income inequalities when these are replaced within the same category (Economy). More troubling still, the subsections within these metrics are incomplete: it is conspicuous that the "Society" metric is so heavily weighted when the only subsection within it is "social welfare"; a highly important rubric, but by no means the only criterion to assess the performance of "Society" in Chinese cities. Moreover, the distinct absence of a Governance metric (one that is otherwise fairly common) is symptomatic of the country's politics, where corruption runs high and the government controls censuses, so they do not reflect this.

More complete and reliable indexes exist, of course, such as the IMD Smart City Index. The latter evaluates cities according to five metrics (Health & Safety; Mobility; Activities; Opportunities (Work/School); Governance) in two separate categories: Structures and Technologies. Yet the report remains static and rooted in metrics that are inflexible and leave no room for relativism. Mexico City, for instance, ranks in 88th place worldwide according to IMD. The city performs badly in the structure rubric, and though it may fare slightly better on the technologies front, Mexico City's score remains low overall. There is little data that seems to predict any upward trend in the city's smartening.

This is because the IMD Index fails to consider context and feasibility. Mexico City's low mobility ratings, for instance, are in great part explained by the difficulty to secure funds and financing for roadworks and public transport, as well as the immense population and voracious demand for (and use of) present road networks. A static index does not consider the contextual differences between cities that leads to incongruous results nearly always favouring developed cities. It seems flawed to compare, like for like, the results of green initiatives undertaken in Paris with those undertaken in Mexico City, as the demand, infrastructure and financing options are simply not the same.

04.

citiesabc indexdna –Our Framework to Define Smart Cities

citiesabc indexdna –Our Framework to Define Smart Cities

The indexdna framework takes a complex systems perspective of Smart Cities. Smart Cities, as defined in section 1, are complex ecosystems, where citizens interact with interconnected systems like transportation, education, health, welfare, etc. These interconnected systems are large and often non-linear dynamic entities. Citizens generate large amounts of data during their interaction with these systems and operate in conditions that are far from balanced. The collective memory of such systems are not static and are part of direct and indirect feedback loops. The interaction of citizens in Smart Cities ecosystems is rich, dynamic, with feedback loops and more importantly cannot be predicted from inspection of any one individual sub-system. This form of emergence allows Smart Cities to be adaptive in nature.

Our framework, while building on a complex systems perspective, is flexible and practical for policy and decision makers as it advocates an interdisciplinary approach to understanding the rich interaction within a smart city ecosystem. This framework is our attempt to clarify the conceptual notions of a smart city rather than propose a prescriptive "measuring system" for Smart Cities.

This framework builds on the concept that citizens are the heart of a smart city ecosystem. Citizens interact with different smart city systems via ICT technologies to access different services. The citizen data generated via this process allows the system to be further refined. This co-evolving interaction between the citizen and the ever-evolving smart city systems forms the first layer (core) of our framework. We view this relation as synergistic in nature and constantly changing. This inner core of our indexdna framework, called a co-evolving core, is important to any smart city indexing activity, as it shows the importance of the citizen as well as the citizens' relationship to the smart service systems. While the importance of co-evolution and co-operation has been highlighted by a number of researchers (T. Nam and T. A. Pardo, 2011), particularly in social systems, none of the existing smart city indexes use this relationship in their indexes. In fact, our framework suggests that the need to understand the complex relationship between citizens and the smart systems is central to the human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes.

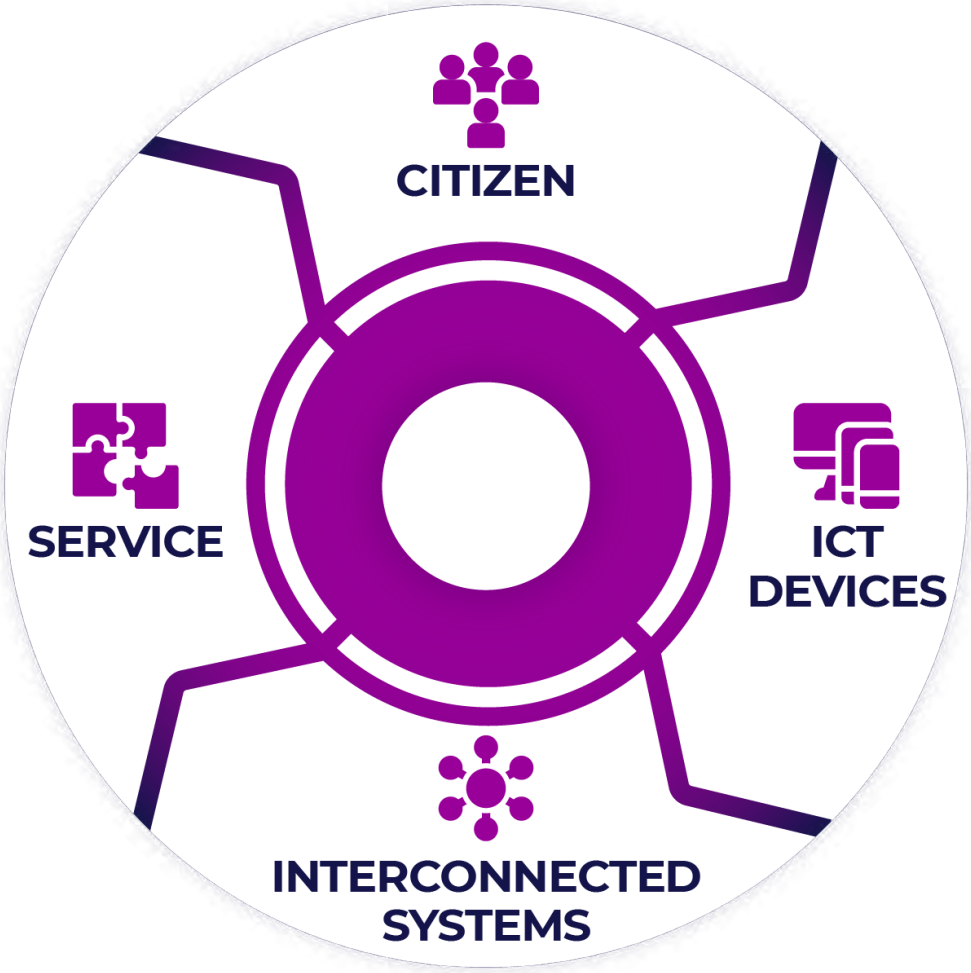


Figure 5. Diagram of the inner core of the indexdna framework

Figure 6. Diagram of the open interaction zone and Quadruple Helix

The second layer in our framework is termed the "open interaction zone" and represents how the key stakeholders interact with the inner core to create outcomes from the complex smart city ecosystem. The index has been built on a matrix structure framework that applies the Quadruple Helix Innovation model, which explores the interactions between university, industry, government and environment sectors within a knowledge economy. In innovation helix frameworks, each sector is represented by a circle (helix), with overlaps showing intersections (much like a Venn diagram).

The Quadruple Helix model provides an inclusive and reliable framework as it incorporates the public through the concept of a media-based democracy. Practically speaking, this means that when a government develops innovation policy to improve the economy, it must adequately communicate the innovation policy to the public and civil society via the media, in order to obtain public support for new strategies.

The Quadruple Helix framework can be described in terms of the models of knowledge that it extends and by the four subsystems it incorporates; knowledge and know-how are created and transformed, circulating as inputs and outputs in a way that affects the natural environment.

The Quadruple Helix model builds on the Triple Helix model assessing interactions between university, industry and government sectors; the addition of a helix focused on the environmental sector is particularly relevant for assessing Smart Cities with an emphasis on sustainability. Socio-ecological interactions via the quadruple helices can serve to highlight opportunities for the knowledge economy; namely, innovation in the field of sustainable development.

As can be seen in our framework, the four key stakeholders in the interaction zone (university, business, government, environment) are connected via multi-directional feedback systems. These stakeholders, while important, cannot be isolated from the core co-evolving zone. It is clear that these four stakeholders are interconnected via smart systems, which also generates large amounts of citizen-centric data, often without the involvement of the citizen. For example, secondary data generated from a university research project might be used by business and government to develop a new smart system in the inner core–without the knowledge or involvement of an individual citizen. We advocate the use of open data to ensure both privacy as well as interaction between the stakeholders. We therefore define this layer as an open interaction zone.

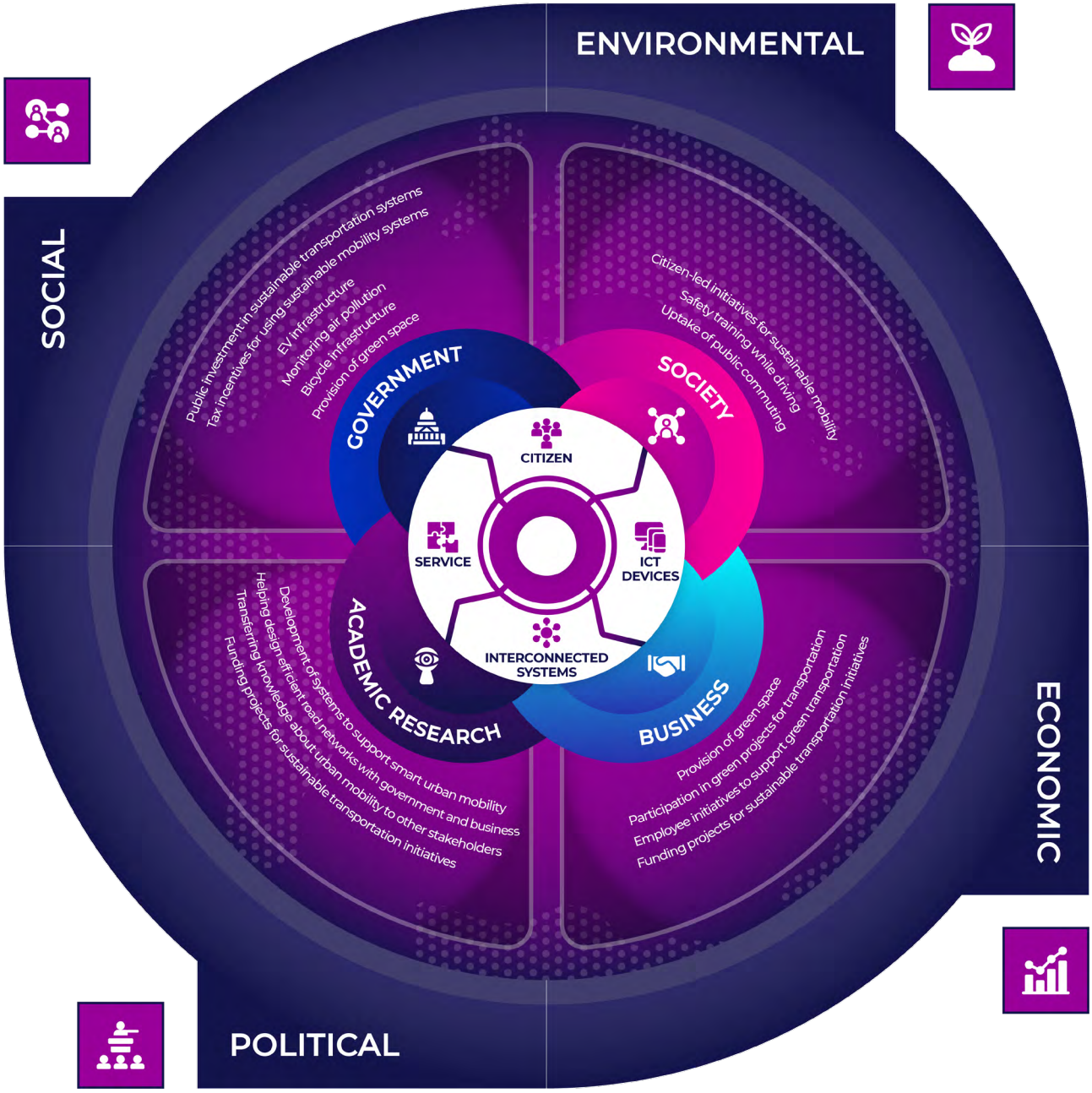


Figure 7. Diagram of the outcome zone, third layer in the indexdna framework

The third layer in our framework is called the outcome zone, where the participation of the interaction zone and inner core can be observed. These interactions are outcomes from either the interaction zone or the inner core or both.

For example, the outcome of accessibility is determined by the interaction between society, universities and government. By studying this interaction, the indexdna can outline the improvements needed to provide a high quality of life for all citizens, regardless of their physical or mental ability. In this example, European government initiatives like the Disability strategy 2020 (C. O'Mahony and S. Quinlivan, 2020) and the European 2020 Horizon (M. Granieri and A. Renda, 2012) agendas have taken societal views to conceive accessibility as an outcome in terms of space, facilities, services and products. While we have listed an example of accessibility, it should be noted that outcomes are connected to one another. For example, accessibility will have an impact on urban environmental issues as well as traffic control systems, etc. Our framework appreciates that outcomes are manifestations of rich interactions rather than standalone measures or key performance indices.

Essentially, the indexdna framework replicates the helices of the Quadruple Helix Model, identifying functional requirements within them. This model allows us to tease out the micro within the macro; the government helix, for example, is identified by both Policy and Society. The performance of an individual city (or region) is thus calculated by examining the relationship between metrics (e.g., Governance, Economy, People) and functional requirements. A city may therefore obtain both high and low scores within the same metric: a city's Governance, for instance, might score highly on the Policy front but badly on the Sustainability front, depending on its implementation of smart schemes in either field. In other words, a city's score depends on the correlation between macro or micro functional requirements and performance evaluation metrics.

The fourth layer is the technology layer. It is clear that most if not all the outcomes can only be realised using ICT. While technology is not the panacea to all the interactions in a smart city ecosystem, it can offer significant leverage to connect all layers of the framework. It is clear that the data from the different layers need to be stored and analysed to help the citizens and the stakeholders from the interaction layer to achieve a human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes. The role of technology is critical to a human-centric smart city ecosystem but is not synonymous with it. There is a plethora of literature (R. R. Harmon, E. G. Castro-Leon and S. Bhide, 2015; S. Vicini, S. Bellini and A. Sanna, 2012; S. Gopikumar, S. Raja, Y. Harold Robinson, V. Shanmuganathan, H. Chang and S. Rho, 2021) that shows the benefits of using different types of technologies, ranging from Artificial Intelligence to Internet of Things, to deliver the outcomes and eventually, the desired impact. Our framework does not advocate any specific technology and is set within the context of the Collingridge dilemma (A. Genus and A. Stirling, 2018). That is, we fully appreciate that "there is always a trade-off between knowing the impact of a given technology and the ease of influencing its social, political, and innovation trajectories" (E. Morozov, 2012). Nevertheless, emerging technologies can offer smart city ecosystems an opportunity to truly transform a human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental change. We realise that the ethical issues raised by how we use and implement technology are critical to this layer. Hence, we term this layer an "ethical technology layer".

The fifth layer of our framework is called the citizen impact layer. Impact is the long-term effect of an outcome. Impact is generally far-reaching and broader in terms of its effect and can take time to observe. We define four types of citizen-focused impact in our framework: social, political, environmental and economic. We do not argue that any one impact is more important than the other. Rather, we take a view that these impacts are interconnected and often any outcome can affect more than one category.

Our five-layer indexdna framework takes a complex systems perspective of a smart city ecosystem. Our framework, while grounded in literature, defines a smart city as "human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes".

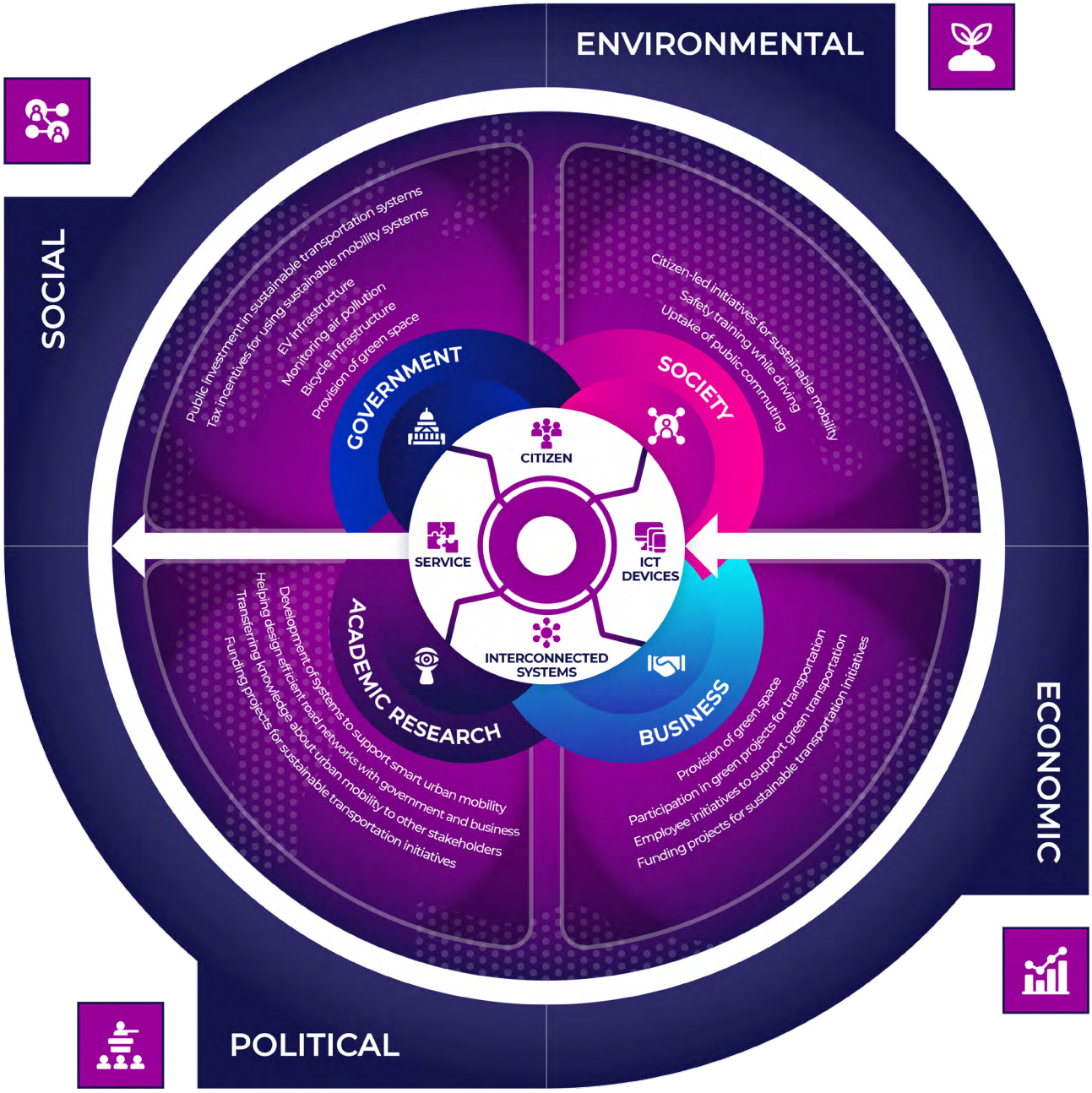


Figure 8. The fifth layer of the indexdna ICT Framework for Smart Cities

Critical Factors in a Smart City Ecosystem

Analysis from our literature review (Figure 3) shows there are eight critical themes or factors that are important to the smart city ecosystem. In addition to this, from a practical perspective, it is important that clear measures be provided for each of these critical themes. In our study we identified a list of 134 indices, or measures, that are important in a smart city ecosystem. Details of these can be found below.

	Physical	Psychological / Emotional	Social	Intellectual	Spiritual	Occupational	Environmental	Cultural	Economic	Climate
Adam et al. 1997	•	•	•	•	•	•				
Anspaugh et al. 2004	•	•	•	•	•	•	•			
Diener et al. 2009	•	•	•	•	•	•	•	•	•	
Dolan et al. 2008	•	•	•	•	•	•	•	•	•	
Durlak 2000	•		•	•						
Hales 2005	•	•	•	•	•	•	•			
Helliwell 2005	•	•	•		•	•	•	•	•	
May 2007	•	•	•	•	•	•	•	•	•	
Myers et al. 2005	•	•	•	•	•	•	•	•	•	
Ryan & Deci 2001	•	•	•		•		•	•		
Ryff & Singer 2006	•	•	•		•		•	•		
Travis & Ryan 2004	•	•	•	•	•	•	•			
Fritze 2008		•					•			•

Table 1 - Dimensions of Wellness. Source: Miller & Foster (2010)

1. Wellness, Health, Education & Liveability (Table 2 Indices 1 to 38)

The World Health Organisation (WHO) defines wellness as "a state of complete physical, mental, and social well being and not merely the absence of disease and infirmity". Table 1 provides a good summary of mapping of wellness to academic literature. (Published by Miller & Foster, 2010). In this study we include wellness, health, education and liveability as one critical factor-as these are connected to one another.

2. SDG Circular Economy (Table 2 Indices 39 to 66)

The EU action plan for the Circular Economy (CE) characterises it as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (European Commission, 2015). The guiding principle behind CE is the development of systems that go beyond linear "take-make-dispose" economic models and achieve closed loops of materials and energy that maintain the value of resources in the economy (Pearce and Turner, 1990). In order to develop and implement a CE strategy in urban smart city environments, it is important to identify a set of indicators to monitor progress and performance. Petit-Boix and Leipold (2018) identified around 300 CE initiatives in their sample of 83 cities and classified those under infrastructure, social consumption, industries and business, and urban planning. It is also very complex for a city to define which combinations of CE initiatives will result in the most environmentally friendly performance (Petit-Boix and Leipold, 2018). In our study, we analysed how 27 indicators across broad categories (as shown in Table 1 indices 39 to 66) such as rate of use of circular material, trade and employment related to circular economy, emphasis on circular economy by the city administration and improving citizen awareness on circular economy, can act as guide for cities to monitor their CE performance and to prioritise their efforts.

3. People Human Resource Talent (Table 2 Indices 67 to 76)

Human resources are one of the most critical elements in a smart city ecosystem. One view that has been advocated to measure progress on the UN's Sustainable Development Goals (SDGs) has been the interaction of people with the planet, prosperity and peace. SDG Goal 8 specifically discusses that promoting sustained, inclusive and sustainable economic growth, including decent work for all, is connected to developing human resource talent. We have identified nine critical factors that must be considered in a smart city blueprint.

4. Energy Net Neutrality (Table 2 Indices 77 to 87)

The recent COP26 conference in Glasgow (2021) showed that over 70% of the world's GDP is now covered by a net-zero target. However, turning this ambition to action needs comprehensive planning and investment from all the stakeholders in a smart city ecosystem: policy makers, universities, industry and citizens. We identified 10 critical factors associated with Energy Net Neutrality that must be considered in a smart city blueprint.

5. Financial Funding–Environmental, Social and Corporate governance–ESG (Table 2 Indices 88 – 105)

Gebru Jember from the Least Developed Countries (LDC) organisation challenged world leaders at COP26 by stating, "Delivering US$100 billion by 2023 isn't soon enough.....there is not enough for adapting to climate change, which was promised to be 50% of the US$100 billion". While Gebru's challenge discusses the importance of funding from developed public funding, it should be noted that a truly ESG financial funding ecosystem can only be achieved if both social and economic sustainability are achieved. In this study, we have identified 17 critical factors that must be considered to achieve "sustainability equilibrium" (see Figure 9). The concept of sustainability equilibrium (Alter 2007) requires industry (working along with policy makers and citizens) to develop new forms of business models that can balance the economic and social sustainability of a smart city ecosystem. This can only be achieved when a smart city ecosystem can provide corporations an opportunity to develop sustainable economic growth. We have identified 17 critical factors that can provide this level of "sustainability equilibrium" where private and public investment can help Smart Cities meet the challenges of the SDGs.

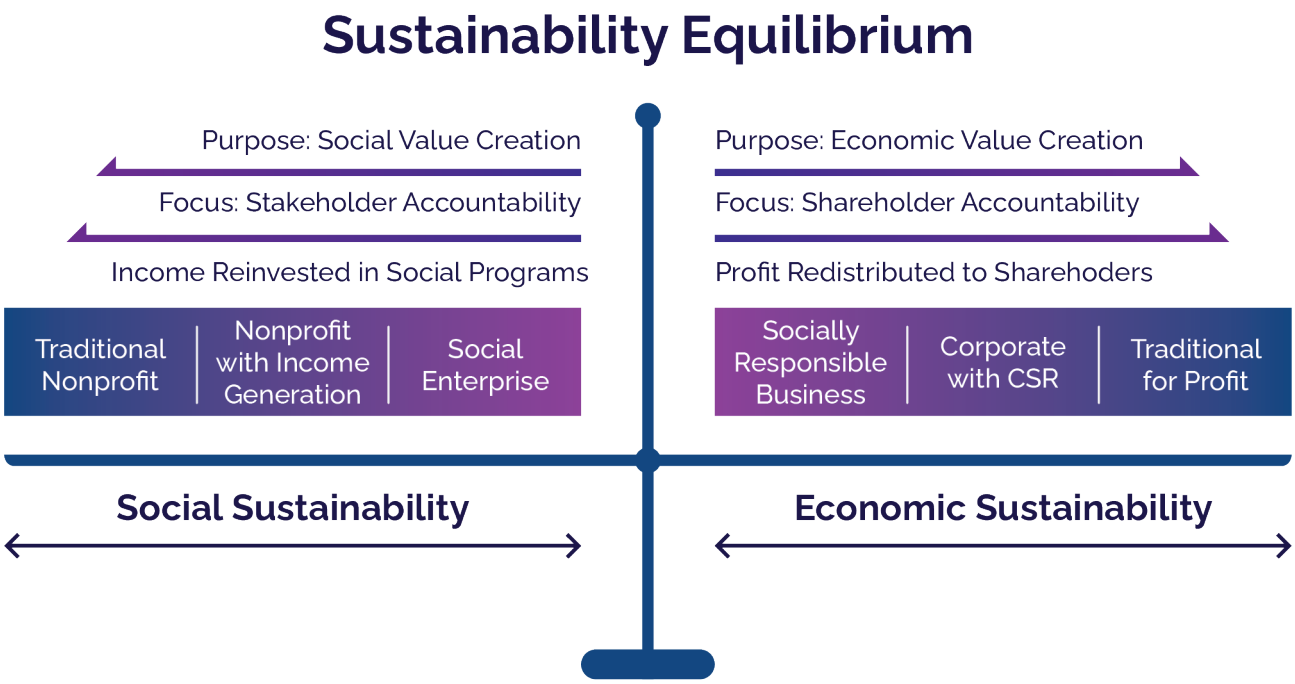


Figure 9. Sustainability equilibrium. Source: Alter 2007, p. 15

6. Leadership & Governance (Table 2 Indices 106 to 120)

Leadership and effective governance are perhaps one of the most important aspects of a smart city. In addition to developing a smart city ecosystem, effective leadership and governance will require strong political leadership, a willingness to change and good, outcomes-based governance. As highlighted by the previous UN Secretary-General Ban Ki-Moon, "unmet commitments, inadequate resources, lack of focus and accountability, and insufficient interest in sustainable development" are the main causes for not meeting any global challenge. In this study, we have identified 14 critical factors that will help foster an environment for collective action, ensuring that the smart city stakeholders are held accountable and are dealing with emerging complex trade-offs among the goals.

7. Technology & Innovation (Table 2 Indices 121 to 129)

Technological innovations have been at the forefront of the changes in human life, particularly in cities, and will play a key role in delivering services in Smart Cities. Deployment of sensors on a wide array of devices, application of AI and machine learning (ML) for decision-making and providing public services, digital twins for simulation on virtual cities (Kim et al., 2021) can be potential applications of IoTs (Internet of Things) for Smart Cities. IoT has played a crucial role in urban management, including parking, lighting and traffic controls (Plautz, 2018). In addition, the IoT sensors enable real-time monitoring to inform environmental attributes, including pollution, heat, and rainfall for emergency management (Kim et al., 2021), a real time traffic management system (RTMS) to dynamically decide the time of traffic lights to discourage formation of gridlock (Saikar et al., 2017). Applications of AI and ML for Smart Cities include detection of on-street parking spaces (Roman et al., 2018). We have identified eight indices, which can capture the use of technology in Smart Cities, can be classified in terms of ease of access to a city's digital services, extent of digitalisation of public services and creation of digital innovation ecosystems. Shown in Table 2.

8. Business Professional–Corporate Social Responsibility–CSR (Table 2 Indices 130 - 134)

Corporate Social Responsibility (CSR) is a well-known concept in the business world. There is ample research to show that effective implementation of CSR can bring a wealth of benefits to society (and the organisation), while contributing to the SDGs. In this study, we have identified four key factors that are essential for developing a smart city ecosystem.

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
1	Life expectancy (years separated by gender)	Quality of life. Access to health & education infrastructure. Clean environment.	1 - Wellness Health, Education, Liveability
2	Child mortality rate / 1,000 lives	Access to healthcare facilities.	1 - Wellness Health, Education, Liveability
3	Deaths from chronic illness - deaths / 100,000	Similar to earlier metrics but could be important from a COVID-19 perspective (captures future pandemics as well). How do governments manage it?	1 - Wellness Health, Education, Liveability
4	Suicide rate - deaths per 100,000 people	Emotional stability is a crucial indicator of wellness. Two indices are proposed for this as the level of emotional stability may vary across cities – a negative index relating to suicide rate and a positive index relating to happiness.	1 - Wellness Health, Education, Liveability
5	Happiness index	A 2018 study in Hong Kong (Hsu et al., 2018) found an inverse correlation, -0.32, between happiness and life satisfaction when correlated with suicide rates.	1 - Wellness Health, Education, Liveability
6	Percentage of people married above the average age for marriage in their city	Stack & Eshleman (1998) had conducted research in 17 countries on the relationship between marriage and happiness. Sixteen out of the 17 countries reported a positive correlation.	1 - Wellness Health, Education, Liveability
7	Adult literacy rate (%)	Smart city goal to achieve 100% adult literacy, especially for cities in developing countries.	1 - Wellness Health, Education, Liveability
8	School enrollment rates (%)	Whether or not a smart city ensures universal primary education	1 - Wellness Health, Education, Liveability
9	Unemployment rate (%)	Health Foundation U.K. (2021) estimated that an additional 200,000 would need mental illness help if the projection of 6.5% unemployment in the U.K. by the end of 2021 is valid.	1 - Wellness Health, Education, Liveability
10	Green space (m2/ person)	Mitchell and Popham (2008) established that in the U.K., low levels of green were related to higher incidence of cardiovascular disease.	1 - Wellness Health, Education, Liveability

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
11	Population density (persons / km2)	Research indicated that population density inversely affects the quality of life and the psychological & environmental wellbeing of a person.	1 - Wellness Health, Education, Liveability
12	Gini coefficient	WHO Commission on Social Determinants on Health identified removing income inequality as a key driver to attain health wellness.	1 - Wellness Health, Education, Liveability
13	Crime rate* / 1,000 people * Includes all economic, violent or other crimes, including homicides	The World Economic Forum (2017) estimated that the world loses 13.6 trillion dollars annually (in purchasing power parity terms) due to all within the city/country and other conflicts.	1 - Wellness Health, Education, Liveability
14	Number of policemen per 1,000 population	Security is a basic factor. This metric captures the infrastructure to protect citizens against crime.	1 - Wellness Health, Education, Liveability
15	Percentage of income spent on housing mortgage	28% is the usual rule specified by most banks (Chase, etc.) & financial websites (CNBC). Mortgage expenses should not exceed 28%. If a city's average is more than 28%, then the people may be under stress.	1 - Wellness Health, Education, Liveability
16	Percentage of income spent on housing rental	The usual estimate for a rental is around the same as a mortgage. Mortgage estimates are at 28%, and rentals are at 30%	1 - Wellness Health, Education, Liveability
17	Median prices of utilities	Measure of affordability of the utilities. Normally water, electricity, and waste disposal are considered.	1 - Wellness Health, Education, Liveability
18	Number and extent of disasters (man made & natural) over the past 10 years	A key measure of security.	1 - Wellness Health, Education, Liveability
19	Median travel time	Normally used to denote congestion on roads and the distances that people need to travel. A measure of liveability.	1 - Wellness Health, Education, Liveability
20	Percentage of population with access to adequate & safe drinking water	Can the city ensure access to basic quality of drinking water to all citizens?	1 - Wellness Health, Education, Liveability

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
21	Percentage of population with access to healthcare services within 500m	Access to healthcare facilities close by.	1 - Wellness Health, Education, Liveability
22	Number of doctors per 1,000 people	Adequacy of doctors	1 - Wellness Health, Education, Liveability
23	Number of hospital beds per 1,000 people	Adequacy of hospital facilities	1 - Wellness Health, Education, Liveability
24	Public sports facilities as a % of total city area	Has the city invested in public sports facilities to provide a healthy recreation alternative to people?	1 - Wellness Health, Education, Liveability
25	Availability and length of biking & hiking trails, in km, per 1,000 people	Multiple indicators have been suggested, such as cinema tickets/ 1,000, % spent on maintaining cultural artefacts, etc. Length of biking & hiking trails is being suggested as this was included as a proposed indicator in most previous publications.	1 - Wellness Health, Education, Liveability
26	Level of corruption	Corruption affects the equitable distribution of resources within the city and may thus lead to unequal opportunities. The UN (2018) has estimated that corruption costs are at least 5% of world GDP.	1 - Wellness Health, Education, Liveability
27	Smoking restrictions to protect general population	Are people being protected from secondary smoke ?	1 - Wellness Health, Education, Liveability
28	Transport-related deaths (Roads/subway) per 1,000 people	OECD estimated that in 2011, transport-related deaths stood at 1.3M annually. Not only is that a human cost but also an economic one.	1 - Wellness Health, Education, Liveability

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
29	Public transport network length per size of the city	Traffic congestion can lead to significant losses. As per Forbes (2020), the 2019 loss due to traffic congestion in the U.S. was $88bn.	1 - Wellness Health, Education, Liveability
30	Share of population with access to public transportation stop within 500m	Is public transport within the reach of everyone? To be a viable option, it needs to be accessible and drive people away from their own transport to energy efficient public transport.	1 - Wellness Health, Education, Liveability
31	Level of particulate matter in air quality – number of days in a year when the air quality has been deemed to be unhealthy.	As per OECD, an increase in air pollution can lead to an impact on labour resulting in an increase in costs to the extent of 1% of global GDP by 2060.	1 - Wellness Health, Education, Liveability
32	Average monthly spending on transportation as a % of median earnings	Most previous publications expected cities to conduct a survey on affordability, which may not be practical.	1 - Wellness Health, Education, Liveability
33	Adult mortality between 15 & 60 years	Most of the GDP and growth rate are driven by this age group. Earlier research reports had indicated that a 10% increase in population 60+ would decrease the GDP growth rate by 5.5%.	1 - Wellness Health, Education, Liveability
34	Total fertility rate. Mean number of children a woman would have up to the age of 50	A fertility rate of 2.1 with children surviving to at least 15 years is a replacement fertility rate where the woman has ensured a steady state of population.	1 - Wellness Health, Education, Liveability
35	New cases of vaccines for preventable diseases, measured by mortality rate per 1,000 people, and rate of cases per 1,000 people	While this indicator was defined in 2018, before COVID-19, this indicator assumes increasing importance in a world where COVID-19 may be endemic.	1 - Wellness Health, Education, Liveability
36	Percentage of people among the total population that are seeking treatment for chronic alcoholism and drug abuse	As per the University of Pennsylvania, the cost of substance abuse for corporations in the U.S. alone was $ 93 billion in 2003. The impact of substance abuse on other variables like violence, traffic accidents, etc. is well documented.	1 - Wellness Health, Education, Liveability

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
37	The youth unemployment level for tertiary-educated population (15-29 years)	According to the Commission of Youth Unemployment, cost exchequer GBP 4.8 bn was in 2012. This metric represents two key components.	1 - Wellness Health, Education, Liveability
38	Pupil-trained teacher ratio by education level	Koc & Celic (2014) studied schools in 81 cities in Turkey and identified that as the number of students per teacher increases, education achievements drop. An increase in students and teachers correlated as 0.56.	1 - Wellness Health, Education, Liveability
39	Cost of overnight business stay	Business visits are often related to the importance of the city as an investment hub or a regional HQ. It also denotes the availability of infrastructure.	2 - SDG Circular Economy
40	Change in employment share to sustainability & new technology jobs	Are people moving toward adoption of new technologies and skills related to those being adopted?	2 - SDG Circular Economy
41	City GDP/head	Ideally this should be adjusted by a global index metric such as McDonald's index to make it real income and not be in nominal terms.	2 - SDG Circular Economy
42	Gini coefficient	Indicator of poverty. Trend would be more important.	2 - SDG Circular Economy
43	Wage and salary growth	Is there a real growth in income (inflation adjusted)?	2 - SDG Circular Economy
44	Expenditure on poverty reduction	What percentage of a city's budget is spent on providing support for the poorer segments?	2 - SDG Circular Economy
45	Number of households below poverty line	What is the total magnitude of the population that needs financial support to subsist?	2 - SDG Circular Economy
46	Unemployment rates	Percentage of unemployment rate with special focus on youth unemployment rate.	2 - SDG Circular Economy
47	Number of corporate headquarters	Indicator of the importance of the city and its ability to generate employment.	2 - SDG Circular Economy

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
48	Presence of Forbes top 2,000 companies	Indicator of the importance of the city and its ability to generate employment.	2 - SDG Circular Economy
49	City investment by sector, including R&D	What is the city investing in? Special focus should be on Cleantech and areas like AI.	2 - SDG Circular Economy
50	Jobs created as a result of FDI	Is the city attracting FDI and is the FDI creating new employment ?	2 - SDG Circular Economy
51	Number of business permits	New business growth with a specific focus on entrepreneurship.	2 - SDG Circular Economy
52	Number and value of small business loans	Are small businesses sustainable ?	2 - SDG Circular Economy
53	Number of commercial flights arriving per year	Does the city have connectivity with other cities ?	2 - SDG Circular Economy
54	Number of tourist nights per year	Tourists are an important indicator of the city as an urban centre and often contribute significantly to the economy.	2 - SDG Circular Economy
55	Tourist expenditure per year	Tourists are an important indicator of the city as an urban centre and often contribute significantly to the economy.	2 - SDG Circular Economy
56	Cost of prime commercial real estate	Affordability & business infrastructure cost indicator.	2 - SDG Circular Economy
57	Amount of prime land with development permits	Indicator of future growth of real estate in the city.	2 - SDG Circular Economy
58	Percentage of municipal waste recycled	Circular material use rate, i.e., the share of material recovered and fed back into the economy	2 - SDG Circular Economy

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
59	Percentage of industrial waste recycled	Circular material use rate, i.e., the share of material recovered and fed back into the economy	2 - SDG Circular Economy
60	Percentage of packaging waste recycled	Circular material use rate, i.e., the share of material recovered and fed back into the economy.	2 - SDG Circular Economy
61	Trade in recyclable raw material within city as percentage of total trade	Importance of recycling as a business within the city	2 - SDG Circular Economy
62	Number of pilot projects in circular economy	Emphasis placed by the city administration on circular economy	2 - SDG Circular Economy
63	Availability of CE strategy at city level	Emphasis placed by the city administration on circular economy	2 - SDG Circular Economy
64	Number of circular economy businesses offered business support	Emphasis placed by the city administration on circular economy	2 - SDG Circular Economy
65	Budget amount allocated to calls for projects on CE	Emphasis placed by the city administration on circular economy	2 - SDG Circular Economy
66	Communication campaigns and events on circular economy, household and food waste reduction	Stakeholder engagement for circular economy	2 - SDG Circular Economy
67	Per capita research papers published every year	Development of new ideas and concepts within the city	3 - People Human Resource Talent
68	Average professional education years of labour force	Average number of years of education. Critical from a smart city perspective with new skill development requirements	3 - People Human Resource Talent
69	Foreign-born population as a percentage of total	Does the city attract talent?	3 - People Human Resource Talent

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
70	Number of local university seats as a percentage of population	Skill development facilities	3 - People Human Resource Talent
71	Number of schools with environmental education programs (seats)	Focus on environmental & sustainability studies	3 - People Human Resource Talent
72	Patent applications filed	Is new information being generated? An indicator of innovativeness	3 - People Human Resource Talent
73	Availability of services and opportunities for finding employment	Facilities for finding jobs, especially key is any government support provided for job support training.	3 - People Human Resource Talent
74	Labour force participation of women	An indicator of diversity	3 - People Human Resource Talent
75	Access to financial services by gender	Indicator of diversity. Are services being limited due to gender?	3 - People Human Resource Talent
76	Proportion of city staff undergoing training per annum, measured against the city's training budget	What % of public funds are being spent on skills enhancement?	3 - People Human Resource Talent
77	Energy efficiency - Energy per unit of GDP	As per IRENA, to ensure that the target or maintaining temp increase to 2 degrees by 2050, is reached. The average efficiency must improve by 2.8% per year until 2050.	4 - Energy Net Neutrality
78	Current percentage of wastewater subjected to some form of treatment	Extent to which water is recycled	4 - Energy Net Neutrality
79	Percentage of energy consumed in city that comes from alternate sources	Is the city developing alternate sources of power? What % of the power is being generated from them?	4 - Energy Net Neutrality
80	Amount of total residential energy used per person or household or unit of floor area	Is there a requirement to sell a specific energy efficient standard? What is the per capita energy use?	4 - Energy Net Neutrality

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
81	Current percentage of people travelling by public transport	Public transport is less energy intensive. What % use public transportation?	4 - Energy Net Neutrality
82	Average age of buses and metro	Older infrastructure tends to consume higher energy. Is there an attempt to renew infrastructure to make it more energy efficient?	4 - Energy Net Neutrality
83	Percentage of local public transport that operates on renewable energy	Are the metros being powered by electricity generated by renewable sources and are the buses hybrid/ electricity driven?	4 - Energy Net Neutrality
84	Average age of cars on road	Older infrastructure tends to consume higher energy. Is there an attempt to renew infrastructure to make it more energy efficient?	4 - Energy Net Neutrality
85	Electric cars as a percentage of total car sales	As per IRENA, 2017 saw 1.24 million electrical cars. The number must reach almost a billion electric cars for the 2050 climate targets and energy neutrality targets to be met.	4 - Energy Net Neutrality
86	Cars driven by alternate fuels – electricity, biofuels, fuel cells (Hydrogen) as a percentage of total	As per IRENA, in 2017, all vehicles released 7.7 GT of CO_2 per year. The new target by 2050 is 3.1 GT Co_2/year, including factoring for growth. The move to electric & alternate fuels will lead not only to neutrality but also to the target of meeting greenhouse emissions.	4 - Energy Net Neutrality
87	Percentage of parking spaces where electronic information about information is available	Clear messages to population about reducing unnecessary driving and energy use.	4 - Energy Net Neutrality
88	Internet connections per million	Originally the metric was growth of the internet year on year. These days, esp. with online learning, wi-fi (broadband) is a basic requirement. A city cannot be smart unless it meets this criteria.	5- Financial Funding ESG
89	Mobile connections per million	Originally the metric was growth of the internet year on year. These days, esp. with online learning, mobile is a basic requirement. A city cannot be smart unless it meets this criteria.	5- Financial Funding ESG
90	Percentage of public space covered by public Wi-Fi	Access to public Wi-Fi. Public Wi-Fi is being considered as the basic infrastructure requirement.	5- Financial Funding ESG

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
91	Net export growth	Are the city's finances sustainable?	5- Financial Funding ESG
92	Extent of preservation of city's cultural heritage as considered with urban planning	Are cultural artefacts being protected?	5- Financial Funding ESG
93	Proportion of total open space by build-up area we can transform into green spaces	Protecting the environment by ensuring the right mix of green & development	5- Financial Funding ESG
94	Percentage of greenhouse gas emissions per capita	Measure of environmental degradation.	5- Financial Funding ESG
95	Percentage of trees in the city in relation to city area	Investment in environmental protection	5- Financial Funding ESG
96	Percentage of green jobs in the local economy	Are more jobs specific to environmental protection being created?	5- Financial Funding ESG
97	Number of homeless people	Measure of sustainability. Similar to some of the earlier measures but while others are in %, this would indicate the total number.	5- Financial Funding ESG
98	Number of household water & electricity connections and ratio to number of households	Percentage of the population with access to a full suite of utilities - clean water, uninterrupted electricity, and sewage.	5- Financial Funding ESG
99	Amount of solid waste generated per head	Per capita waste generation	5- Financial Funding ESG
100	Current levels of household liquid waste disposal.	Per capita liquid waste generation	5- Financial Funding ESG

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
101	Recycling of solid waste	Percentage of solid waste that is recycled	5- Financial Funding ESG
102	Types of noise complaints	Number of noise complaints filed by residents with civic authorities.	5- Financial Funding ESG
103	Dedicated cyber security teams	With crime now moving to digital, cybersecurity is a key part of sustainability. City cannot be sustainable if it is digitally vulnerable.	5- Financial Funding ESG
104	Level of cybersecurity & data breaches in the last 3 years in the city systems	With crime now moving to digital, cybersecurity is a key part of sustainability. A city cannot be sustainable if it is digitally vulnerable.	5- Financial Funding ESG
105	Percentage of transactions that are paid through contactless means	Reliance on digital payments reduces the need to mint money, making the process more sustainable.	5- Financial Funding ESG
106	Level of business satisfaction with the city	Business satisfaction scores	6 - Leadership Governance
107	Level of citizen satisfaction with government.	Citizens' satisfaction score	6 - Leadership Governance
108	Extent of contact initiated by city governance (meetings between city authorities & public-interaction/channels)	Access to citizens of government information and their participation in co-creation.	6 - Leadership Governance
109	Voter participation level	Are voters engaged in the policy making process? The first signal is their participation in the voting process.	6 - Leadership Governance
110	Number of elected representatives/population	Are people adequately represented?	6 - Leadership Governance

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
111	Ratio of city employees (public) per 1,000 population	Are the government services adequately staffed?	6 - Leadership Governance
112	Percentage of population with access to at least six types of commercial amenities providing goods for daily use within 500m	Does the planning provide access to conveniences to the entire population?	6 - Leadership Governance
113	Amount of unaccounted service disruptions in the past 3 years (public transport/utilities)	Unaccounted service disruption is a point of failure. This metric will capture those points of failure.	6 - Leadership Governance
114	Realisation of annual city plans according to its budget. Calculates delays and deficits.	Financial management is a key indicator of governance. This indicator will capture this.	6 - Leadership Governance
115	Level of debt service charges as percentage of city's budget	If a city is under financial stress, it will not be able to invest in future ready infrastructure.	6 - Leadership Governance
116	Number of public sector projects that do not recover money within the expected timeline	Indicator of governance mechanisms.	6 - Leadership Governance
117	Share of budget spent on public services operations & maintenance	Is the money being spent on new capital or maintaining the current infrastructure?	6 - Leadership Governance
118	Amount of prime land held by public sector	Is the government locking its funds in real estate that can be deployed to generate growth?	6 - Leadership Governance
119	Political stability risk	Is there a stability risk?	6 - Leadership Governance
120	Corruption index	At a country-wide level, but country indices are expected to cascade down	6 - Leadership Governance

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
121	Percentage of coverage of fixed and mobile high-speed broadband network	Ease of access to digital infrastructure	7 - Technology & Innovation
122	Percentage of urban management services such as parking, lighting, and traffic controls controlled by IoT	Extent of digitalisation of public services	7 - Technology & Innovation
123	Use of IoT sensors for real-time monitoring of pollution, heat and rainfall for emergency management	Extent of digitalisation of public services	7 - Technology & Innovation
124	Real-time analysis of sensor and surveillance camera video data for faster reaction to public safety threats	Extent of digitalisation of public services	7 - Technology & Innovation
125	Use of drones for inspection of buildings, energy utilities, highways, police and fire services	Extent of digitalisation of public services	7 - Technology & Innovation
126	Percentage of transportation routes combining all modes that use technology and data to provide real-time and fully personalised transportation guidance	Extent of digitalisation of public services	7 - Technology & Innovation
127	Percentage of households covered under smart utility meters	Extent of digitalisation of public services	7 - Technology & Innovation
128	Number of technology hubs to facilitate the sharing of knowledge in the forms of research centres, start-up incubators and accelerators	Creation of digital innovation ecosystem	7 - Technology & Innovation
129	Percentage of the population accessing digital governance services	Extent of digitalisation of public services	7 - Technology & Innovation

#	Indices/Metric Identified	What does the metric denote?	Mapping with Critical factor(s)
130	Percentage of social/ affordable housing	Key inclusiveness indicator	8 - Business Professional CSR
131	Energy efficiency of office buildings and data centres	Number of buildings that are Green certified (LEED or equivalent)	8 - Business Professional CSR
132	Percentage of total workforce that is diverse and inclusive	Support talent growth irrespective of gender or sexual orientation	8 - Business Professional CSR
133	Percentage of competitive sourcing opportunities that include at least one diverse supplier	Open sourcing that is not biased to a gender, ethnicity or sexual orientation	8 - Business Professional CSR
134	Contributions made by companies to charity	Percentage of revenues spent on charity	8 - Business Professional CSR

Table 2. Critical indices for a smart city ecosystem

05.

Blueprint for Smart Cities –A Social Contract

Cities are complex urban systems that have several heterogeneous agents (e.g., citizens, policy makers, etc.) each making decisions about how they act and behave. The key interacting stakeholders in a smart city are universities, industry, government and society. All four (Quadruple) stakeholders have an important role to play in developing or creating a smart city or ecosystem.

Stakeholders play different but complementary roles in the development of a smart city.

- Policy makers (often governments) play an important role in developing regional policies and infrastructure that include technology, human resource & talent development and social protection.
- Universities or regional centres of excellence need to play the following role: effective and efficient transfer of knowledge as well as knowledge co-creation with the other stakeholders.
- Industry, which is the engine of economic growth in a smart city, needs to ensure that equitable wealth is created for the benefit of society.

It is critical that these stakeholders will only collaborate with each other via "social contracts". Social contracts (D'Agostino, 1996, 23) suggest that an individual's moral and/or political obligations are dependent upon a "contract or agreement among them to form the society in which they live" (D'Agostino, Gaus, & Thrasher, 2019). We argue that a social contract is essential for the development of a smart city. The social contract between the four (Quadruple) stakeholders allows us to develop a blueprint for a smart city.

We represent our blueprint in Figure 10. The rest of the section will explore these areas and corresponding levers.

	Policy Makers	Universities	Businesses	Citizens/Society
Social Contract / Strategic Action	**Policy Makers** Regional policies and infrastructure Develop regional policies and infrastructure that includes technology, human resource & talent development and social protection.	**Universities** Knowledge transfer and co-creation Develop effective and efficient knowledge transfer merchanisms as well as co-create knownledge with other stakeholders.	**Businesses** Equitable wealth creation Ensure that equitable wealth is created for the benefit of society.	**Citizens/Society** Participate and adopt systems Citizens participate well and are active partners, both in the development of knowledge and in the adoption of emerging and new technologies, so the benefits from automation and industry 4.0 can result in social, economic, political and environmental impact.
Value Creation	• Integration into resident business clusters • New business clusters • AI and Industry 4.0 framework for region	• Knownledge transfer partnerchip with resident business clusters • Incubator and accelerator programs to spin off new business clusters.	• Business models that are based on "sustainable equilibrium" • Be active partner in the quadruple helix ecosystem	• Citizen-led projects for social, scientific, educational and sustainable benefits • Participation in the quadruple helix ecosystem
Levers	• Develop technology adoption incentives • fast-track digital regulations • Develop digital infrastructure and data • Support smart governance	• Upskill regional labour • Host regional innovation networks • Steer and support research project to engage with regional challenges • Raise the quality of regional innovation strategy	• Create shared value in products and services with society • Connect regional business to global value chains and trade corridors	Both digital and non-digital citizens become active participants in the design of smart eco systems. Design and lead citizen-driven projects for the benefits of all stakeholders.
Intelligence	1. Wellness, health, education & liveability 6. Leadership & governance	3. People, human resources & talent 7. Technology & innovation	2. SDG circular economy 4. Energy net neutrality 5. Financial funding 8. Business professional	**OUTCOME** Social Environmental Political Economic

Figure 10. Blueprint for Smart Cities – A Social Contract

Policy Makers

Social Contract/Strategic Action

Develop regional policies and infrastructure that include technology, human resource & talent development and social protection.

A study led by Durham University Business School in partnership with one of the UK's Local Enterprise Partnerships (North East LEP) shows that targeted regional policy is one of the most critical factors in creating an innovative ecosystem. While there is a surge in the use and adoption of technology in businesses, the rate of adoption is not uniform. Any government blueprint for developing Smart Cities must expedite technology adoption and focus on accelerating innovation and productivity. The MGI industry digitalisation index shows that "digitally advanced nations" have gaps in their digital infrastructure and human talent. It is therefore important for governments to have both national and regional policies that support infrastructure that includes technology, human resource and talent development, and social protection. It is not surprising to note that the OECD (Organisation for Economic Co-operation and Development) has recommended that all governments should develop a Digital Strategy to increase innovation and productivity. For example, the UK government has developed the UK Digital Strategy that sets out to show how the UK will build on its digital success to date to develop a world-leading digital economy that works for everyone. This strategy specifically considers technology and human resources. Other governments like Singapore, Canada, China, Finland, France and the U.S.A. also have developed such national strategies. Therefore, this white paper calls for policy makers to consider both national and regional digital strategies that include technology, human resources talent development and social protection.

Value Creation

Value creation as a concept implies that all stakeholders benefit from any action. Value creation within this context means governments must develop regional policies that consider the following three critical perspectives:

1. Regional policies must ensure that resident business clusters are fully integrated into the policies. Often, government policies are so focused on developing "new business clusters" and "new opportunities" that resident business clusters are not consulted or are often ignored at the expense of proposed new clusters. For example, proposing the development of a new "creative digital" cluster at the expense of an existing "manufacturing" cluster.

2. Development of new business clusters that connect to a place. These new business clusters must take into account the importance of the "place" as well as the challenges associated with retraining local talent.

3. Developing an Artificial Intelligence and Industry 4.0 framework for regions. There is an urgent need to develop a regional AI and Industry 4.0 framework. These must not only dovetail into national policies but ensure that "sustainability equilibrium" can be achieved by the developed AI and Industry 4.0 strategies.

Levers

Policy makers must view levers as "signals" and "nudges" rather than mechanisms to dictate or control the stakeholders. We have identified four developmental levers that should be adopted by policy makers as part of this social contract.

1. Develop technology-adoption incentives
2. Fast-track digital regulations
3. Develop digital infrastructure and data
4. Support smart governance

Intelligence

Intelligence in our framework is a mechanism for the relevant stakeholder to judge their individual progress. For example, questions like "Are we achieving the aims of our social contract?" can be answered.

In our study, we argue that the following indices are a good proxy for providing policy makers with the intelligence to judge their contribution to this social contact:

Wellness, Health, Education & Liveability (Indices 1 to 38)
Leadership & Governance (Indices 106 to 120)

Universities

Social Contract/Strategic Action

Develop effective and efficient knowledge transfer mechanisms as well as co-create knowledge with other stakeholders.

Universities or regional knowledge centres are not the key hub for knowledge creation and dissemination but are engaged with societal engagement. This bi-directional interaction between a university and its region (also known as university-industry-region interaction) is becoming a critical component in the design of regional strategies. We argue that universities or regional knowledge centres should work with the other stakeholders (policy makers, industry and citizens) in the co-creation of knowledge that is relevant, timely and essential to the development and sustainability of the smart city ecosystem.

Value Creation

Value creation within this context means that universities must develop regional engagement practices that consider the following two critical perspectives:

1. Knowledge transfer partnership with resident business clusters
2. Incubator and accelerator programmes to spin off new business clusters

Levers

We have identified four developmental levers that should be adopted by universities as part of this social contract.

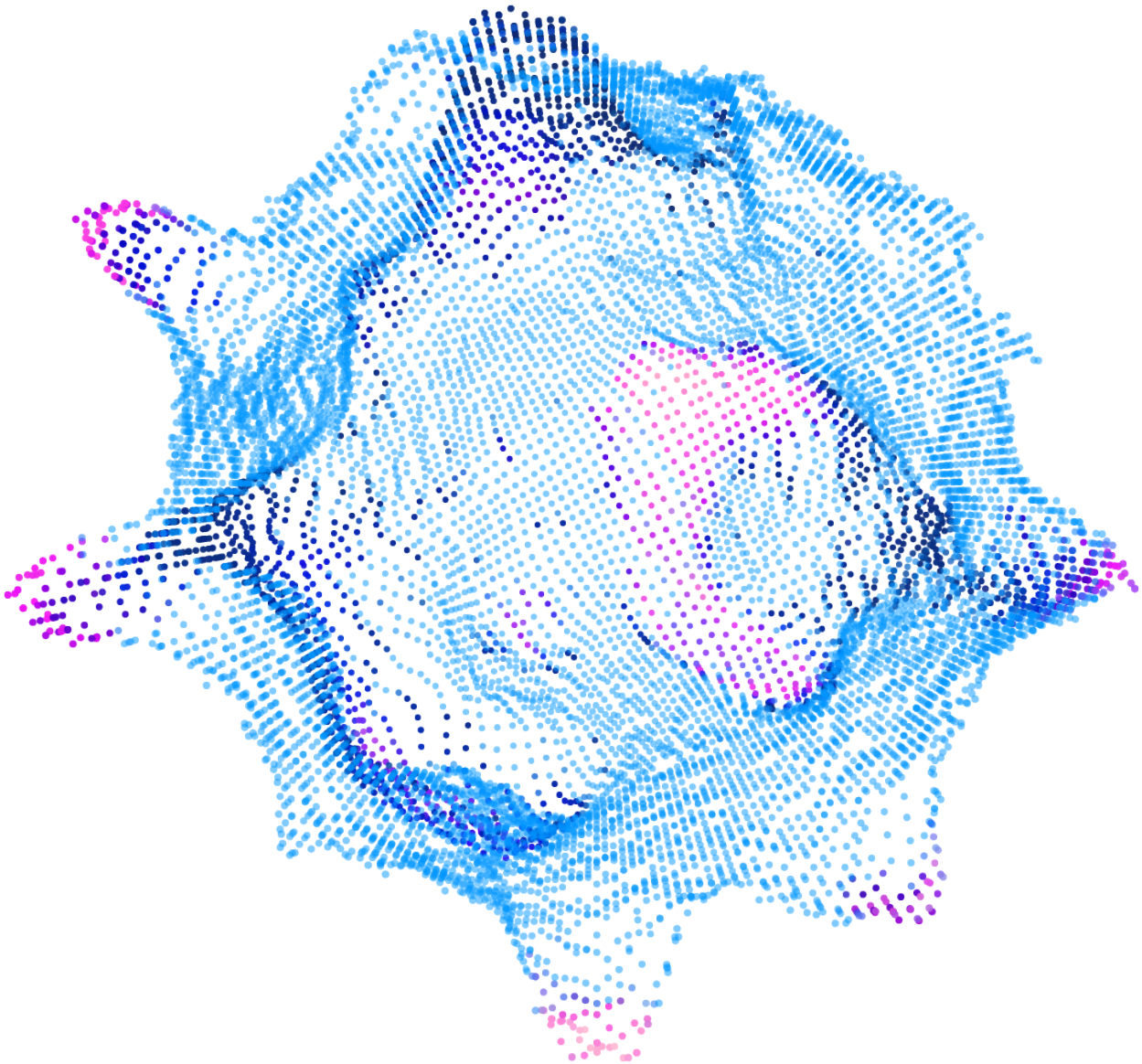
1. Upskill regional labour
2. Host regional innovation networks
3. Steer and support research projects to engage with regional challenges
4. Raise the quality of regional innovation strategy

Intelligence

In our study, we argue that the following indices are a good proxy for providing policy makers with the intelligence to judge their contribution to this social contact:

People Human Resource Talent (Indices 67 to 76)

Technology & Innovation (Indices 121 to 129)



Industry

Social Contract/Strategic Action

Ensure that equitable wealth is created for the benefit of society.

Entrepreneurs and industry are critical and become the economic power engines to increase the supply side of the industrial economy. We argue that businesses must focus on developing new forms of "sustainability equilibrium" models to ensure that equitable wealth is created for the benefit of society.

Value Creation

Value creation within this context means that businesses must develop regional engagement practices that consider the following two critical perspectives:

1. Business models that are based on "sustainable equilibrium"
2. Being active partners in the quadruple helix ecosystem

Levers

We have identified two developmental levers that should be adopted by businesses as part of this social contract:

1. Create shared value in products and services with society
2. Connect regional business to global value chains and trade corridors

Intelligence

In our study, we argue that the following indices are a good proxy for providing policy makers with the intelligence to judge their contribution to this social contact:

SDG Circular Economy (Indices 39 to 66)
Energy Net Neutrality (Indices 77 to 87)
Financial Funding–Environmental, social and corporate governance–ESG (indices 88 – 105)
Business Professional – Corporate Social Responsibility – CSR (Indices 130 – 134)

Citizens

Social Contract/Strategic Action

Participate and be active and willing partners in the development of knowledge as well in the adoption of emerging and new technologies so benefits from automation and industry 4.0 can result in social, economic, political and environmental impact.

The main aim of a smart city ecosystem is to ensure that a smart city is a "humancentric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes". Therefore, in this study, we argue that citizens need to be willing and active participants in the creation of a smart city ecosystem.

Value Creation

Value creation within this context means that citizens must develop regional engagement practices that consider the following two critical perspectives:

1. Citizen-led projects for social, scientific, educational and sustainable benefits
2. Participation in the quadruple helix ecosystem

Levers

We have identified two developmental levers that should be adopted by businesses as part of this social contract:

1. Citizen-led projects for social, scientific, educational and sustainable benefits
2. Participation in the quadruple helix ecosystem

Intelligence

As stated earlier, intelligence in our framework is a mechanism for the relevant stakeholder to use to judge their individual progress. The main outcome for a citizen in a smart city is that Social, Environmental, Political and Economic aims are met to create a "humancentric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental changes".

06.

Application of the Developed Blueprint for Smart Cities

In this section, we consider four complex city regions to highlight how a blueprint can be developed to create a smart city ecosystem. See Table 3.

-	City A	City B	City C	City D
Type	Small Town	Regional Metropolis	National Metropolis	Megacity
Governance	Elected Counselors	Civil Servant Commissioner	Director General of Municipality	Elected Mayor
Region Type	Rural	Urban	Urban	Urban
Key Economy	Rural Tourism	University City	Manufacturing	Finance and Service
Area	12.4 sq miles	38.10 sq miles	1,588 sq miles	1,572 sq miles
Population	48,069	951,118	5,000,000	14,257,962
Density	4,000 sq miles	25,000 sq miles	11,670 sq miles	14,670 sq miles
Continent	Western Europe	South East Asia	Middle East	Western Europe
Country	England	India	UAE	England

Table 3. Profiles of four city types

The four city regions in Table 3. A range of city regions spanning from small towns to megacities.

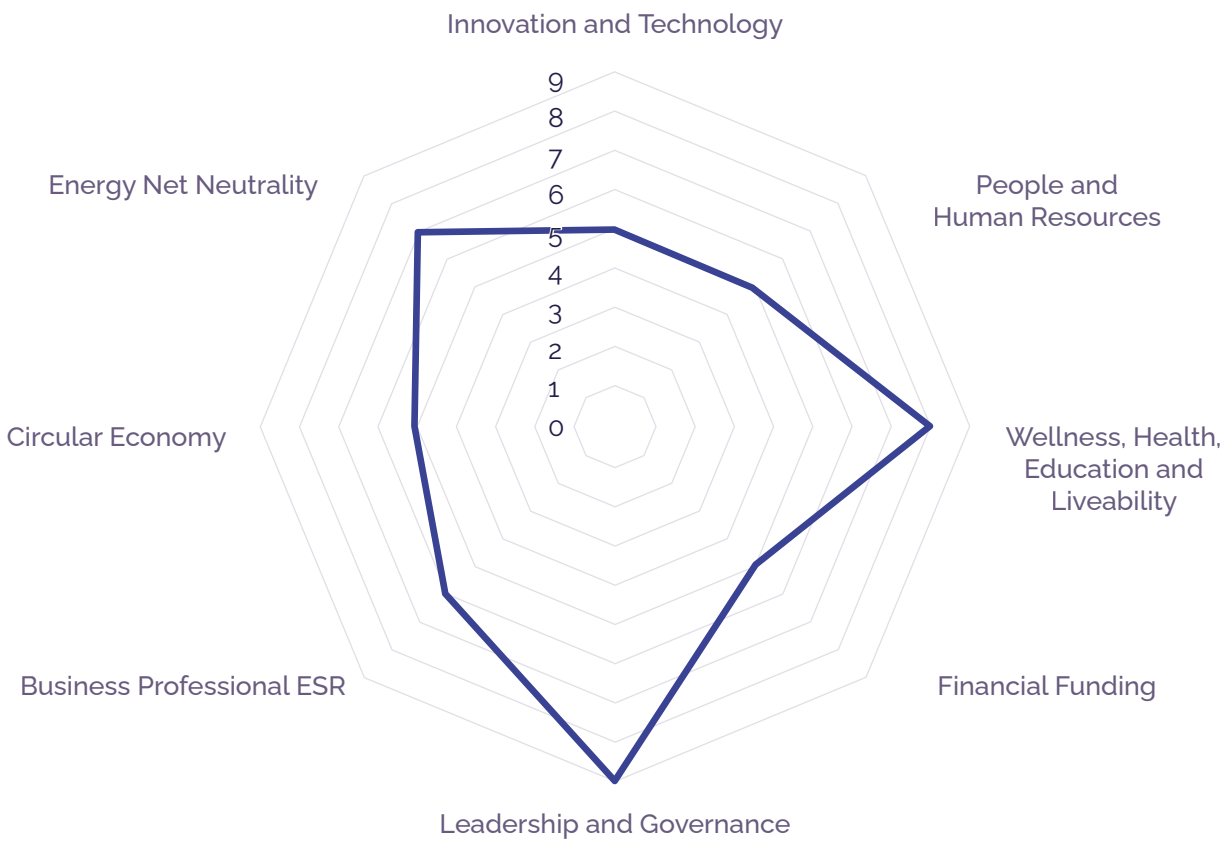


Figure 11. City A Profile

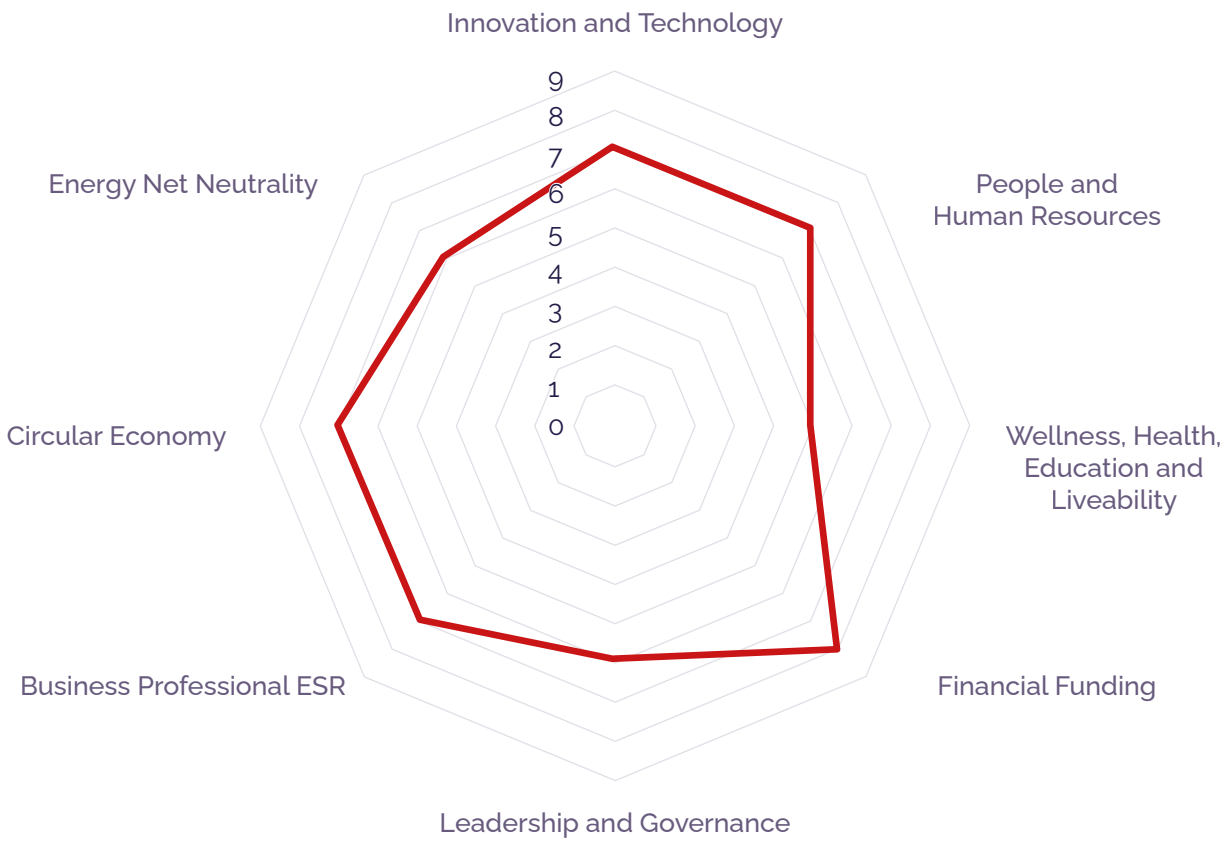


Figure 12. City B Profile

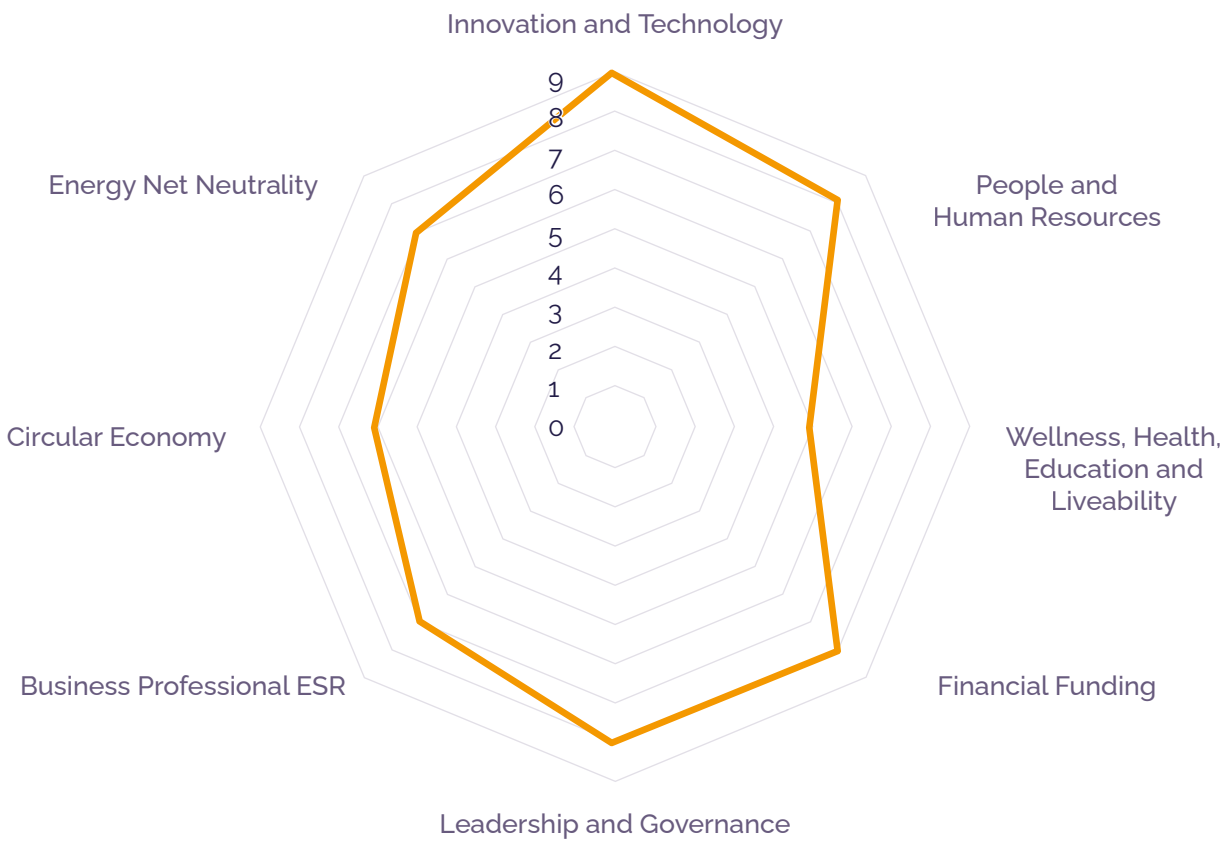


Figure 13. City C Profile

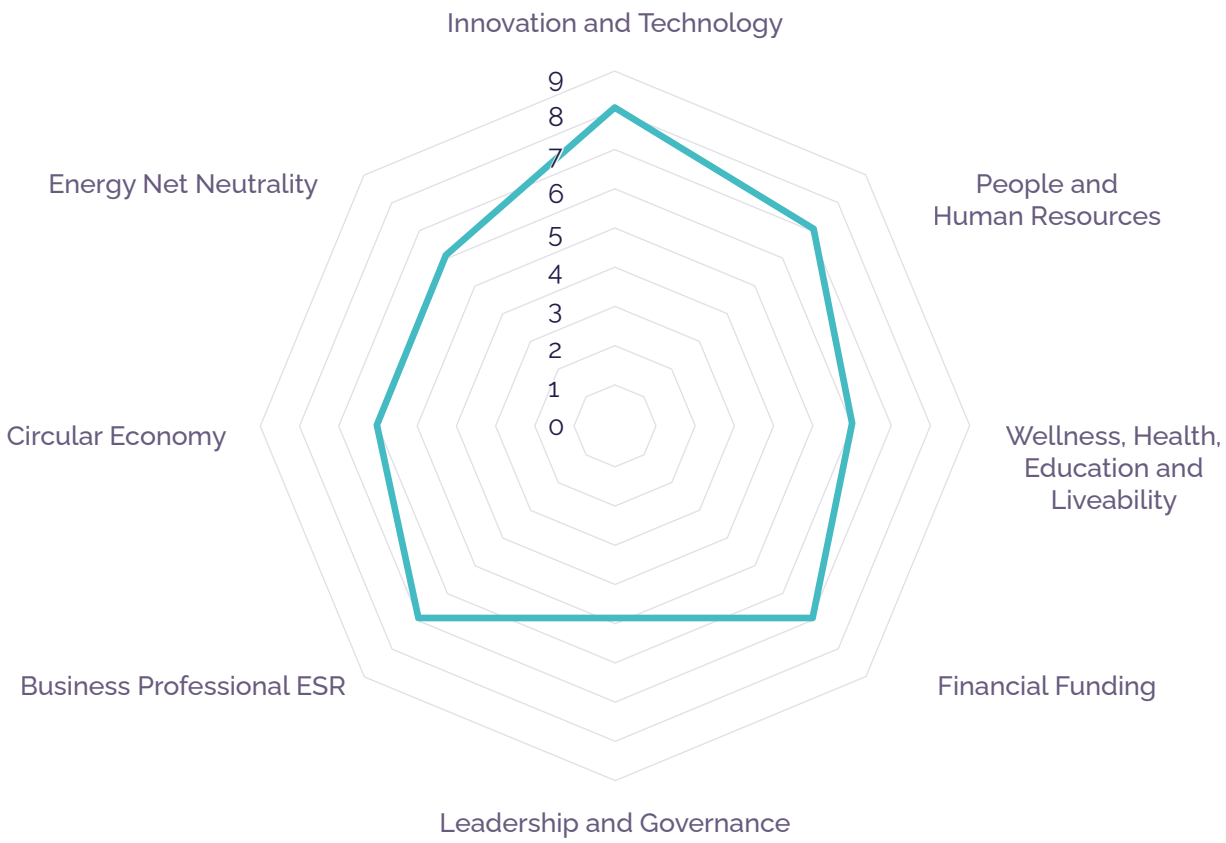


Figure 14. City D Profile

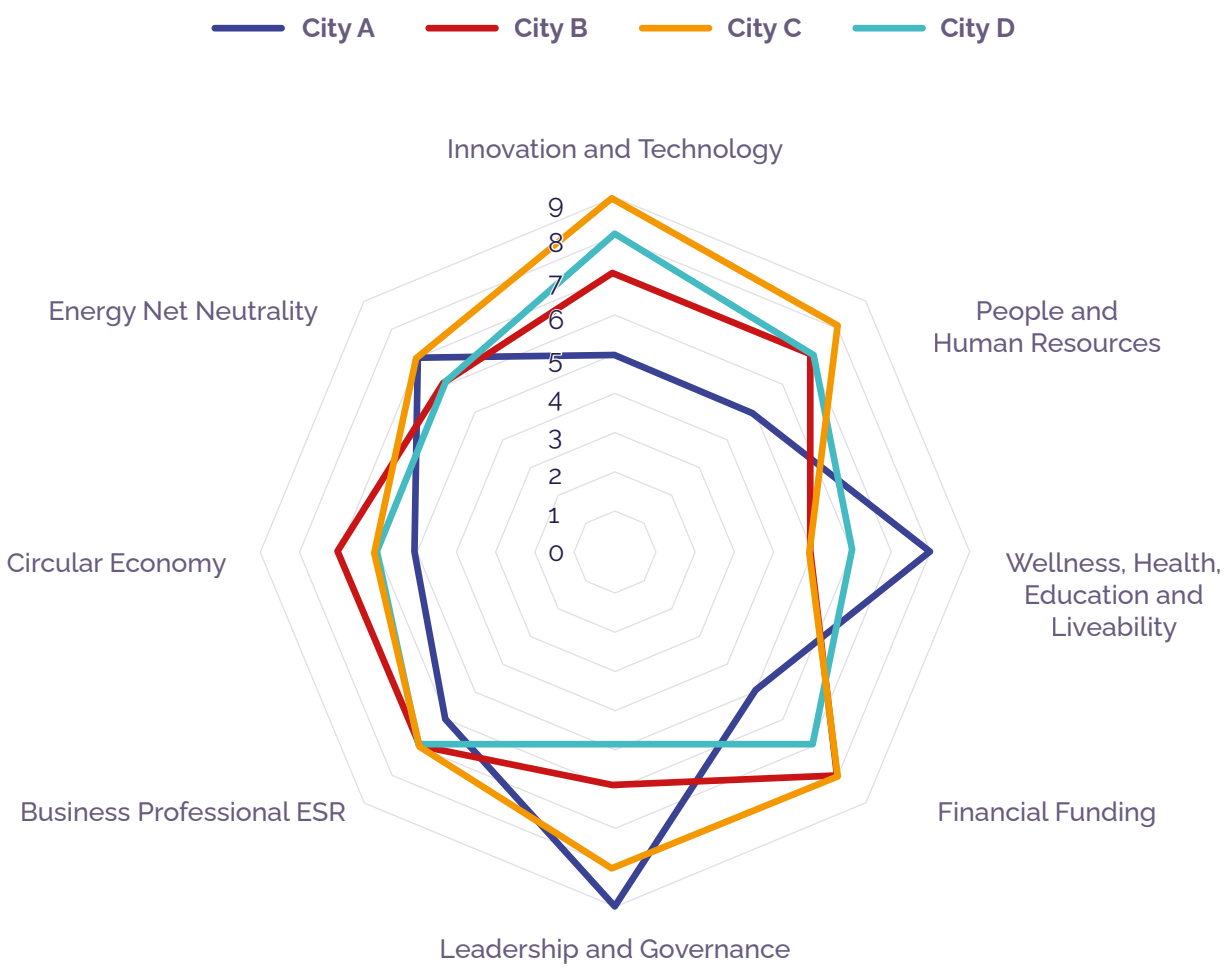


Figure 15. Comparison of the City Profiles

As can be seen in the above figures, profiles of cities can be compared using the eight critical factors developed made up of 134 key performance indicators. However, it is not the intention of this report (or our methodology) for cities to use this to create rankings, but rather use the findings to develop knowledge communities. Knowledge communities can collaborate to develop workable and tangible plans to develop certain factors. For example, in figure 13 above, City C scores 5 on the Leadership and Governance dimension, while Cities A, B and D score 6, 8 and 9 respectively. These are cumulative scores based on indices 106 to 120. In this example, City D could take a lead in developing a knowledge community on issues related to Leadership and Governance, which can then be used by cities B, A and C in particular. Issues that could form the basis of discussions in these knowledge forums are access to citizens of government information and their participation in co-creation (index 108) or citizen satisfaction (index 107).

List of Figures and Tables

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www.durham.ac.uk

www.citiesabc.com

www.ztudium.com

www.techabc.org

www.openbusinesscouncil.org

Citizens, industry, policy makers and society need to act together to create a human-centric ecosystem where physical and cyberspace systems are interconnected to bring about social, economic, political and environmental change.

...

Cities play an important role in tackling climate change due to human population and the ever-growing pressure on energy usage. Cities are currently under huge pressure due to the COVID19 pandemic, which is not only impacting public health but also the economy and social wellbeing of citizens. Building cities that are inclusive, safe, resilient and sustainable requires extensive coordination between policy makers, universities, industry and citizens (also called quadruple stakeholders in our report). This report outlines a response to the circularity challenge by proposing a social contract model to engage the quadruple stakeholders in developing inclusive, safe, resilient and sustainable cities – which contributes directly to SDGs 8 & 11. We identify the following eight factors that are essential to this social contract and are detailed in this report: Innovation & Technology, People & Human Resources, Wellness, Health, Education & Liveability, Financial Funding, Leadership & Governance, Business Professional ESR, Circular Economy and Energy Net Neutrality.

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