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Smart city

How smart is it actually?

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TIIVISTELMÄ:

Väestönkasvu, siitä aiheutuva muuttoliike ja nopea kaupungistuminen ovat maailmanlaajuisia megatrendejä, jotka usein vaikuttavat kielteisesti elämisen ja asumisen laatuun kaupungeissa. Älykaupunki on ylemmän tason konsepti, jonka avulla kaupungit yrittävät muokata sosiaalista, taloudellista ja ympäristönsä kehitystä kestävämmälle pohjalle. Tässä tutkielmassa tarkastellaan, miten älykaupungin konsepti on määritelty, mitkä ovat ne taustaolettamukset ja perusteet, joiden varaan älykaupunkien tieteellinen tutkimus pohjautuu, mitkä ovat älykaupunkitutkimuksen viimeisimmät tulokset ja innovaatiot, miten älykaupunkihankkeet saavuttavat tavoitteensa ja miten niiden perusteet ja taustaolettamukset vaihtelevat älykaupunkien välillä. Tämän tutkimuksen tavoitteena on kriittisesti tarkastella älykaupunkien tutkimusparadigmaa ja löytää mahdollisia sudenkuoppia sekä ristiriitaisia tutkimusaiheita ja -tuloksia, joita voitaisiin käyttää älykaupunkien jatkotutkimukseen ja -kehittämiseen tulevaisuudessa. Tämä tutkimus on toteutettu perinteisenä kriittisenä kirjallisuustutkimuksena. Lähdeaineistona on käytetty älykaupunkien viimeisimpiä akateemisia tutkimustuloksia ja julkaisuja, älykaupunkihankkeiden omia nettisivustoja ympäri maailman sekä kontrastin vuoksi myös viimeisimpiä populaarin lähdekirjallisuuden käsittelemiä aiheita ja ilmiöitä. Kirjallisuustutkimusta on täydennetty kvalitatiivisella älykaupunkivertailulla, jossa Helsingin, Singaporen ja Lontoon älykaupunkihankkeita on vertailtu keskenään. Työn tutkimusstrategia muistuttaa ankkuroitua teoriaa, jossa induktiivisen päättelyn avulla pyritään lähdeaineistosta löytämään ja luomaan väitteitä, perusteluja ja johtopäätöksiä älykaupunkien muodosta, olemassaolon oikeellisuudesta ja tulevaisuudesta. Tutkimuksessa havaittiin seuraavat pääkohdat: älykaupunki voidaan määritellä usealla, myöskin samanaikaisesti päällekkäisellä tavalla; älykaupunkien kehittäminen nähdään yleensä tieto- ja viestintäteknologisten innovaatioiden kehittämisenä, vaikka samanaikaisesti usein vaaditaan myös inhimillisemmän näkökulman korostamista; älykaupunkihankkeet muodostavat monitahoisia, monia tieteenaloja koskettavia alustoja, jotka vaativat nykyistä kokonaisvaltaisempaa tarkastelua ja arviointia; nykyiset älykaupunkien menestyksen mittarit ja arviointitavat vaihtelevat huomattavasti, jolloin älykaupunkien älykkyyden ja onnistumisen yhteismitallinen arviointi on vaikeaa; jotkut havaituista älykaupunkien ominaisuuksista ja ratkaisuista ovat tehottomia tai jopa kielteisesti älykaupunkien tavoitteisiin vaikuttavia. Tässä tutkimuksessa päädyttiin seuraaviin johtopäätöksiin: älykaupunkihankkeiden monimutkaisen ja ristiriitaisen luonteen takia nykyinen älykaupunkitutkimus- ja kehitys ei täysin pysty vastaamaan näiden ristiriitaisuuksien ja keskinäisriippuvuuksien tuomiin haasteisiin; nykyinen älykaupunkitutkimus ei myöskään ole tieteellisesti riittävän monialaista. Tämän tutkimuksen pohjalta voidaan suositella, että tulevaisuudessa älykaupunkien kehitys voisi pohjautua enemmän tietojärjestelmätieteiden tutkimusmetodologioiden hyödyntämiseen, jolloin älykaupunkien vaatimat sosiotekniset ja monitieteelliset näkökulmat saataisiin paremmin havaittua, katettua ja arvioitua tutkimustuloksissa. Tulevaisuudessa tarvitaan myös tutkimusta siitä, kuinka tehokkaasti monitieteellinen älykaupunkitutkimus onnistuu.

AVAINSANAT: Avoin tieto, kaupungistuminen, kestävä kehitys, älykaupunki, älykkäät kansalaiset, älykäs hallinto, älyliikenne, älytalous

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ABSTRACT:
The global megatrends of population growth and fast urbanisation are negatively impacting the life in the cities. Smart city is the high-level concept by which the cities try to address the need to improve their social, economic and environmental sustainability. This thesis studies how the smart city concept is defined, what are the underlying hypotheses and assumptions on which the smart city research is based on, what are the latest results and innovations of the smart city research, how the smart city initiatives are meeting their objectives, and how the hypotheses and assumptions may vary between the smart city initiatives. The objective of this study is to critically review the smart city research paradigm to find possible pitfalls, conflicting results and topics for further study and improvement. This research is conducted as a traditional critical literature review, covering the current academic literature on the smart city topic, the websites presenting the smart city initiatives around the world, and the latest popular literature for contrasting views. A qualitative comparison of the smart city initiatives in selected cities – Helsinki, Singapore and London – complements the literature review. The research strategy in this study approximates the grounded theory, utilising inductive reasoning to generate arguments and conclusions about the form, validity and future of the smart city. This study produced the following key findings: there are many different and overlapping definitions of smart city; the smart city development is mostly seen as the responsibility of smart ICT implementations, while simultaneously demanding for a more focused human viewpoint; the smart city initiatives form complex, multidisciplinary platforms that require holistic evaluation; the current evaluation methods and rankings of the smart cities vary considerably, making the evaluation of the success of the smart cities difficult; some of the existing smart city elements and proposed solutions are ineffective or even counterproductive for the smart city objectives. The main conclusions of this study were that the complex nature of the smart city initiatives and the conflicts and interdependencies of the smart city objectives are not fully addressed in the current smart city research, and that the current smart city research is not adequately multidisciplinary in nature. For the future, this research argues for the increased utilisation of research methods used in information systems science for their ability to address socio-technical and multidisciplinary problems. Also, the need for a future research on the efficacy of the multidisciplinary research of smart cities is identified.

KEYWORDS: Open data, smart citizens, smart city, smart economy, smart governance, smart traffic, sustainability, urbanisation

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Abbreviations

3G	Third generation wireless digital cellular network technology
4G	Fourth generation wireless digital cellular network technology
5G	Fifth generation wireless digital cellular network technology
AI	Artificial intelligence
ANN	Artificial neural networks
API	Application programming interface
CaaP	City as a platform
CAD	Canadian Dollar
CANN	Cascaded artificial neural network
CAV	Connected and autonomous vehicles
CI	Community informatics
CKAN	Comprehensive knowledge archive network
CO_2	Carbon dioxide
EC	European Commission
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
ENoLL	European Network of Living Labs
FaaS	Freight as a service
GBP	Pound sterling
GDP	Gross domestic product
GNSS	Global navigation satellite systems
GPS	Global Positioning System
HRI	Helsinki Region Infoshare

HSY	Helsingin seudun ympäristöpalvelut, Helsinki Region Environmental Services Authority
IC	Information and communication
ICT	Information and communication technology
IMD	International Institute for Management Development
IMDA	Infocomm Media Development Authority
IoT	Internet of things
IS	Information systems
ISS	Information systems science
ISO	International Organization for Standardization
L3	London Living Labs
LL	Living lab
LoRa	Long-range, low-power wide-area network technology
MaaS	Mobility as a service
NFC	Near-field communication
NGO	Non-governmental organisation
ODI	Open Data Institute
OIP	Open Innovation Platform
PIR	Private information retrieval
PPDM	Privacy-preserving data mining
QoL	Quality of life
R&D	Research and development
RFID	Radio-frequency identification
SDC	Statistical disclosure control
SMLL	Smart Mobility Living Lab
TfL	Transport for London
TTP	Trusted third party
UN	United Nations
UK	United Kingdom
USD	United States Dollar
WCCD	World Council on City Data
Wi-Fi	Wireless local access network technology

1 Introduction

Today's world is facing two trends that greatly affect our way of life simultaneously: population growth and urbanisation. While the growing cities offer job opportunities, accommodation and infrastructure to support better quality of life (QoL) for the increasing number of citizens the dramatic urbanisation also negatively impacts the environment, the lifestyles in the societies and the governance of the cities (Silva, Khan, & Han, 2018).

1.1 Background

The smart city is a common concept under which various research and development programmes are collected to prevent and mend the negative impacts of the rapid urbanisation. The term smart city is said to have first appeared in the middle of the 1990s, when the cities promoted themselves after introducing new information and communication technology (ICT) infrastructure or e-governance services, or when attracting technology companies to provide new economic growth to the region (Hollands, 2008). The smart city development is today a global phenomenon and it is closely related to the 17 so called sustainable development goals listed in the 2030 Agenda for Sustainable Development of the United Nations (UN) Department of Economic and Social Affairs (United Nations, 2019). All UN member states have adopted the agenda in 2015. Especially, the sustainable development goal 11 lists objectives for inclusive, safe, resilient, and sustainable cities on which many of the background assumptions and hypotheses of the smart city research are based.

However, regardless of the recent visible enthusiasm on the smart city development, it is not yet quite clear if the smart city initiatives really are making the cities smarter. Are the alleged smart city innovations useful or effective in improving the city sustainability? Are the cities becoming easier to plan and govern? Is the modern technology simplifying or complicating the smart city development? And, do the citizens find the smart cities more liveable and desirable places to dwell and work in? What if the smart city development is found to be counterproductive for the objectives and good intentions of the smart city?

1.2 Research focus

This study first focuses on the many definitions of smart city to find common nominators and differing factors among them. Secondly, the typical innovation areas within the smart city research are introduced. Special attention is paid to the smart city innovations touching the information systems science (ISS). At the same time, it is realised how multidisciplinary the smart city research needs to be in order to produce practical and useful results by which the cities and the life of their citizens can be further developed and improved. Thirdly, a set of three representative smart cities – Helsinki, Singapore and London – are studied to compare what are the actual smart city research projects and innovations they are concentrating on, are there any similarities or differences to be found in their background assumptions, and how these cities value and utilise their results. Finally, this study then concludes with the evaluation on how the smart city ideology meets its objectives.

1.3 Research aim

The research aim of the study is to better understand the underlying hypotheses and background assumptions of the smart city ideology. The objectives of this study can be formulated as the following four Research Questions:

1. What attracts the current enthusiastic smart city research and development?
2. Is the evaluation of the smartness of the cities based on sound judgement?
3. Are there any issues or challenges that may have been overlooked or neglected in the smart city research so far?
4. What may be the opportunities for better future smart city research and development?

1.4 Research method and strategy

This study is carried out as a traditional literature review to find out what are the current points of interest in the smart city research. The emphasis is on the latest academic and peer-reviewed literature, but the novelty of the subject also necessitates a peek into the popular business and science publications to see if there are any new trends or undercurrents that may have so far been neglected by the science community.

The selected research strategy for this study approximates the grounded theory. This exploratory strategy allows for the empirical study and perception of the largely unstructured smart city phenomena. The grounded theory also enables the building up of a more holistic conceptual model of the smart city as a synthesis influenced by the reviewed literature.

1.5 Literature review

The literature review for this study is conducted as keyword-based searches for academic literature, popular literature and websites that cover the topic of smart city. The keyword “smart city” is complemented by searching for keywords that further define the smart city, including “smart sustainability”, “smart governance”, “smart economy”, “smart traffic”, “smart mobility”, “smart technology, “smart data” and “smart citizens”. It is evident that the keywords “smart technology” and “smart data” result in numerous references to detailed topics of cloud-based services, internet of things, sensor networks, artificial intelligence, big data, and information and communication technology. Each of these topics would be an interesting study subject of their own. In this work, however, it is not feasible to describe and explain these topics in detail. Instead, the intention is to capture only their essence in forming and enabling the smart city.

The tools used for the literature search consisted of a normal Windows base personal computer and the Google Chrome web browser. The main sources of literature were the

Finna search services through the Tritonia Finna portal, and the Google search tools, especially through its Google Scholar search engine. The smart city is relatively young as a research topic. Therefore, it was not difficult to limit the age of the articles. All the used articles are from the third millennium, and the bulk of them from the latter half of the 2010s.

In the following chapters the literary review is structured so that first, in Chapter 2, the definition of the smart city is studied from various perspectives: what is the infrastructure of the smart city, what are the dimensions of the smart city, and who are the stakeholders of the smart city. The chapter ends with an introduction to the interesting smart cities and smart city initiatives around the world. Chapter 3 contains the grounded theory section of the literature review. By inductive reasoning from the literature, the apparent building blocks of the smart city are formulated and introduced. Chapter 4 concludes the literature review by providing a synthesis and a framework of the smart city based on the findings of Chapter 2 and Chapter 3.

The literature review is complemented in Chapter 5 with a qualitative comparison of three representative smart cities and their smart city initiatives around the globe. The aim of this chapter is to present how the cities themselves define their smart city initiatives, and the practical actions the cities take towards becoming smart. Here the official smart city websites of the selected communities offer and interesting starting point to explore what achievements the cities themselves value the most in their smart city development, and what challenges they rather may not mention.

1.6 Value of this research

This study adds value to the research on smart cities by providing a critical view to the topic. The study combines the results of the latest academic smart city research and the practical smart city initiatives and draws conclusions on the practicality and usefulness of the smart city development. This study also endeavours to add a philosophical approach to the ICT research and to the discussion about the topic of the digital transformation of the society.

The topic and the findings of this thesis hopefully also interest the broader audience and scientific community as the smart city concept considers so many of today's megatrends: urbanisation, sustainability, clean and safe environment, intelligent traffic, and mobility solutions. The topic is also very closely related to internet of things (IoT), open data, and especially the privacy and safety of personal data, which are increasingly utilised the more sophisticated and complex the smart city applications become. This should offer opportunities and complex challenges for truly multidisciplinary research projects and scientists in the future.

2 Definition of smart city

This chapter seeks to find out how a smart city is defined and why smart cities are considered important, or even necessary, today. There are various stakeholders involved in the smart city development, for example: citizens, educational institutions, municipal administrators, and urban planners, and they all have a slightly differing view of the smart city.

2.1 European smart city

The digital single market policy of the European Commission (EC) provides a good starting point for defining what a smart city is:

> *A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business.*
>
> *A smart city goes beyond the use of information and communication technologies (ICT) for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population (European Commission, 2019).*

This smart city definition suggests that the smartness of the city is built on the old, existing city infrastructure, instead of having to build a completely new infrastructure. Then, the old infrastructure is put to better use with the help of digital ICT innovations. This should ensure higher efficiency, lower resource consumption and less waste and pollution, while making the city safer, more liveable, and the city administration more approachable. Interestingly, in the European context the ageing of the population is highlighted in the smart city definition over the accelerating population growth of the cities.

The EC definition of smart city also illustrates the enormous depth of the smart city problematics and the unfaltering confidence in the information systems. The clever use of ICT is expected to solve any problem from the old plumbing and sewage to city administration all the way up to the political decision making, too.

The EC addresses the issue of growth from the viewpoint of the economic and financial crisis experienced during the first decade of the new millennium (European Commission, 2010). In order to catch up with the lost years of economic and social progress, the Europe 2020 strategy has prioritised objectives for smart, sustainable and inclusive grow: The smart growth develops the economy from the innovation and knowledge perspective. The sustainable promotes the competitiveness of the economy from the resource efficient and environmentally friendly perspective. The inclusive growth targets higher employment rates through social and regional unity.

Vienna University of Technology has been profiling and benchmarking medium-sized, between 100 000 and 500 000 inhabitants, and large, 300 000 to 1 million inhabitants, European smart cities since 2007 (Giffinger, Kramar, Haindlmaier, & Strohmayer, 2015). Their fourth, and latest, release of the smart city model is from 2015. The model ranks the smart cities by comparing how the cities perform in six key fields of smartness: smart governance, smart economy, smart mobility, smart environment, smart people and smart living, depicted in Figure 1.

These six key fields provide a good starting point for comparing how the other definitions of smart city cover these same fields: The smart governance ranks the cities by their political awareness, the quality of public and social services and the efficiency and transparency of the city administration (Giffinger, et al., 2015).

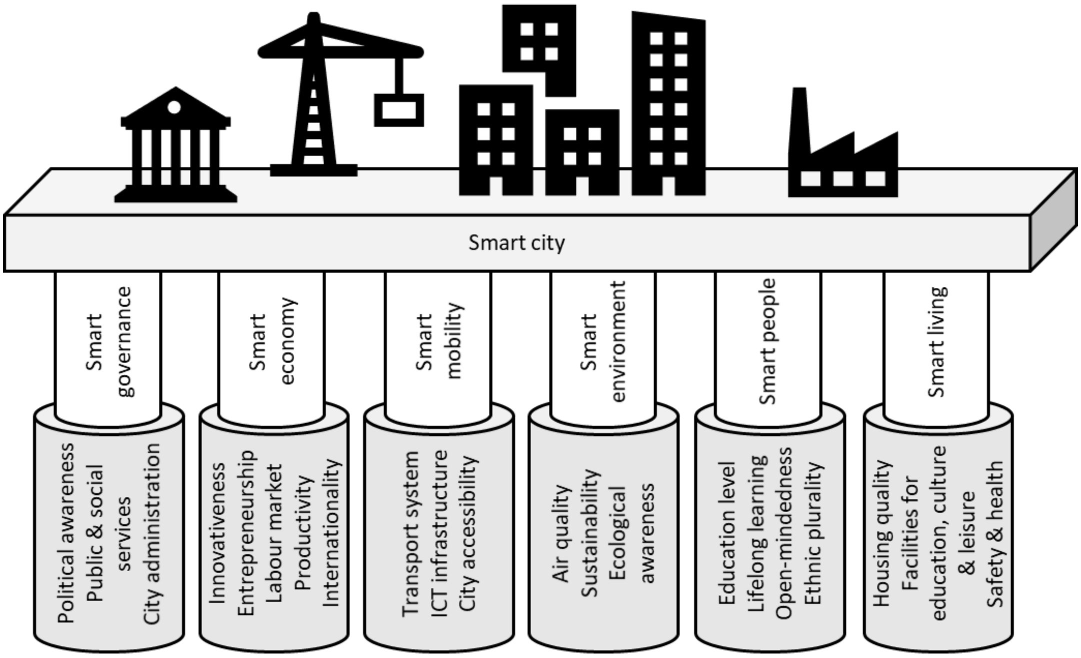

Figure 1. Six key fields of urban smartness (adapted from Giffinger, et al., 2015).

The smart economy field considers the spirit of innovativeness and entrepreneurship, how well the labour market is working, how productive the city is, and how deep the city is integrated internationally (Giffinger, et al., 2015). Additionally, the smart economy regards a softer factor of what is the overall city image.

The smart mobility combines the two main definitions of mobility – the local transport system, and mobility provided by the ICT infrastructure – under one heading (Giffinger, et al., 2015). The sustainability of the transport system and the accessibility of the city, both domestic and from abroad, are also evaluated under the smart mobility field.

The smart environment evaluates the air quality, the sustainability of the resource management and the ecological awareness of the city (Giffinger, et al., 2015). Interestingly, pollution is only mentioned separately related to the air quality, without considering the possible pollution of the ground, water or built environment.

The smart people are defined by their level of education and their affinity for lifelong learning (Giffinger, et al., 2015). The smart city also assumes a level of open-mindedness and ethnic plurality from its citizens. The definition does not advise how the smart city should react in the presence of possible narrow-minded and uneducated people, though.

The smart living is a broad field ranging from the quality of the housing to the facilities available for education, culture, and leisure. It also includes considerations for personal safety and health (Giffinger, et al., 2015). Furthermore, smart living should provide social cohesion and an attractive city for tourists.

2.2 Smart city infrastructure

Another way of defining the smart city is to look at the infrastructure on which the smart city is built. In a recent study the smart city lays on four infrastructure pillars: institutional infrastructure, physical infrastructure, social infrastructure and economic infrastructure, depicted in Figure 2 (Silva, et al., 2018).

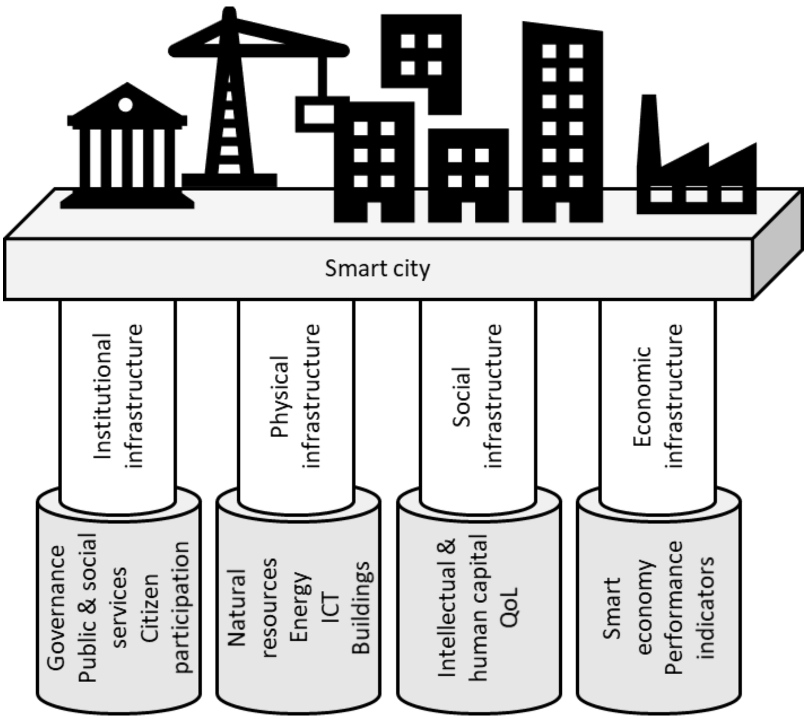

Figure 2. Smart city infrastructure (adapted from Silva, et al., 2018).

The institutional infrastructure consists of the smart city governance including the political strategy development, transparency of the governance with the citizens participating in the decision making and the public and social services of the city (Silva, et al., 2018). The institutional infrastructure should provide cooperation and integrate with public, private and civil organisations both locally and nationally to ensure adequate interoperability between services and integration of various administrative bodies. The institutional infrastructure should also form liaisons with both regional and national government levels. It is seen that the technocratic governance, that is, the availability of all smart city services and features through technical solutions, enables the optimisation of complex social issues via computational capabilities. Finally, a careful and sensitive consideration of political perspectives is said to make the governance of a smart city much easier. This can lead into an interesting dilemma: how a smart city, predominantly assisted with an information systems solution implemented with digital technology and true-false logic, is able to adjust and provide reliable results for the both ends, with usually opposing opinions, of the political spectrum?

The physical infrastructure consists of the natural resources and energy, ICT infrastructure, buildings, and urban planning (Silva, et al., 2018). The main goal of the physical infrastructure is to ensure the sustainability of the smart city today and in the future. With the help of green buildings, green urban planning, sustainable renovation of the buildings and municipal services, the use of renewable energy sources and the sustainable conservation of scarce natural resources the physical infrastructure can ensure the longevity of the smart city.

The social infrastructure covers the intellectual and human capital and the quality of life (Silva, et al., 2018). It is noted that the smart city concept can become popular and successful only if the citizens are aware of, responsible for and committed to its goals. The social infrastructure and social awareness are seen essential for the evolution and sustainability of the smart city. The three other infrastructure pillars would not be able to guarantee the success of the smart city without the social infrastructure pillar properly in place. It is stated that the smart city attracts better educated and competent citizens enabling the growth and further knowledge based urban development. Another study further defines similar social infrastructure factors, like smart inhabitants, degree of education, social interaction skills, integration with the public life and open attitude to the wider world as factors of a successful smart city (Ismagilova, Hughes, Dwivedi, & Raman, 2019). Typically, the studies present that the socially smart citizens help to build smarter cities from bottom up. It is seldom considered how the smart cities could improve the QoL of their less fortunate or less educated citizens.

There are several definitions for the economic infrastructure of the smart city, or the smart economy, ranging from the utilisation of e-commerce and e-business to the various performance indicators to analyse the public expenditure, energy consumption, employment rates, funding of the smart city projects and the GDP of the citizens (Silva, et al., 2018). Interestingly, constant and steady economic growth is seen as a key success factor for the smart economy of a prosperous smart city. The attitudes towards economic growth, especially in relation to sustainability, have not always been as straightforward, and the issue has traditionally been the topic of much debate (Haughton, Counsell, & Vigar, 2008).

2.3 Smart city dimensions

Apart from the six smart city dimensions by EU, as in chapter 2.1, the smart city can also be categorised by just three dimensions: the technology dimension, the human dimension and the institutional dimension, depicted in Figure 3 (Nam & Pardo, 2011). Each of these dimensions can then be further defined by collecting conceptual relatives of the smart city terminology under each dimension. These various concepts within the dimensions are at first sight slightly overlapping, interconnected, and even contradicting, but together they give a holistic understanding of the contents of the smart city.

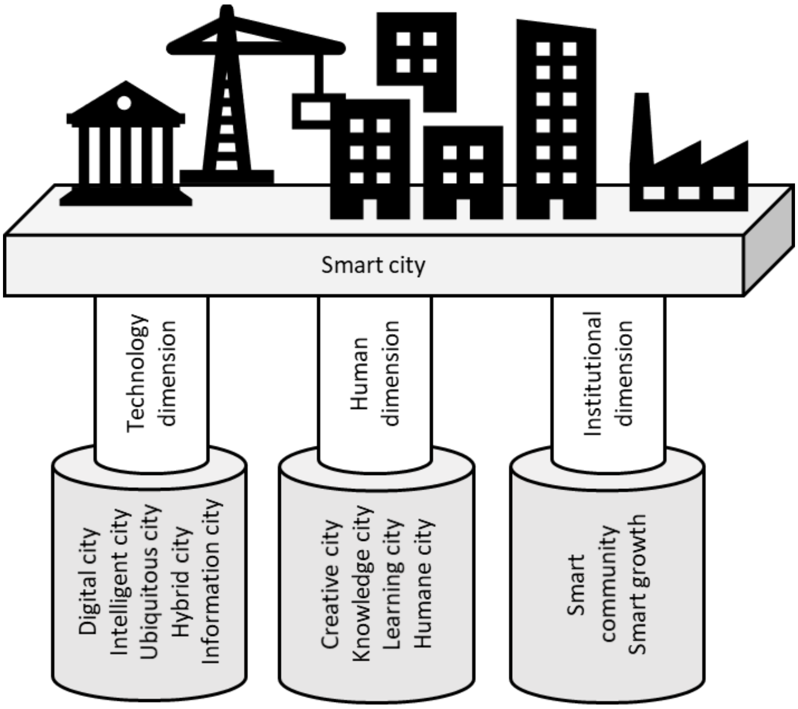

Figure 3. Smart city dimensions (adapted from Nam & Pardo, 2011).

2.3.1 Technology dimension

The technology dimension consists of concepts, like digital city, intelligent city, ubiquitous city, hybrid city and information city (Nam & Pardo, 2011). The digital city is built around a broadband communications network that connects the community for seamless information sharing, interoperability, and collaboration between the citizens.

The intelligent city emphasises the knowledge and creativity of the society, where human and social capital are the most important factors (Nam & Pardo, 2011). The ICT infrastructure together with the latest telecommunications, electronics and mechanical technology enable the conscious transformation of the intelligent city. This transformation is seen as fundamental and significant, instead of an incremental change.

The ubiquitous city extends the idea of the digital city by providing the citizens with an access to all services regardless of the time, place or device (Nam & Pardo, 2011). All elements of the built environment – the citizens, buildings, infrastructure, and open spaces – have ubiquitous access to computing.

The hybrid city combines the elements of the physical smart city with the latest developments of a fully virtual city that exist only in the cyberspace of cloud computing (Nam & Pardo, 2011). One interesting new research topic for the hybrid city is the development of the smart city digital twins (Mohammadi & Taylor, 2017). A digital twin is a parallel virtual version of the city that receives real IoT data from the city infrastructure and makes progressive and adaptive predictions of the future behaviour of the real city.

The information city collects data from the local communities and transfers it to the public use through web portals (Nam & Pardo, 2011). The information city generates an urban platform of commerce, social and civic services and social media for its citizens. Many of them become info-habitants that can work and live on the internet domain.

2.3.2 Human dimension

The human dimension emphasises the concepts of a creative city, knowledge city, learning city and humane city (Nam & Pardo, 2011). Learning and education of the citizens are the driving forces towards smart city. The learning city should also generate competitive and skilled workforce for the information economy. The knowledge city can be used as a synonym for the learning city. The earlier concepts of technopolis and ideapolis have evolved into a knowledge city that provides digital, purposefully built facilities to promote the knowledge economy.

The creative city must provide a creative atmosphere for the emergence of the smart innovations (Nam & Pardo, 2011). This includes knowledge networks and the involvement in the voluntary organisations. It is also mentioned that the creative city should provide a crime-free society where the after-dark entertainment economy can thrive.

The concept of a humane city openly admits that it is meant mostly for the creative, better-educated citizens (Nam & Pardo, 2011). The smart city provides higher education to create and attract skilled knowledge workers and high technology industries. This causes the smart cities to become even smarter with the inflow of smarter and more creative people, while the other communities suffer from the opposite.

2.3.3 Institutional dimension

The institutional dimension covers the governance and the urban planning of smart city (Nam & Pardo, 2011). The governance of the smart community is seen as a partnership of shared interest between the citizens, governing institutions, businesses, and other organisations, where information technology is consciously used for improving and transforming the work and life significantly for the better.

The role of urban planning is to ensure smart growth so that the smart city becomes bigger, while not necessarily wider (Nam & Pardo, 2011). The urban planning should also find solutions for the environmental challenges like congested traffic, pollution, diminishing open space, overcrowding, and increasing cost of public facilities.

2.4 Smart city by stakeholders

The smart city development attracts various groups of people, institutions, and corporations. The all have a slightly differing view about the direction, goals, and results of this development. It is sometimes difficult to combine and coordinate these views. The varying smart city perspectives of some of the key stakeholders of the smart city development – universities, citizens, government, urban planners, and businesses – are presented in the following chapters.

2.4.1 Smart universities

The universities and research institutions see the smart city as a possibility to collect and coordinate the other smart city stakeholders on an open platform (Ferraris, Belyaeva, & Bresciani, 2018). The universities then coordinate the sophisticated innovation and research of the independent participants. The role of the universities is to provide qualified personnel, knowledge, facilities, and opportunities for innovation development. The universities also offer a creative and educational environment, and an independent and impartial access to public funding for the smart city development projects.

2.4.2 Smart citizens

From the citizens' perspective the smart city enthusiasm is unfortunately not always that tangible. It is noted that the research and literature tend to focus on the technology aspects of the smart city, instead of the topics associated with its citizens (Marrone & Hammerle, 2018).

In a study conducted in Curitiba, Brazil – a city often mentioned as being one of the ten smartest cities in the world – the results indicate a low citizen satisfaction with their hometown as a smart city (Macke, Casagrande, Sarate, & Silva, 2018). The citizens' QoL was analysed to be defined by four factors: socio-cultural relationships, environmental wellbeing, material wellbeing, and community integration. However, regardless of the award-winning smart city status of Curitiba, the study points out that these human factors are often neglected in the digitally enhanced urban experiments.

Instead of helping the less privileged people, the smart city often tends to require the people to become smart citizens first, before the city itself can become smart. In Caguas, Puerto Rico, the integration of the educational institutions to the city strategy should produce knowledge and intellectual capital for smart people that may then provide sustainability to the city (Ortiz-Fournier, Márquez, Flores, Rivera-Vázquez, & Colon, 2010). Similarly, the increase in citizens' social, cultural and environmental awareness are seen as the key to the sustainable future of the smart city (Staffans & Horelli, 2014). Also, in the ranking of the European Smart Cities, the education and lifelong learning of the citizens are seen as the building blocks of a smart city, not vice versa (Giffinger & Haindlmaier, 2010).

The social-cultural relationships and the ability to be a smart citizen can also be defined with a 3T definition: tolerance, technology and talent (Nam & Pardo, 2011). A smart citizen must have the creativity and talent to create and understand the technology needed and used in a smart city. Surprisingly, the smart citizen also needs increased levels of tolerance to cope and thrive in a smart city. One would think that a smart city would be a more tolerable place to live than a conventional city. Apparently, it is vice versa.

2.4.3 Smart governance

The problem of low satisfaction with the smart city has been noticed elsewhere, too. A study about the smart city governance concludes that the most advanced technology does not necessarily provide an atmosphere where the citizens would enjoy developing a sustainable and vital city together (Effing & Groot, 2016). At the same time, it is seen essential that the citizens and companies should cooperate with the local government in the co-creation of the smart city, instead of the government having to be the leading authority alone. The innovative participation of the citizens in the development of various e-participation methods would enable the cities to transform into so called social smart cities.

Where the traditional urban governance relies on steering through norms, policies, programmes, information and economic incentives, the smart city is increasingly governed by self-organisation, co-governance, deliberation and monitoring (Staffans & Horelli, 2014). This leads to recursive decision-making between formal and informal governance methods, involving citizens, businesses and local forums to interact with the city councils.

2.4.4 Smart urban planners

The urban planning of the smart city can be viewed as an evolutionary process (Komninos, Kakderi, Panori, & Tsarchopoulos, 2018). Cities are becoming so complex and chaotic systems, that it is not practical anymore to plan and construct them from scratch. Instead, the decision-making should take place under constant and non-linear change, which converts the smart city planning into an evolutionary process, where the digital technology utilized in the planning changes so rapidly that the technology does not often even exist at the beginning of the planning process. This new evolutionary urban smart city planning idea of “cities are becoming cities” differs greatly from the conventional 20th century urban planning concept where “cities are planned as cities”.

Another view to the smart city planning expands the traditional top-down, comprehensive-rationalistic urban planning theory, which is said to still being applied today, by emphasising the incremental and pragmatic planning of the smart cities with the help of the participating citizens and other stakeholders (Staffans & Horelli, 2014). The introduction of ICT and the empowerment of the communities in the form of community informatics (CI) has enabled city planning to transform into participatory e-planning. Furthermore, the urban planning is not seen any more as an individual, separate activity. Instead, the city planning function has become an interweaved activity with the city governance and community development.

Ultimately, the citizen participation and innovation needed in the smart city planning and governance is transforming the city into a platform. Instead of the city being a bureaucratic mechanism of separately organised silos, the urban planning and governance can be offered on a unified city as a platform (CaaP) (Anttiroiko, 2016). The CaaP is the place where the citizens and other stakeholders can gather to discuss, exchange ideas and participate in the co-creation of smart solutions. The CaaP is said to democratise the smart city innovation.

2.4.5 Smart businesses

For the businesses in the ICT sector the smart city development has been identified as an enormous global market potential. A few years ago, it was estimated that the value of the smart city market would be over 20 billion USD in 2020. This has interested the corporations in developing and promoting their own smart city strategies (Söderström, Paasche, & Klauser, 2014). However, the rapid development and inaccuracy of the estimations regarding smart city is clearly demonstrated in another study, which is only four years newer, which estimates that the global market would actually be 400 billion USD in 2020, instead of 20 billion USD (Yigitcanlar & Kamruzzaman, 2018).

In many views the smart city development is seen having a too strong and overemphasised focus on technical solutions, prioritising public spending on ICT and relying too heavily on data and software at the expense of human knowledge and expertise (Söderström, et al., 2014). This has given an opportunity for private technology businesses to define urban management models for smart cities. IBM is used as a prime example of an IT company that has shaped the smart city ideology towards IT centric entrepreneurialism, having registered the Smarter Cities trademark already in 2011.

A study has used IBM as a reference to describe and criticise how the corporations have used their communications power to create a story of a positive transformation by which the smart city technology solutions of the corporations are essential in solving the urban problems (Söderström, et al., 2014). This may lead to the corporatisation of city governance where technocratic systems analysis largely replaces the political debate on the direction and priorities of the municipal development. Ultimately this raises the question about who actually has the authority to define the smartness of the city.

IBM also arranges Smarter Cities Challenge competitions, where the winning cities are granted with a team of IBM experts and computing platforms and tools for three weeks to develop the winning project ideas further (IBM, 2020). The latest competition was held in 2017, with the focus on topics related to the environment, economic development, social services, and emergency management. The winning cities were Busan in South Korea, Yamagata City in Japan, Palermo in Italy, San Isidro in Argentina, and San Jose, in the United States. From the viewpoint of the participating cities the winners are provided with fast access to the needed smart city expertise and resources. This also easily locks one vendor permanently in to drive their own technology-based smart city vision, instead of allowing the city to proceed freely based on their smart city needs.

Often mentioned other IT companies shaping the smart city include Cisco and Siemens (Söderström, et al., 2014), Alcatel (Staffans & Horelli, 2014) and Intel (Mulligan & Olsson, 2013). Interestingly, Nokia has acquired large parts of both Siemens and Alcatel, together with Bell Labs, enabling also Nokia to strongly promote their smart city strategy (Nokia, 2020). It has been noted that this kind of division into ICT players and telecommunications players is also a cause for the development of the smart city architecture being hindered by the battle between two business models: ICT and telecommunications. An architectural evolution is required to integrate these two technologies optimally in smart cities (Mulligan & Olsson, 2013).

2.5 Smart cities of the world

It is nowadays easy to find smart cities, or cites wanting to be called smart, all over the world. It is much more difficult to evaluate what is the actual smartness level in these cities. It is criticised that many of the alleged smart cities use the term for self-promotional purposes to become more acceptable and attractive in the eyes of the stakeholders the cities hope to tempt in. A study presents examples where the investments in the ICT, in the name of smartness, do not yet reveal or solve the underlying social problems of the city, or how the temporary boost in the ICT investments may not guarantee a longer term accumulation of smartness or wealth in the city (Hollands, 2008). It is also noted how the public funding of private ICT innovations may benefit the multinational corporations elsewhere rather than the intended smartness development locally.

In India, the smart city initiatives are coordinated on the government level. The big and world's second most populous country is battling with fast urbanisation. The problems ahead and the measures taken are massive. In 2015 the Smart Cities Mission, hosted by the Ministry of Housing and Urban Affairs of India, launched a Smart Cities Challenge to find and select 100 cities whose smart city initiatives would receive funding from the government (Smart Cities Mission, 2020). The total budget for the Smart Cities Mission is estimated to 7,5 billion USD over five years. The target is to develop urban planning, governance, and the economic, social and physical infrastructure of the selected 100 cities. The project impacts the life of almost 100 million citizens in India.

As in India, the smart city initiatives in Canada are also organised under a government coordinated competition, named Smart Cities Challenge (Impact Canada, 2020). The challenge statement of the competition exemplifies the key focus areas and the current biggest concerns of the cities in Canada: The safety and security of the high crime rate neighbourhoods is surprisingly listed as the first issue requiring a smart solution. The post-industrial transformation of old industrial neighbourhoods and the stimulation of economic growth after a long decline is another major concern in Canada. The health and wellbeing related topics of activating, especially, the ageing population require attention from the smart city innovations. The environmental health and the inclusion and empowerment of the most vulnerable citizens are also highlighted. Interestingly, the Canadian smart city challenge is one of the few where the focus on innovations in IC technology are not apparently visible as one of the key development areas. Instead, the focus and the targets are much softer and more citizen-oriented, and ICT just provides the possible underlying tools to achieve the targets. The winning cities of the currently latest competition round were announced in May 2019 (Infrastructure Canada, 2019). Montréal won the grand prize of 50 million CAD, while the smaller prizes from 5 to 10 million CAD were awarded to the town of Bridgewater, Nunavut communities and the joint proposal of the city of Guelph and Wellington county.

In Russia, the smart city activities have a showcase in Moscow. There are seven main smart city initiatives listed on the official website of the Moscow mayor (Moscow Government, 2020). A city-wide mobile internet and free Wi-Fi access to the internet is available in the streets, parks and public transport system. The smart transport is controlled by the traffic management centre, which can make forecasting based on traffic patterns. The city government provides an internet access to e-services. There is also a unified medical services portal for finding medical centres, arranging doctor's appointments and handling medical paperwork online. The citizens of Moscow are encouraged to participate in the city planning and management by awarding points and small rewards to the most active voters in the opinion polls. The electronic school project of Moscow includes an electronic library of lesson material that the teachers can share and co-create. The school records and registering are also provided online. Finally, Moscow also boasts about its 146 000 publicly installed surveillance cameras, allegedly being one of the top ten cities in the number of cameras. It is mentioned that the camera recordings are used in solving 70 % of the crimes and violations is Moscow. The camera footage is used also used for supporting and monitoring the city utility services.

In Brazil, the public and private smart city initiatives are collected and ranked by a private event organising company Connected Smart Cities (Urban Systems, 2019). They arrange annually a Connected Smart City exhibition and conference, and since 2015 they have annually published a ranking of the Brazilian smart cities. There are 11 main smart city indicators by which the performance and the ranking of the cities are evaluated. These follow the typical smart city dimensions and building blocks: mobility and accessibility, environment, urbanism, technology and innovativeness, quality of life, security, education, entrepreneurship, energy, governance, and economy. The latest publication of the Connected Smart Cities ranking is from September 2019, and according to it the top three smartest cities in Brazil are Campinas, São Paulo and Curitiba.

The smart cities of Africa still have a long way ahead before surfacing on top of the smart city polls. For example, Cape Town, Abuja, Cairo, Nairobi, Rabat and Lagos, the only

African cities mentioned on the latest smart city index of IMD, are occupying the rankings below 90 on the list of 102 smart cities, Lagos holding the last position (International Institute for Management Development, 2019a). Interesting critique of the African smart city aspirations is presented in a Cape Town based study, which argues that the fantasies of creating glass-box tower architecture, mimicking renowned smart cities like Dubai, Shanghai or Singapore, is actually worsening the inequality of the citizens in the African cities (Watson, 2015). Many of the smart cities in Africa are implemented as satellites of existing cities, which ignores the citizens' human and social dimension of co-created innovation essential for the smart cities. The low education level and poverty of the citizens, uprooted and disconnected from their original habitation due to urbanisation, amplifies the disproportion between the smart city vision and the reality of the citizens. The rhetoric of urgency to create smart cities to fix the problems of fast urbanisation takes resources and attention away from the more urgent needs of clean water, housing, sanitation, and uninterrupted power supply.

The history of the rapidly expanded smart city development in China is said to trace back to the government's publication of the 12th Five-Year Plan in 2010 (Yu & Xu, 2018). This study about smart city innovation diffusion theories and quantitative empirical analysis of the performance of the Chinese smart cities presents two interesting viewpoints: First, the differences between the smart city approaches in the East and West are noticed to still exist. China, representing the eastern culture, is said to prefer the central government controlled top-down approach, while in the west the direction of the development prefers local bottom-up approach. Secondly, it is argued that the smart cities can fix environmental issues only to a point. If the pollution situation, as in many aspiring Chinese smart cities, gets too severe, the resources and the attention of the city gets distracted from the smart city initiatives towards the more pressing environmental issues.

If only one example from the United States should be named, then New York would be the winner or top contestant of many smart city rankings. In New York, the smart city activities are driven directly from the mayor's office. The city has a long-term

OneNYC 2050 strategy that has been kept updated since its original launch in 2015 (OneNYC, 2020). The OneNYC 2050 strategy summarises the focal points of the smart city initiatives in New York: The continuing urbanisation and population growth put pressure on the city development. The diversity, safety, security, and affordability of the housing are the key for the neighbourhoods of New York. The emphasis on children's equal access to quality education and the availability of health care for everyone are topics that seem to be deriving from the national level debate over the American social system. The environmental sustainability requires ending the reliance on private cars and fossil fuels, with the hope of developing technologies for new modes of transportation. In 2050 New York should also have a modern and reliable infrastructure, the economic power to provide entrepreneurial or job opportunities for all, and a vibrant democracy that encourages the citizens to actively participate in the development of the city.

In Europe, the individual smart city initiatives are supported by the common objectives of the urban agenda of the EU (European Commission, 2020). The priority themes for the EU cities cover familiar smart city topics, including digital transition, sustainable energy and environmental issues, urban mobility, prevention of poverty and unemployment, affordability and sustainability of housing, culture and education. Three themes in the EU agenda seem unique among the many international smart city initiatives: The recent influx of refugees into the EU has prompted the inclusion of migrants and refugees in cities as one priority theme. The theme of circular economy is also seldom mentioned in other smart city initiatives. Finally, the governance related activities within the EU concentrate on the special theme of innovative and responsible public procurement in the cities. Also unique in the European smart city development is the deliberate aspiration for cooperation and partnerships (European Innovation Partnership on Smart Cities and Communities, 2020). The EU maintain a special platform, or a marketplace of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC), with funding, matchmaking, guiding and various initiatives and projects that foster European inter-city cooperation on smart city development.

3 Building blocks of smart city

The various definitions of the smart city in the previous chapter also reveal the most important building blocks of the smart city. This chapter introduces the most important, typical or interesting innovations, implementations and research initiatives by which the smart cities are built in practice.

3.1 E-governance

The smart city is often defined by requiring a citizen-centric, participatory, collaborative, integrated and transparent governance, which is achieved by e-governance solutions that rely on ICT infrastructure (Nam & Pardo, 2011).

E-governance is the area of smart city development where the innovations in information technology intersect with the political evaluation of the success of the administration. A study has noticed that the political side of the e-governance requires more research as it is currently not adequately represented in the literature (Abu-Shanab, 2013). This study uses transparency as the measure of the quality of the administration in e-government. By investigating international reports on e-governance development, it was noticed that the e-governance readiness correlates significantly with the perceived level of corruption and the openness of the budget of the government, which were the two selected indicators for the transparency of the governance. Even though this study demonstrates the success of e-governance with the transparency of the administration, the study concludes that more research on the subject is needed with more measures and indicators than just transparency, corruption, and openness of the budget.

Another study points out that the smart governance should take care of the proper local spatial development plans so that the highest investor interest, like technology parks, R&D companies, business incubators, technology transfer centres and industrial complexes should be incorporated in the plans, as these are seen as crucial parts of the smart city (Hajduk, 2016a). This kind of planning ensures the accumulation of adequate intellectual resources, institutions, and developed infrastructure to form a smart city.

E-governance enables collaboration, but this does not yet ensure that the citizens, communities, public institutions, corporations, voluntary organisations, and schools are committed or willing to collaborate. It is said that without the commitment from the stakeholders to collaborate the smart city does not really exist (Nam & Pardo, 2011). It could also be asked, do the citizens really want to collaborate with the government, or do they want the government to increasingly collaborate with them just for the sake of city smartness? When does the government collaboration turn into unnecessary intervening with all community initiatives?

Also, when the openness and improved transparency of the smart e-government is said to increase the public support to raise more funding for the e-government projects (Abu-Shanab, 2013), it could be asked if the political objective of the smart city and smart governance is to collect more money from the citizens? Should the technology and political objective actually help in creating a leaner, more economical and less laborious governance system?

3.2 Smart traffic

Smart traffic, or more broadly smart mobility, is one of the key initiatives of all smart city developments today. The challenges of the traffic largely include the same topics that drive also the development of the smart cities in general: fast urbanisation, mobility issues of the aging population, control and reduction of the climate change and pollution, mobility service development through innovative digitalisation, and discovery of sustainable and efficient energy sources for the traffic (Hautala, Karvonen, Laitinen, Laurikko, Nylund, Pihlatie, Rantasila, & Tuominen, 2014).

In an assessment of urban transport, it is noted that the urbanisation and the related increase in road traffic will cause congestion and air pollution, simultaneously reducing the quality of life (Hajduk, 2016b). The EC has made a forecast that the freight transport will increase by 40 % and the passenger transport will increase by 34 % from 2016 to 2030. Thus, the EC has obliged the European cities to develop sustainable mobility strategies with the goal of improving passenger and freight traffic and reducing environmental degradation in the cities. The proposed means to achieve this include the promotion of public transport as well as alternative forms of movement, like walking and cycling. The coordination of timetables between different transportation means, the integration and creation of rhythmic timetables between train, tram, subway, and bus services, with properly planned interchange locations enable the creation of synchronised, multimodal transport means. The development of intelligent transport systems allows the management of public and private traffic on the roads, including rail traffic, fleet, and cargo transport, and even information for the drivers about traffic congestion and the availability of parking spaces. Interestingly, the study also encourages the cities to invest in road construction, especially the modernisation of the ring roads and the exit routes from the city to the national roads are seen important. Still, for example, the city of Helsinki continues the controversial planning of converting its main exit routes into slower and narrower city boulevards (Lempinen, 2019).

The latest international research presents some interesting examples that widen the scope of the smart traffic concept to new areas of innovation. For example, the typical car-sharing services have so far used standard mass-produced cars. However, a design and manufacturing study in Bogotá, Colombia, attempts to create an electric super-compact vehicle uniquely for car-sharing purposes (Mendoza-Collazos, 2018). The design of the car is motivated by the desire to reduce the congestion with the small car size, the goal to preserve the user experience of a private car, and the wish to simultaneously improve the usability of a super-compact car.

Another study example presents how the computational power available today can be utilised in a traffic flow forecasting method that is based on a cascaded artificial neural network (CANN) (Zhang, S., Kang, Hong, Zhang, Z., Wang, & Li, 2018). The writers assume that this is the first study where CANN is used in traffic flow prediction. The developed system utilises open data and APIs to input and process weather information, map and route information, and traffic schedule, holiday, and behaviour information of the citizens to the system. The municipal road surveillance cameras provide pattern recognition information from the license plates to identify and timestamp the cars on the road. This information is fed into three artificial neural networks (ANNs): The long-term ANN calculates the periodicity of the traffic on a weekly lever, the medium-term ANN computes the daily periodicity and travel habits of the drivers, and the short-term ANN calculates the numeric variation trends of the flow of the traffic. The cascaded results of these three ANNs indicate promising performance and increased effectiveness in the traffic flow predictions compared to the more traditional prediction methods.

A prime example of a solution for the last-mile problem in multi-modal smart traffic initiatives is proposed in the form of shared, short-term rental electronic scooters. These e-scooters promise sustainability, reduced environmental impacts, and the benefits of collaborative consumption as part of the burgeoning sharing economy. However, a recent study has noticed that the e-scooters may not necessarily reduce the environmental impacts, and potentially may increase the life cycle emissions in comparison to the transportation methods they replace (Hollingsworth, Copeland, & Johnson, 2019). More efficient collection of the e-scooters for charging, shorter distances of e-scooter distribution, and prolonged e-scooter lifetimes could reduce much of these negative effects.

Unfortunately, the recent news indicate that the lifetime of the e-scooters may often be calculated in days instead of years, that the sharing economy may leave the e-scooter collectors with low wages, while the riders increasingly find themselves injured by e-scooter accidents. A study by an online business publication reports from Louisville, Kentucky, that the average lifespan of an e-scooter is only about 29 days, the longest lifespan observed was just 112 days, and about 4 % of the e-scooters disappear during their first day in service (Griswold, 2019). A Finnish newspaper reports that the e-scooter companies may pay only one euro per a scooter for the collectors, with a possible freelancer agreement including inadequate employment terms and conditions (Harju & Nuuttila, 2019). Furthermore, the daily newspaper from Helsinki reports increasing amounts of injured e-scooter riders with fractured facial bones, even brain injuries, broken teeth and upper limb fractures requiring surgery (Kantola, 2019). A research from the United States confirms similar findings, with close to a fourfold increase in hospital admissions, with nearly a third of the patients having a head injury, due to e-scooter accidents between 2014 and 2018 (Namiri, Lui, Tangney, Allen, Cohen, & Breyer, 2020).

3.3 Smart sustainability

Sustainability and the ICT are often seen as the main tools that drive the smartness of the cities. Moreover, both these tools should also be used when developing and studying the smart cities further. The sustainability of the smart cities usually focuses on three dimensions: the economic, social, and environmental sustainability. The economic sustainability is addressed by smart economy solutions, like e-commerce and e-business, that drive the attractiveness of the smart city in the eyes of both the potential employers and employees in order to maximise the employment rate (Silva, et al., 2018). Smart economy also drives the optimisation of public expenditure and energy consumption. The maturity of the social infrastructure and the social awareness of the citizens drive the social sustainability of the smart city.

The overall urban ecosystem must also maintain environmental sustainability, otherwise the longevity of the smart city and the entire planet is in danger. The smart city can contribute to the sustainable environment directly by smart environment initiatives that address the air quality, resource management and ecological awareness of the city (Giffinger, et al., 2015). The smart environment initiatives include smart technology solutions for cleaner energy, energy savings, and smarter, more sustainable housing. Also, the smart traffic solutions address environmental sustainability from many, partly contradictory angles. The smart traffic solutions try to reduce the overall amount of traffic, improve the traffic flow, reduce the used amount of energy, and increase the use of renewable energy sources. However, the environmental sustainability is interlinked with the economic sustainability and the social sustainability. The environmental sustainability cannot be achieved if the goals of also the social sustainability and economic sustainability are not aligned with the environmental goals. Smart economy can help in optimisation of, for example, the energy efficiency, while the social responsibility and understanding of the environmental issues can be increased by the goals of social sustainability.

In a study a content analysis was made to see how ICT and sustainability are connected in official smart city reports with the six smart city characteristics of the European Smart City Model: smart economy, smart people, smart governance, smart mobility, smart environment and smart living (Bifulco, Tregua, Amitrano, & D'Auria, 2016). It was noticed that the sustainability had the strongest connection with the smart governance, smart economy, and smart people characteristics. Thus, the smart city reports seem to emphasize the economic and social dimensions of sustainability. The fourth strongest connection was noticed between sustainability and smart mobility, indicating that the environmental sustainability dimension is mostly seen as the responsibility of the reduced CO_2 emissions and renewable fuels provided by smart traffic solutions.

An interesting recent study investigated how the level of the city smartness impacts the carbon dioxide emissions and, therefore, the level of sustainability the smart cities achieve with their smart city initiatives (Yigitcanlar & Kamruzzaman, 2018). The study investigated 15 cities, with various levels of city smartness, in the UK during 2005–2013. Surprisingly, the study concluded that there is no strong evidence on positive correlation between the adoption of smart city technology and the increase of sustainability. Furthermore, it was noted that the smartness of the city did not have any real effect on changing the CO_2 emissions over time, either. The researchers suggest that the smart city strategies should be better investigated and aligned to gain any substantial results on sustainability.

Similar conclusions regarding the sustainability of smart cities have been reached in a study analysing and comparing smart city assessment frameworks and urban sustainability assessment frameworks (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017). It was noticed that the smart city frameworks tend to concentrate much more on the modern technologies and smartness of the city than on the urban sustainability frameworks. The smart city frameworks emphasize the social and economic indicators while lacking environmental indicators. Thus, even though one of the main goals of the smart city is to improve the economic, social, and environmental sustainability of the city, this goal is not adequately represented in the smart city performance indicators.

The apparent conflict between the methods of achieving the objectives of the mutually exclusive dimensions of economic, social, and environmental sustainability is another topic of lively debate and study. For example, a concept of sustainable sufficiency is developed and presented to tackle all three dimensions of sustainability simultaneously (Lamberton, 2005). It is proposed that the neoclassical economic priorities of the Western society should be replaced by the principles of the Buddhist economics, emphasizing the mutually beneficial, tolerant, peaceful, and environmentally friendly aspects of the Buddhist economics. Unfortunately, this interesting study does not yet include any real-life cases of predominantly Buddhist societies where the smart cities would present successful examples of sustainable sufficiency.

3.4 Smart technology

Much of the smartness of the smart city relies on the innovative, interoperable, and synchronised use of various IC technologies, forming a network on top of which the socio-technical information systems of the smart city can operate. Fast communication networks are needed to convey the massive amounts of data generated and collected by the smart cities. The data is processed in powerful cloud-based computing systems. The use of IoT technologies have a pivotal role in enabling the collection, access and utilisation of the data that makes the cities smart.

The importance of the role and use of the IoT technology in successful smart city implementations has been recognised in a study (Park, del Pobil, & Kwon, 2018). The utilisation of IoT in the smart city can be categorised into five main sectors: First, in the energy sector the IoT technology is essential in creating smart grid systems that automate the electricity services and optimise the energy consumption of the cities. The energy sector is said to be one of the biggest potential markets for the IoT technology. Correspondingly, the IoT technologies related to energy are also considered the most essential for the smart city infrastructure. Secondly, in the smart home sector IoT is utilised in the implementation of home automation, building automation, and building management solutions. Energy usage monitoring and energy load management play an important role in the smart home control. The smart building optimisation is implemented based on big data that is collected on cloud servers and analytical prediction and modelling technology. Connected home appliances, home sensor networks, context aware technology, and advanced user interface methods with speech and image recognition are the other important enablers of the smart home services. Thirdly, in the smart traffic sector IoT enables a more sustainable mobility by solutions for fleet management, vehicle telematics and smart parking. Fourth, the security sector uses IoT for surveillance, home security, and protection of children and elderly citizens. Fifth, the use of IoT is rapidly increasing in the smart healthcare and smart hospital sector with, for example, electronic medical records, order communication systems and medical personnel tracking solutions.

It is naturally not feasible to define a universal smart city technology architecture due to the many variations needed in the solutions. However, a study has formed an illustrative approximation of a generic smart city technology architecture based on an analysis of various existing architectures (Silva, et al., 2018). The constructed generic smart city architecture is comprised of four bottom-up technology layers: data collection layer, data transmission layer, data management layer and application layer. The protection of the sensitive data moving between the layers is handled by various security modules that vertically cover all the other four layers. This generic smart city technology architecture is illustrated in Figure 4, below.

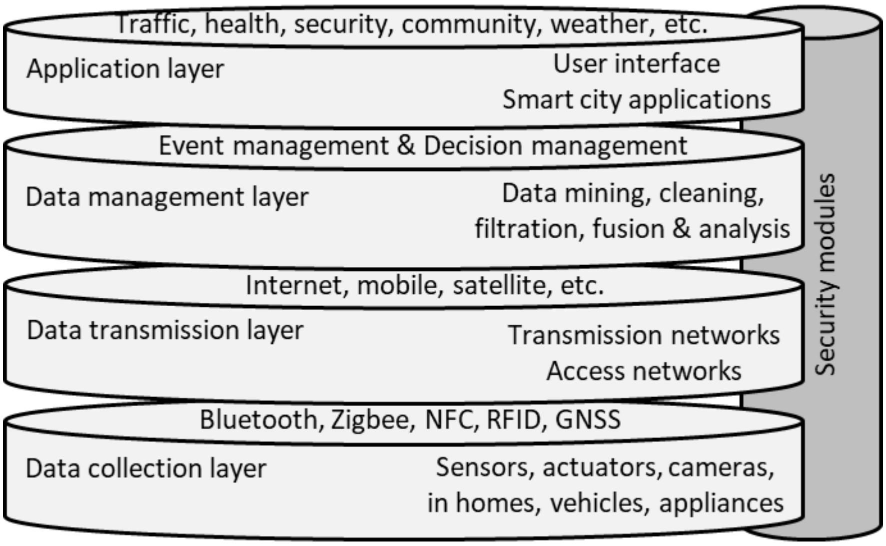

Figure 4. Smart city technology architecture (adapted from Silva, et al., 2018).

The data collection layer in the bottom consists of the sensors, actuators, cameras and other sensing devices capable of collecting vast amounts of diverse data, ranging from personal health information to ambient, climate and weather data, and to live video footage and exact geolocation of moving objects (Silva, et al., 2018). The data collection can be considered as the most important operation of the smart city, as it has the control over the rest of the smart city operations. The data collection can also be to most challenging layer because of the enormous amount of heterogenous data that must be handled.

The data collection layer interacts with the data transmission layer through various wireless and radio-frequency technologies and protocols, such as Bluetooth, Zigbee, near-field communication (NFC), radio-frequency identification (RFID), and global navigation satellite systems (GNSS, for example GPS) (Silva, et al., 2018). The transmission layer also takes care of delivering the collected source data to the data management layer over the internet or various mobile telephony networks. The reliance of the data transmission on mobile telephony networks potentially constructs a huge legacy problem that should be considered more carefully. First, the older mobile networks will sooner or later start to struggle with the ever-increasing data amounts collected from the sensors. Secondly, the network operators tend to completely shut down older networks in order to free up spectrum for newer network technologies. For example, Vodafone, one of the biggest mobile operators, has announced that they are shutting down their 3G networks globally to make way for the newer 4G and 5G technologies (Vodafone, 2019). This may sound trivial from the operator perspective, and even from the perspective of the mobile phone users who can have various levels of eagerness to update to a newer phone. However, the millions or billions of sensors and cameras scattered around the cities, with an old mobile telephony chipset embedded in them, will render themselves useless the second the operator switches the old network off. The same will happen again with the 4G and 5G technology in due course. The task of changing the installed device base every few years will be enormous and keeping their protocols, operating systems, drivers, software platforms and applications up to date and interoperable nearly impossible.

The data management layer takes care of the manipulation, organisation, analysis, and storage of the data (Silva, et al., 2018). The heterogenous nature of the collected raw data causes requirements for the maintenance of the vitality of the data. Data cleaning, data filtration and data fusion enhance the usability and processing efficiency of the data. The data may also include valuable pieces of unknown or hidden information. Data mining is a technique for revealing this information. It is proposed that the data analysis performed on the data management layer could consolidate big data analytics methods for the real-time analysis of the large data amounts collected from the smart city environment. The storage of the data requires innovative use of cloud-based, hybrid and scalable storage architectures. Finally, before conveying the data to the application layer, precise and real-time decisions from the heterogenous data are made by the event management and decision management algorithms of the data management layer. The correct decision making is vital for the uninterrupted operation of the smart city. Therefore, the decision-making algorithms are under extensive research and development now.

The application layer on the top provides the citizens with the user interface to the smart city technology and services (Silva, et al., 2018). The application layer is therefore in a crucial position to influence the adaptation of and satisfaction to the smart city services. The applications cover the various topics and initiatives of the smart city, like weather information, transport and mobility solutions, health care solutions, security applications and community development and feedback solutions. It is also emphasised that separate and individual smart applications are not as beneficial to the performance of the smart city as interoperable or integrated solutions with shared information would be.

The four-layer architecture representation, above, does not explicitly include or categorise the technical devices at the users' end into the smart city technology architecture. Another study mentions mobile telephones and publicly available interactive screens a such user devices (Staffans & Horelli, 2014). This study also points out that the technical devices themselves do not add smartness, until the intentional choice and coordinated use of the technology can create a real-time digital environment. A study of the smart city from the information systems (IS) perspective also points out the importance of integration, easy usability of the system and seamless interaction of the citizens (Ismagilova, et al., 2019). The benefits of the system need to be also communicated to the users to ensure the adequate adoption of the system.

3.5 Smart data

Much of the smartness of the city relies on first collecting, arranging, and storing vast amounts data, and then processing and utilizing it in various applications. The data collected or administered by the local government is often shared as open data for the public and private sector to utilise. Similarly, the government or the corporations are not able to alone provide all the innovation resources needed for developing the smart applications that utilise the open data. Therefore, the citizens are engaged and encouraged to participate in open innovation platforms for the application development, too.

3.5.1 Open data

The smart ICT technology generates data basically from all spheres of human activity. The processing of this data requires adopting the methods of big data, artificial intelligence (AI) and IoT. Many researchers point out that the utilisation of data is essential for enhancing the built urban environment, and that the characteristics of big data bring advantages for which the smart cities are considered as the main beneficiaries (Allam & Dhunny, 2019).

It is also pointed out that the adoption of big data increases the complexity of and the reliance on data systems (Allam & Dhunny, 2019). The researchers also warn about blindly adopting technology alone, the confidentiality issues and ethics of using big data, and the reliance on closed systems. Instead, the smart cities should increasingly integrate the social element in utilising the smart data.

Open data is more and more considered as a defining factor of the smart city (Ojo, Curry, & Zeleti, 2015). The open data initiatives are seen essential for the city governments in their efforts to add transparency, boost innovation and encourage the citizens to participate and bring a more societal view to the smart city development. The open data initiatives also bring cost benefits, simultaneously lowering the risk of the complex and risky activities when they can be implemented as pilot or trial projects.

A study analysed what kind of impact the open data initiatives and the publicly available datasets have in the smart cities (Ojo, et al., 2015). The biggest impact was noticed on the economy, governance, and transport sectors of the smart city. The economy sector was characterised by the creation of ecosystems and marketplaces of open data applications, services for the social sector, and development of tools and foundations for further innovation. The governance sector is characterised by the development of enablers for information sharing, data standardisation, increased transparency and enhancements in interoperability, policies and decision making. The transport sector concentrates on smart mobility applications relying on the open data related to traffic flow and public transport schedules. The datasets of open data are typically available for transportation, mobility, environment and safety, including data for car parks, electric vehicle charging stations, city bike stations, and traffic accidents, as well as surveillance camera data, road works, weather, and even regional crime figures.

The governance of large amounts of open data must also be arranged so that the data is managed effectively by entitled persons who have the authority to make the related decisions. This also causes some concerns. A study proposing a data governance framework for smart cities has recognized technical obstacles to the data governance (Paskaleva, Evans, Martin, Linjordet, Yang, & Karvonen, 2017). These include the shortage of historic data, difficulties in managing large data volumes, incompatibilities between various technologies and devices, lack of common standards for the data formats, and challenges related to data security and integrity.

Furthermore, it was noticed that, in addition to the open data initiatives shaping the smart city development, the concept of smart city itself shapes the open data initiatives (Ojo, et al., 2015). It could be said that many of the open data innovations still revolve around the better utilisation of the open data itself. The researchers point out, that the assessment of the actual efficacy of the open data initiatives in the context of smart city still requires more rigorous research and formal evidence, however.

3.5.2 Smart applications

The smart city needs open innovation that combines the knowledge and social capacity of its citizens to develop more competitive and simultaneously more sustainable environment on top of the physical infrastructure (Paskaleva K. A., 2011). The social and environmental capital on top of the ICT are said to distinguish the smart cities from the merely digital or intelligent cities. The living lab (LL) is an innovation ecosystem for fostering and incubating this social and environmental capital from the citizens. The LL is formed usually locally as a partnership of the city government, businesses, and citizens. The LL encourages the citizens to participate in a user-driven research and development of ICT solutions for the smart city. The LL provides a bottom-up approach and a real-time environment for the citizens to create, prototype and utilise new ICT products and services in a more effective and inclusive manner.

The LLs have become an increasingly important platforms for the smart city innovation globally (Paskaleva K. A., 2011). In Europe, the cooperation and benchmarking of the LLs is coordinated within the federation of European Network of Living Labs (ENoLL). There are currently over 150 active global living lab members in ENoLL, with over 440 past members since the founding of ENoLL in 2006 (European Network of Living Labs, 2020).

3.5.3 Data privacy and security

Data privacy and security are nowadays always a topic when big data, IoT, AI, cloud-based services and so-called platform economy are concerned. Much of this development happens inside the smart city context too. A study proposes a privacy aware smart city where the five typical dimensions of citizens’ privacy: identity, queries, location, footprint, and ownership can be preserved with existing privacy enhancement technologies (Martínez-Ballesté, Pérez-Martínez, & Solanas, 2013).

The identity of the user of the smart city services could be preserved by using multiple independent pseudonymiser services (Martínez-Ballesté, et al., 2013). The correlation of users and their queries could be hampered using trusted third party (TTP) solutions and private information retrieval (PIR) approaches. However, the researchers admit that, due to the high computational and communication costs, the PIR approaches are not yet practical in many real-life applications. The location of the user could be preserved with a cloaking service or by the collaboration of the users to veil their exact locations. The footprint of the user refers to the big data and open datasets, collected from e.g. various sensor networks, revealing the users' whereabouts and utilisation of these services to third parties. The use of statistical disclosure control (SDC) for the datasets is proposed before their publication. The ownership of the queries made across databases can be preserved from third parties with the help of SDC and privacy-preserving data mining (PPDM) techniques. Even though these technologies exist for securing data privacy, there are still many open legal, political and commercial questions related to who should implement these techniques, how this information should be transported between multiple infrastructure domains and what is the related cost.

The increasing amount of smart data and user data that is utilised by the big social media and platform economy corporations has raised the concern of data monopolies (Mulligan & Olsson, 2013). These are companies that collect and store vast amounts of user data in exchange for seemingly free services. The users are practically becoming unpaid labour for these platform corporations. There is a concern that the user data of the smart city applications should not become monopolised. Instead, the data should be made available as a public good for common civic improvement, and the users should retain the ownership of their data.

Furthermore, it is noted that many of the platform economy and internet giants make profit also by utilising technologies that were originally developed with public funding, like search algorithms, touchscreen displays, Global Positioning System (GPS), and virtual assistants that use machine learning and AI algorithms (Mazzucato, 2018). Even the internet itself has its roots in publicly funded development of military and defence technologies. At the same time these giant data monopolies avoid regulation that would be typical in any other monopolistic industry. It is argued that the citizens' data should be regulated and owned by a public repository that can sell the data to private companies, instead of the large technology companies imposing their conditions on the data users.

3.6 Measuring smart city performance

The smart city can be characterised by three main categories: The level of utilising the ICT infrastructure to improve the efficiency of the urban development, the level of competitiveness the city offers to increase the prosperity, and the level of sustainability and social inclusion the city can provide. But how can these characteristics be measured?

The smartness of the city cannot be properly evaluated, unless there are some commonly accepted and reliable measurement and assessment methods in place. Typically, the smartness is measured by various global and regional smart city rankings, provided periodically by research institutions and private consulting companies. There are also municipal environmental services that provide physical measurement data on environmental variables. There is nowadays also an ISO standard for measuring the performance of city services and quality of life.

A study about the effectiveness of the smart city rankings analysed 20 different smart city rankings (Giffinger & Haindlmaier, 2010). It was able to identify five general types of city rankings with different characteristics. These are: Commissioned economy- or consulting-oriented rankings, commissioned rankings by expert panels or private research institutes, rankings by magazines or non-governmental organisations (NGOs), rankings by universities or research institutes, and special rankings that cannot be properly categorised.

The commissioned economy- or consulting-oriented smart city rankings typically include relatively many cities globally, but without explaining how the sample cities have been selected (Giffinger & Haindlmaier, 2010). The details of the ranking results are usually only partially included, the number of indicators is moderate, and the actual indicators, the used data base and the calculation methods are usually not documented. The commissioned rankings by expert panels or private research institutes are typically lacking transparency, and the selection of the city samples is not clear. However, the rankings usually include a wide range of cities. Although the results and some original data is published on a detailed level, the used data base is not documented properly. The city rankings by magazines or NGOs are usually country specific, or they include cities from one continent, resulting in a relatively small number of selected cities. The selection is often based on the size of the population. These rankings are typically made without sponsoring. The selected method is well documented, and the results are presented in a detailed level. The ranking is based on average values. The rankings made by universities or research institutes generally have the methodologically most advanced rankings, with transparent and good-quality documentation rankings, indicators, and calculations. In the fifth category the researchers have found some peculiar city rankings that they call outliers that do not fit in any of the other four groups.

The study warns about the potential risks and negative effects of the city rankings (Giffinger & Haindlmaier, 2010). The simple concentration on the final ranks alone can often lead into theatricality, beauty contests, self-promotion, and recursive self-affirmation by the winning cities, while the losers simply ignore the results. Instead, the cities should take advantage of the detailed methods and indicators presented in the city rankings, and utilise this information as an instrument of strategic planning, as a guide for the cities to evaluate their strength and weaknesses, and as a tool to improve their competitiveness. At best, the transparency presented in the better-quality city rankings also forces the cities to make their decision making understandable and transparent accordingly. The writers of this study are also behind the development of the European Smart

Cities ranking (Giffinger, et al., 2015), which is often referred to in other smart city related studies.

Because of the multitude of the smart city rankings and the differing measures, indicators, characteristics and city selection criteria used in them it is unfortunately impossible to say what is the smartest city in the world, region or country, although many of the cities and city rankings can be found to proclaim so by themselves. The reader must be aware and take note of the source, sponsor, commissioner, and method of each city ranking. Reading through several different city rankings, preferably with both geographical and temporal variation, will give the enlightened reader an approximation and overview of the cities that generally are successful and recognised for their smart city efforts.

Another perspective to the evaluation of the smart cities is the way how the cities themselves measure and report the success of their smart city initiatives. The intention of the ISO 37120:2014 standard: Sustainable Development of Communities – Indicators for City Services and Quality of Life is said to be the most practical method for the cities to measure and monitor the performance and efficiency of their sustainable development (Hajduk, 2016a). The standard and its methodology can be applied regardless of the size, location, or position of the city. The standard also provides five certification levels – aspirational, bronze, silver, gold and platinum – for the cities to make comparisons and learn from each other The ISO 37120:2014 standard defines 100 city performance indicators structured around 17 themes. The 100 indicators are divided into 46 core and 54 supporting indicators. The 17 themes of ISO 37120:2014 are depicted in Figure 5 (World Council on City Data [WCCD], 2020). The standard has been developed to a newer ISO 37120:2018 version, with slightly updated themes and indicators (International Organization for Standardization, 2018). The new themes and indicators are listed in Appendix 1.

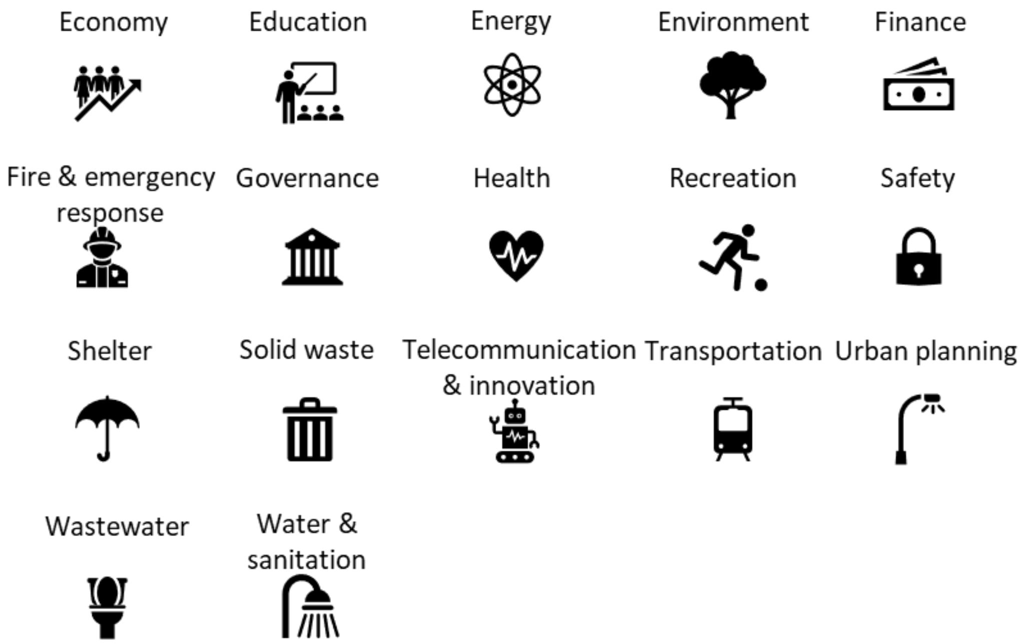

Figure 5. 17 themes of ISO 37120:2014 (adapted from WCCD, 2020).

The ISO 37120 is said to introduce two important benefits that have not been previously available: First, the 100 indicators of the standard are carefully selected and qualified from the thousands of existing and varying city performance indicators. Secondly, the standard also provides precise definitions for the indicators (Fox, 2015). The objective of this is to give the cities consistently interpreted and applied metrics by which the cities can compare their performances. A study has noticed that, although the standard provides objectiveness and relevance to the city performance evaluation, the standard has challenges in providing results which are consistent and sustainable over time, auditable, comparable, effective, and statistically representative. Only the indicator values are reported without the background data about the source of the values. Thus, it is only possible to notice that the indicator values may vary over time, or in comparison with other cities, but it is not possible to detect why this may happen. The study seeks to provide an automated method for longitudinal and transversal analysis of the indicator values and their metadata, so that it is possible to evaluate how and why the indicators change over time or vary between each other. This way the root causes of the differences could be detected.

On the local level it is also possible for the individual cities to provide metrics and measurements of their performance. For example, Helsinki climate watch (Helsingin ilmastovahti), measures the progress towards the goal of carbon neutrality by year 2035 (City of Helsinki, 2019). The web page displays over 200 functional, tactical, and strategic measurements by which the city of Helsinki monitors how the goals of the 147 agreed actions are reached. Similar kind of climate change related measurement data is also provided by HSY, Helsinki Region Environmental Services Authority (Helsingin seudun ympäristöpalvelut, 2019). This kind of public measurements data does not only inform the city about the progress, but it is also a good way of getting the citizens committed to the common sustainability goals.

4 Literature review synthesis

For the smart city, the literature would have known many other definitions than what are presented in this study. However, after a while the smart city terminology starts to repeat itself, the defining terms become synonyms of each other, and the same terms become grouped under different subtopics. In the following two sections the smart city is first synthesised based on the relevant smart city definitions found from the literature, and then synthesised as a conceptual framework based on the goals, initiatives, building blocks and stakeholders of the smart city.

4.1 Research synthesis of smart city definitions

Table 1, below, first lists three smart city definitions, found from the literature, that adequately cover the various viewpoints to the smart city phenomenon. Additionally, the table also summarises the synthesis of the key smart city stakeholders and building blocks that were identified during the literature review. This information should further answer the questions of who the actors of the smart city really are, and what are they actually doing to build the smart city.

Table 1. Research synthesis of smart city definition.

Smart city viewpoint	Smart city definition
European smart city	Smart city performance is defined by six key indicators of smartness: smart governance, smart economy, smart mobility, smart environment, smart people, and smart living (Giffinger, et al., 2015).
Smart city infrastructure	Smart city lays on four infrastructure pillars: institutional infrastructure, physical infrastructure, social infrastructure, and economic infrastructure (Silva, et al., 2018).
Smart city dimensions	Smart city is categorised by three dimensions: the technology dimension, the human dimension, and the institutional

	dimension, and further defined by their conceptual relatives under each dimension (Nam & Pardo, 2011).
Smart city stakeholders	Key stakeholders of smart city are universities, citizens, governance, urban planners, and businesses
Smart city building blocks	Smart cities are built with e-governance, smart traffic, smart sustainability, smart technology, smart data, and performance measurements.

4.2 Smart city framework

Another way to synthesise the smart city phenomenon is to present it in the form of a conceptual framework that explains how the various levels and factors of the smart city communicate and interact with each other. However, as the smart city development is partly symbiotic, partly top-down, partly bottom-up and partly co-created in nature, it is almost impossible to depict it as a conventional flowchart with inputs, outputs, and feedback loops. There would simply be too many of these input, output, and feedback permutations. Instead, a spherical and onion-like framework, as depicted in Figure 6, could be more illustrative in explaining the smart city interactions. A three-dimensional globe would be optimal, but let us settle for the two-dimensional simplification, below.

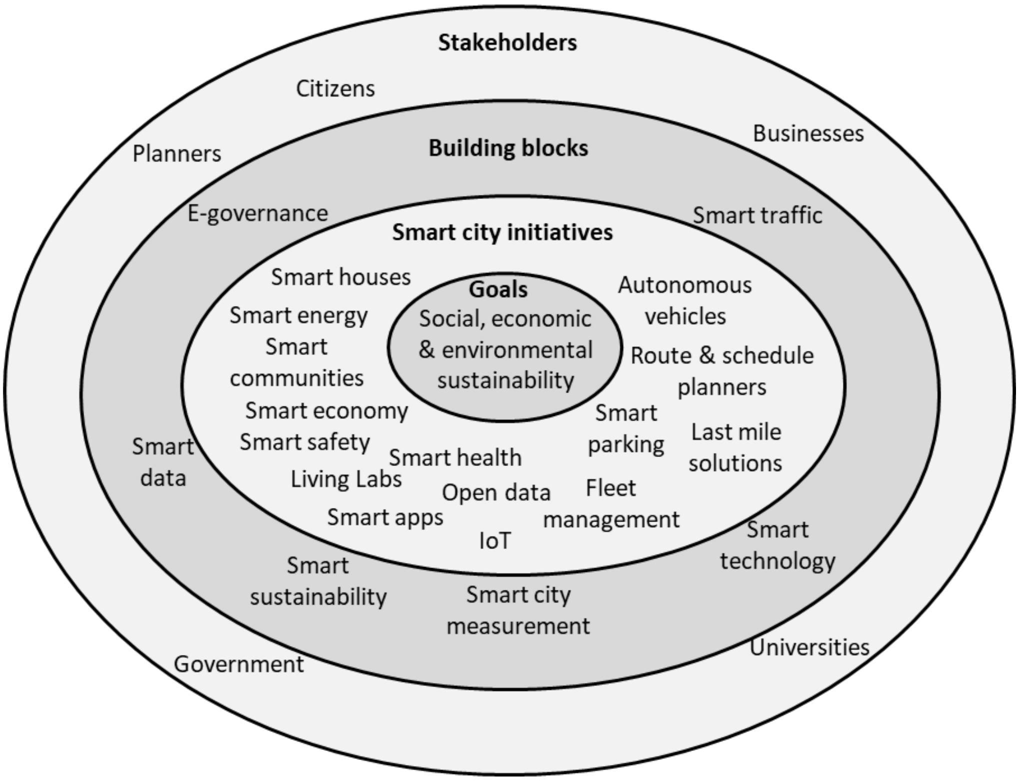

Figure 6. Conceptual smart city framework.

The conceptual smart city framework in Figure 6 depicts the various smart city stakeholders on the outer sphere of the framework. The stakeholders the interact in various ways with the smart city building blocks which are further divided into a multitude of smart city initiatives. The successful execution and interplay of these smart city initiatives then enables reaching the core of the framework, thus, achieving the ultimate smart city goals of social, economic, and environmental sustainability.

A simplified real-life example can illustrate the smart city framework even further. For example, the citizens may use their mobile devices to access their smart health services, to control their smart homes, to assist them in finding a free parking spot or to catch the next approaching bus. Each of these services, or smart city initiatives, are realised by using building blocks of smart technology and smart data. The messages and commands from the citizens' devices are conveyed through fast mobile ICT networks. The health services access cloud-based big data solutions to find the correct medical records of the citizens. The smart home application gets information from various IoT devices, by which the citizens can control their safety and living comfort. Both the parking service and the bus service may utilise traffic information, location information, schedule information and various other big data sources by which AI solutions can predict the availability of parking slots or the schedules of the approaching buses. The comfortable and safe homes increase the social sustainability of the city. The optimised energy and water consumption of the houses, and the timely and congestion free bus traffic increase the environmental sustainability of the city. In addition, the well-functioning healthcare services increase the economic sustainability of the city, to name a few.

The citizens, however, are not merely simple users of the smart city services and applications. The citizens can also actively contribute to the development of the smart city by using their knowledge in implementing smart applications, by utilising open data that the city has made available, or by suggesting improvements in the e-governance via community informatics. The citizens are often also members of the other smart city stakeholder groups. They may study smart technologies in universities to become more knowledgeable and tolerable smart citizens. They may participate in smart city living lab projects governed by the universities. They may be elected city council members making decisions about the future direction of the smart city. On the other hand, they may work for businesses that offer smart technologies or smart applications to the city.

The example case above demonstrates how the parts of the smart city framework are intertwined. One stakeholder group does not represent just itself, but a mixture of other stakeholder groups, too. It is not possible to make an isolated decision on a specific topic without it affecting the other parts of the sphere. For example, a decision to increase the use of IoT may become a sudden burden for mobile telecommunication networks, or cause an unexpected cost, and a source of new revenue for the businesses, in the form of legacy IoT devices and sensors that require regular updating and replacements. An optimised solution to increase, for example, social sustainability may have a negative impact on economic or environmental sustainability.

5 Smart city comparison

In this chapter, three cities – Helsinki, Singapore, and London – have been selected for a comparison of their smart city initiatives. These cities should provide for an interesting view on the similarities and differences of the targets, initiatives, and results of the smart city development in three different geographical locations, political governance models, and cultural surroundings.

This comparison is structured so that first, the organisation and main content of the smart city initiatives in each of the three cities is studied from their representative websites to see how the cities themselves perceive their smartness. Secondly, a closer look is taken at two of the more interesting smart city building blocks to see how the three cities have organised their smart data and smart traffic development activities. Thirdly, interesting examples of smart city innovation and research, connected to Helsinki, Singapore, and London, are studied and presented from the recent literature. Fourth, the similarities and differences in the smart city initiatives in the three cities are analysed and compared.

5.1 City selection criteria

Helsinki with its aspiring smart city platform, but with supposedly the most limited financial resources, serves as the smallest and perhaps not so highly recognized home base for this comparison. Singapore brings an Asian cultural viewpoint and its ambitious and highly considered smart city platform to the comparison. Being a young, small, and populous city-state, Singapore exemplifies how the smart city ideology can be incorporated also into the national level strategy. Singapore is also one of the wealthiest nations in the world, potentially giving them the most resources to pour into their smart city initiatives. London, having the biggest population, oldest infrastructure, and most interesting geopolitical situation at the self-proclaimed fringe of European cooperation, would at first sight have the most challenges to develop its smartness. Other good candidate cities would have been found from the USA – New York, Los Angeles, San Francisco, for example – from Canada – Montréal, Toronto, Vancouver – or from the Continental Europe – Paris, Amsterdam, Vienna, to name a few, but in the end London was selected as the representative in the category of old and large cities partly because of their peculiar political situation amidst the other European smart cities.

5.2 Helsinki

Helsinki usually pales in comparison with Singapore and London in the global smart city rankings. However, in a comparison by the European Parliament Helsinki is "one of the top six" smart city initiatives in Europe (Forum Virium, 2020). Helsinki has also recently gained increasing recognition having been named during 2019 as the European capital of smart tourism, having the best digital twin in the Kalasatama neighbourhood, the most innovative region in Europe, the best European mid-sized region for foreign investments, the third best city for start-up companies globally, and both the fifth and eighth best smart city in the world in two different rankings.

A smart city requires new kinds of cognitive capabilities from the citizens. A study points out that the smart cities require continuous adaptability and innovativeness from their citizens (Laitinen, Piazza, & Stenvall, 2017). This should be realised in accordance with the concept of lifelong learning. It is argued that the existence of smart cities would not be possible without the development of smart communities. Traditionally, in Helsinki the citizens have been divided to those who plan and those who do, but the smart city is quickly changing this so that the citizens and the workforce need to increasingly participate in the city planning, also. This increases the amount of interaction and flexibility in the planning. This new and increased information flow creates a challenge for the citizens' ability to learn to analyse this new information and to adapt their behaviour accordingly in the smart city. In Helsinki, the citizens are noticed being aware of the need of change and to renew the system. The role of the expert professionals is seen as essential in the development of smart city where collaboration between participants with various levels of flexibility is needed to face the new situations in an open learning community.

A study performed in Helsinki noted the need to develop new kinds of performance measures to evaluate the effectiveness of the smart city and its services (Argento, Grossi, Jääskeläinen, Servalli, & Suomala, 2016). The traditionally measured vertical performance of each municipal service on its own is not adequate anymore. Instead, new interdepartmental and horizontal performance measures are needed in evaluating the results of the entire service system of the smart city. The study revealed that these new performance measurement initiatives could potentially improve the identification of the problems in the structures of administration, the communication, and the transparency of the smart city. These could also help in streamlining the operations and in reaching the societal and sustainability goals.

Forum Virium, the innovation company of the city of Helsinki, points out the importance of digital smart city solutions co-created with companies, universities, citizens of Helsinki and other public sector organisations, and in collaboration with other European smart city initiatives (Forum Virium, 2020). The significance of open and transparent public data, user-driven open innovation, and agile piloting culture is highlighted.

5.2.1 Forum Virium Helsinki

Forum Virium Helsinki reports having 81 projects for co-created smart city solutions, involving 750 companies, 170 research facilities and 60 partner cities (Forum Virium, 2020). The amount of participating private citizens is not mentioned. The many projects of Forum Virium are loosely grouped under four main headlines: IoT, Smart City, Smart Mobility, and Forum Virium being the fourth headline under which there are two projects concentrating on the development of a European AI ecosystem and the cooperation of the smart city development of the six largest cities in Finland. The aim of Forum Virium is to make Helsinki the most functional smart city in the world.

The IoT initiative includes projects ranging from the development of disruptive ICT technologies for the city infrastructure to the modelling of digital solutions to attract tourists to the Helsinki archipelago (Forum Virium, 2020). One project concentrates on the utilisation of AI in the attempt to reduce greenhouse gas emissions in the partnering cities. From the practical need of developing the charging and parking infrastructure for electronic vehicles grew the larger project of developing the open standards and interfaces required to build an open innovation ecosystem to support new IoT system innovations. There are also two separate air quality projects in the IoT initiative: one project seeks for solutions to the lack of high-resolution real-time air quality information, while the other experiments how the 5G networks could be utilised to transfer large data amounts, like the real-time air quality information. The IoT and the big data collected from housing companies are utilised in the project to control and reduce the energy consumption in the blocks of flats based on the actual needs of the residents. This project also faces the challenges related to the ownership and usage rights of the collected data between private residents, housing companies, changing service providers and public energy companies. Finally, there is also a project for developing digital technologies and operational models for the circular economy related to the re-utilisation of industrial side streams and earth masses from the earthworks.

The Smart Mobility initiative lists nine current projects (Forum Virium, 2020). However, many of the projects have overlapping elements: there are two separate projects for drone services, two projects for self-driving buses, two projects for smart neighbourhood development, and two projects for the last mile problematics. One of the drone projects has the objective of piloting carbon neutrality in logistics, remote security and environmental supervision. The other project studies the last mile delivery problems, drone transportation being one of the study areas. The other last mile project includes the replacement of automobile deliveries by lighter, electricity-assisted, autonomous vehicles, and the goods delivery to shared local distribution stations. Both robot bus projects study the first and last mile problematics using autonomous minibuses as part of public transportation services, seeking to find a systemic proof of concept for automated last mile transport fleet operations integrated to an existing urban transport system. The projects concentrate on different neighbourhoods in Helsinki, and they have a slightly differing durations and schedules. At least one of these neighbourhood bus services has already stopped its operation (Helsinki RobobusLine, 2019). A special smart mobility test area is established in the Jätkäsaari neighbourhood. One aim of the test area is to recognise and boost start-up companies specialising in mobility, with support for their pilot projects. The Jätkäsaari test area is also one of the target locations for the last-mile mobility solution development. The mobility urban values project seeks to the change the mobility behaviour of the citizens to favour low-emission mobility choices with the help of gamification and illustration. Finally, a project between Helsinki and Tallinn experiments various solutions to tackle the increasing congestion at ferry terminals.

Many of the projects in the Smart City initiative take place in the Kalasatama smart city district which functions as a living lab for the projects (Forum Virium, 2020). One project drives carbon-neutral city planning and diverse use of green infrastructure first in Kalasatama and then in other new neighbourhoods. The flexi space project investigates how underused spaces could be utilised by the residents by making them more visible and accessible. The Kalasatama neighbourhood also belongs to the cooperation project for sharing of the best practices between other living labs in the Nordic Smart City Network. The other projects in the Smart City initiative include a Get Home Safely project where the feeling of safety is enhanced with a smart lights system. There is also a health care project with the objective of enabling businesses and cities to co-create customer-oriented health and wellbeing solutions. The smart learning projects seeks to find better business opportunities for companies that develop education services, products, and technologies for smart learning environments. At the same time the project aims to promote the development of user-oriented learning environments. The AI projects included in the IoT initiative are included also in the Smart City initiative. The Smart City initiative also drives the development of a European Union wide AI ecosystem.

What is notable about the smart city initiatives of Forum Virium Helsinki is that almost all projects are run in cooperation with several other cities, either domestically, between neighbouring or regional countries, or with an EU wide perspective. Large parts of the funding of the projects are also credited to coming from the European Union (Forum Virium, 2020).

There are three options to participate in the development of the Helsinki smart city with Forum Virium: First, the companies of all sizes are invited to participate in challenge-based open calls where the companies can propose solutions to the problems that Forum Virium has defined. Secondly, the citizens are invited to join selected projects in the Smart City, IoT and Smart Mobility initiatives. Thirdly, the universities are invited to create collaborative research and innovation projects for which Forum Virium can provide funding (Forum Virium, 2020).

5.2.2 Helsinki Lighthouse

Helsinki, together with Nantes and Hamburg, is also one of the three so called Lighthouse Cities of mySMARTLife, an EU funded project for making the cities more environmentally friendly (García Pajares, 2020). The target is to reduce the CO_2 emissions and increase the use of renewable energy sources. The mySMARTLife project also concentrates on topics like inclusive cities, smart people and smart economy with the targets of higher quality of life for the citizens, and a more dynamic economic concept ensuring employment and adequate income.

The Helsinki mySMARTLife activities are divided into 47 actions taking place in four zones of intervention: Zone 1 includes the Merihaka and Vilhonvuori retrofitting neighbourhoods with smart metering and heating demand optimisation through IoT. Zone 2 consists of the new Kalasatama construction area where electronic vehicles can be charged with electricity from renewable energy sources, the heat from waste is utilised, and all the apartments have smart metering and other smart home solutions. Zone 3 demonstrates a high-performance office building utilising renewable energy sources in the Viikki neighbourhood. Zone 4 takes place in the Vanhankaupunginlahti neighbourhood where various smart mobility trials are being implemented (Viitanen, 2020). Many of the projects of mySMARTLife are interlinked with the Forum Virium projects.

5.2.3 Smart data of Helsinki

The open data of Helsinki and the neighbouring cities is coordinated under a common Helsinki Region Infoshare (HRI) website (Helsinki Region Infoshare, 2020). The data collected by the Helsinki metropolitan cities was opened to the public in 2011. Coincidentally, Singapore made their open data public in the same year. The HRI currently lists 636 datasets, 254 applications, and 147 APIs. Majority of the datasets, about 30 % of them, consider various kinds of map data. The population and census related datasets form the second group with about 23 % share of all the datasets. Interestingly, even though smart people are seen essential for smart cities, it seems to be difficult to generate datasets for education. Only about 6 % of the datasets on the HRI website are related to education.

Regarding smart applications, a study indicates that much of the progress of Helsinki as a smart city can be contributed to the application developed in competitions (Hielkema & Hongisto, 2012). The software competitions organised by the living labs, such as Forum Virium, are said to offer many benefits: The competitions inspire the skilled software developers to the use of the open data and APIs. The participating developers will then add value and relevance to the available information. The competitions add publicity, interest and awareness to the available data and the developed applications. This also generates innovativeness and entrepreneurial thinking for the smart city initiatives. Furthermore, the competitions are said to improve the overall quality of the smart city applications.

In practice, it is not anymore so easy to find open application development competitions in Helsinki. The Apps4Finland competition, for which Forum Virium was one of the main organisers, was active in 2004–2014. After that the competition continued as Open Finland Challenge and Databusiness Challenge (Forum Virium, 2020). However, Open Finland Challenge does not seem to have had any activity since awarding the 2015 competition winners (Open Finland Challenge, 2015). Moreover, the Databusiness Challenge has not updated its website after the competition in 2017 (Databusiness Challenge, 2017).

One active smart data application development platform in Helsinki is the Helsinki Loves Developers website of the open software development team of the city of Helsinki (Hel Dev, 2020). They are actively publishing their ongoing projects on their website and the active code development is published on an open development platform. The team also shares a list of the Helsinki related open APIs in collaboration with Helsinki Region Infoshare. The citizens are encouraged to register their applications to the website of the open software development team. Helsinki Loves Developers was also one of the studied platforms in a comparison of the convergence between open data initiatives and several smart cities (Ojo, et al., 2015). The study demonstrates that the open data initiatives have a significant impact especially on the economy, governance, transport, and mobility domains of the smart cities. The nature of the published open datasets supports innovation in the smart cities. While the open data initiatives have an impact on shaping the smart cities, it is realised that the smart city concept itself also shapes the open data initiatives. The study concludes that the smart cities driven by open data and open innovation could be characterised as open innovation economies.

5.2.4 Smart traffic of Helsinki

The viewpoints of Helsinki and Finland to the main challenges of the smart traffic initiative are summarised well in the TransSmart research programme, run ca. 2013–2017 (TransSmart, 2020). The programme had two strategic development areas: sustainability and digitalisation. These were divided further into four main research themes: utilisation of low carbon energy, development of advanced vehicles, smart mobility services and transport systems.

Taking a closer look at the Smart Mobility initiative of Forum Virium the same four themes can be clearly seen there too: Low carbon or carbon neutral energy is utilised in the drone service trial and in the electric autonomous minibus trials (Forum Virium, 2020). These are also examples of advanced vehicles. In addition to the autonomous bus trials, the smart mobility services and transport systems are present in the smart last mile city logistics project, too.

The same themes are visible in the five smart mobility solutions piloted in the ports of the Helsinki–Tallinn ferry route (Forum Virium, 2020). The first project experiments a queue management system controlling truck movements at the downtown passenger ports to reduce congestion. The second project studies passenger flow management by travel service packages. These packages could offer complimentary services, like free beverages, included in the travel ticket price. The third project is concepting the use of smart containers as a short-term storage for the purchases made by the travellers. The same containers could also be used in the sharing economy concepts of the citizens. Fourth, an automatic hands-free tram ticketing system is tested to see how the passenger movement in the ferry terminals could be expedited. The fifth project experiments with the anonymised mobile subscribers’ location data to analyse the movement trends of the ferry passengers in the city.

It could be asked why there needs to be two simultaneous self-driving minibus projects ongoing in Helsinki under Forum Virium, a third, recently discontinued project by mySMARTLife and a fourth one discontinued already in 2016 (Forum Virium, 2020). Both live autonomous bus projects have the target of piloting the service as a part of the existing public transportation services in Helsinki. The other one has the additional target of producing information about eco-friendliness, while the other concentrates more on the operations and system level concepting. Both projects receive funding from the EU, albeit from different research programmes. Both projects are also partnering with other European countries. One of the projects has six international partners, while the other has eight international partners. Only Finland, Estonia and Norway participate in both projects.

There are only few readily available and recently published research papers related to the smart traffic in Helsinki. One paper has studied the role and ways of utilizing open data in sustainable mobility initiatives in nine European and American smart cities, including Helsinki (Yadav, Hasan, Ojo, & Curry, 2017). The report summarises that there are 22 datasets related to the smart mobility in Helsinki Region Infoshare, compared with, for example London having 77 and Dublin 16 smart mobility datasets. The study has noticed some interesting local variations: Helsinki and London are the leaders in the amount rail traffic datasets with 29 and 25 datasets, respectively, whereas New York leads the bus traffic category having 38 datasets. The role of sustainability is pronounced in Helsinki. Helsinki has 25 sustainability datasets giving Helsinki the third place in the sustainability related open data ranking. This study also demonstrates how quickly the smart city projects evolve and the data gets outdated. There are currently 84 datasets, instead of 22 mentioned in the study, in Helsinki Region Infoshare (Helsinki Region Infoshare, 2020), 89 datasets, instead of 77, in London Datastore (London Datastore, 2020), and 83 datasets, instead of 16, in Dublinked Open Data Store (Dublinked, 2020) that are categorised as related to mobility, traffic or transport.

Another recent study introduces dynamic route lighting that combines the smart traffic and smart urban living initiatives into a single project (Juntunen, Sarjanoja, Eskeli, Pihlajaniemi, & Österlund, 2018). In the study a smart lighting control system that uses infrared sensors to detect the movement of the route users was developed. The system can predict the route of the users. This enables the illumination of the route more in front of the users than behind them. The tested system was able to achieve about 70 % energy saving compared to a traditional lighting control system.

The city of Helsinki has published an interesting trial that combines mobility as a service (MaaS) with the related smart mobility application to facilitate boat rides for accessing the island in the Helsinki archipelago (Helsinki, 2018). The passengers needing a boat ride can use a mobile application to book on-demand boat rides from the participating voluntary boat owners. This Bout service was soft launched in 2018, with continued tests during 2019 (Bout, 2020). The service reports that they are currently finalising their mobile phone application for the season of 2020. The Bout service is a participant in the EU funded last mile project in the Helsinki region.

A recent newspaper article discusses about the high cost of wasting time when searching for a free parking space in the city centre of Helsinki (Riikonen, 2019). There are now two commercial parking application providers that are cooperating with Helsinki Region Infoshare to collect parking data and publish it at HRI website. The car park navigator applications can then use artificial intelligence to predict a free parking place based on the open data.

5.3 Singapore

Singapore is often named as the prime example of a smart city. For example, the Smart City Expo World Congress chose Singapore the Smart City of 2018, rewarding their Smart Nation urban transformation project (PR Newswire, 2018). Also, in the Smart City Ranking by ABI Research in 2018, Singapore took the lead, scoring highest on the criteria related to innovation (Drubin, 2018). Especially mentioned are Singapore's innovations related to freight as a service (FaaS), MaaS and the innovative use of next-generation technology and disruptive paradigms in solving difficult structural problems. Interestingly, Singapore did not take the top position in the utilization of open data policies, where London took the third ranking.

Again, in 2019 Singapore took the smartest city ranking in the first ever smart city index by IMD, International Institute for Management Development (International Institute for Management Development, 2019b). Singapore's ranking may have not changed much even if IMD, a Switzerland-based institute, did not have an affiliate in Singapore, and even if the smart city index were not presented in partnership with Singapore University of Technology and Design.

Singapore is also an interesting case to demonstrate how the legacy of the developmental era central planning policy, typical to many Asian countries, still affects the innovation policy (Hartley, Woo, & Chung, 2018). The entrepreneurship and start-up economy are the characteristics and the source of the post-developmental, new smart city innovation, whereas the developmental planning steered by the government, concentrated on large corporations where the government usually also had a strong foothold. Now, in the post-developmental era, much of the innovation takes place in the smaller start-up and entrepreneurial companies where the government does not have a formal history.

5.3.1 Smart Nation Singapore

Singapore's smart city development is concentrated under the Smart Nation initiative, launched in 2014 (Infocomm Media Development Authority, 2014). At that time the Singapore government aim was in building a technical architecture for the word's first Smart Nation. Infocomm Media Development Authority of Singapore was given the leadership in the holistic development of both hard and soft infrastructure. This included standardisation of the use of IoT and the development of Smart Nation Platform. The Smart Nation Platform was targeted at being a new enhanced connectivity network, that provides heterogenous networks, pervasive connectivity and a nationwide IoT sensor and data analytics capability. The Smart Nation Platform would then allow companies and government agencies to innovate smarter services for the citizens. In addition to the Smart Nation Platform there were also two other Smart Nation initiatives identified: a seamless smart device connectivity at homes, and an innovative virtual reality-based user interface and service development utilising game science.

About four years later, an updated plan to develop the Smart Nation further was introduced in 2018 (Smart Nation, 2018). Now the targets and the used terminology had changed noticeably. The focus remained in the technology that would drive the smart city services, but now with an additional focus on the national transformation. The original user interface and connectivity development initiatives had been reshaped into the development of remote health services, and collaborative, self-directed education services. The smart home connectivity trials and IoT initiatives would now concentrate on urban solutions, like safety, energy saving and sustainability. Additionally, the Smart Nation initiative now also included two new key domains: the development of smart transportation solutions, like autonomous vehicles, and the objective of maintaining Singapore's status as the regional and global finance hub.

The original Smart Nation Platform has also evolved to include an Open Innovation Platform (OIP) (Infocomm Media Development Authority, 2019). This is a structured virtual crowdsourcing platform between so called problem owners and problem solvers. Every few months the OIP launches facilitated innovation calls, a type of innovation competitions, with the possibility to win prize money. The purpose is to find solutions to real business problems. The candidates must apply in order to become admitted into the Open Innovation Platform (Open Innovation Platform, 2020). The applicants must also register as either problem owners or problem solvers. The problem owners are expected to be either enterprises or government agencies, while the problem solvers may be technology innovators, researchers, start-up companies or other commercial businesses. Interestingly, the participation of private citizens, in the spirit of true open software development principle, is not mentioned at all.

Today, Smart Nation is divided into six main initiatives: urban living, transport, health, digital government services, start-ups and businesses, and strategic national projects.

The urban living initiative consists of some citizen centric projects, like an automated water consumption metering trial, a drone-based mosquito breeding inspection aid, a mobile application for environmental news updates, an elderly alert system and a citizens' municipal issues reporting application (Urban Living, 2020). The urban living initiative includes also projects related to the urban planning. A smart towns framework utilises sensor networks, computer simulations, data analytics and digital tools to improve housing planning, environmental conditions, maintenance management and social engagement in the suburbs. There is also a dynamic 3D virtual city modelling platform to aid solution development, simulations, and collaborative planning.

The transport initiative experiments with autonomous vehicle research, on-demand shuttle bus services, contactless public transport payments, and open data sets for urban transport planning (Transport, 2020). The transport initiative also includes research for the development of standardisation and test requirements for the autonomous vehicles.

The health initiative of Smart Nation includes trials of a healthcare portal for accessing medical records, a tele-healthcare practice for video consultation and therapist's remote monitoring, and assistive health care robotics, including drone deliveries of medicine, robotic food, linen and document delivery and augmented reality services for doctors (Health, 2019). Interestingly, the health initiative also includes a national physical activity programme using step trackers. The purpose is simply to incentivise the citizens to walk more during the day.

The digital government services initiative builds easy to use e-government applications, for example for registering new businesses, registering babies, supporting children's healthcare, selecting and administering schools and reselling public housing (Digital Government Services, 2020). In addition to the English language, the Singapore government is also developing a policy for multilingual digital services, comprising the other commonly used languages in Singapore: Malay, Mandarin and Tamil. There is also blockchain-based platform by which the physical validation of academic records and certifications can be replaced by a cryptographic validation method.

The start-ups and businesses initiative includes a digital corporate authentication system for e-government services, a common business park and digital village for start-up companies and universities with integrated community facilities, a platform for financial technology innovations, a data innovation pilot programme targeting for an industry-led dataset utilisation (Startups and Businesses, 2020). There is also a networked trade information management platform supporting Singapore's large trade industry sector.

Finally, the initiative for strategic national projects consists of the key enabler projects driving the Smart Nation vision (Strategic National Projects, 2020). These include a national digital identity system, a national electronic payment infrastructure, a data architecture and shared software suite for development digital government services and applications, a nation-wide sensor platform for improving municipal services, operations, planning and security, a smart urban mobility project that shares components with the previously mentioned transport initiative, and a moments of life initiative for the family related e-government applications included in the digital government initiative introduced above.

5.3.2 Smart data of Singapore

The open data of Singapore is published at the Data.gov.sg website (Govtech, 2020). The site was first launched in 2011, the same year when Helsinki Region Infoshare went public, too. Now, after about nine years of operation, the Singapore site reports still being in public beta phase. The site collects open datasets from 70 public agencies, and it is reported that over 100 applications have been developed based on the government's open data. There are currently about 20 real-time or CKAN APIs and over 1 800 datasets made available for the developers.

Separately from Data.gov.sg, the Smart Nation initiative lists a large selection of other open data resources for the potential developers to utilise. For example, the Inland Revenue Authority of Singapore currently lists 14 APIs for the developers of tax and duty related applications (Inland Revenue Authority of Singapore, 2019). The Land Transport Authority publishes a DataMall of APIs in hopes of co-created transport solutions (Land Transport Authority, 2020a). The APIs of Monetary Authority of Singapore reflect the position of Singapore as the financial hub of Asia (Monetary Authority of Singapore, 2020). There are also APIs for National Digital Identity for the development of applications that require trusted identity and data access (Government Technology Agency, 2020). The Singapore Land Authority maintains a detailed digital national map of Singapore with location-based data and APIs from the government agencies (OneMap, 2020). Another geospatial map is published by the Urban Redevelopment Authority about the planned land use and property use for the building professionals (Urban Redevelopment Authority, 2020). The Department of Statistics shares a large collection of national and international statistical data (Singapore Department of Statistics, 2019). An interesting map portal by National Parks shares information of about 500 000 urban trees planted in the neighbourhoods of Singapore (Trees.sg, 2019).

5.3.3 Smart traffic of Singapore

A closer look at the Transport initiatives of the Smart Nation programme reveals some interesting projects and facts. Strategically, the objective in Singapore is to optimise the use of the limited space with more efficient, reliable and safer vehicles, with enhanced transportation methods and systems (Transport, 2020). Autonomous vehicles seem to play a key role in these projects: there are, or have been, three trials with self-driving sedan-sized cars, four trials with autonomous shuttle buses of various sizes, including autonomous on-demand shuttles, autonomous electric minibus service for garden visitors, driverless shuttle buses in a university campus, and a larger, 40-seater autonomous electric bus. There are also trials towards enabling the emerging development of FaaS. One project trials driverless trucks that are guided by transponders installed in the road, and another project trials platooning, with heavy vehicle leader-follower formations (Ministry of Transport, 2017). Unfortunately, it is difficult to find any public evidence of the progress of, for example, the platooning trial after its initial publication in 2017 and the expected end of the trial in December 2019.

The Transport initiative of Smart Nation also includes a project for the utilisation of open data and analytics for the urban transportation (Transport, 2020). The anonymised fare card data collected from the commuters and the sensors installed in the buses are utilised to improve the transport planning. The reported results claim a 92 % reduction in the number of bus services with crowding problems and three to seven minutes of shortened waiting times on average on the popular bus services. The open traffic data is also made available for the third-party application developers and through the Land Transport Authority hosted API and developer site

The DataMall of the Land Transport Authority includes an application section for the applications that the third-party developers have created for the transport-related services (App Zone, 2018). Three main topics, which also address the Singaporean lifestyle, can be picked from the 48 applications currently listed on the site: Most of the applications are related to the bus schedule and transit services. The second group consists of the applications supporting car parking. The third most common set of applications is related to the taxi services of Singapore. Unfortunately, the application site does not seem to have been updated since 2018.

A recent news release from the Land Transport Authority of Singapore also reveals the complexity related to the promotion of electric vehicle ownership (Land Transport Authority, 2020b). On the one hand, the authorities report launching a three-year early adoption incentive, in the form of reduced registration fees, to reduce the upfront cost gap of owning a more expensive electric vehicle as compared to owning a conventional combustion engine vehicle. However, on the other hand, the authorities simultaneously increase the annual road tax of the electric vehicles, to match up with the fuel excise duties that the combustion engine vehicles must pay.

A few interesting smart traffic studies that concentrate on the characteristics of the Singaporean traffic can be found from the current research. A conventional parking guidance system is enhanced so that the driver is able prioritise the parking space selection based on the parking fee and the proximity to the destination (Niculescu, Lim, Wibowo, Yeo, Lim, Popow, Chia, & Banchs, 2015). The system can also redirect the driver to another car park if the initially selected car park is becoming full. The system updates its information once per minute by reading open data provided by the Land Transport Authority of Singapore. The system does not forget the human factor either. The local traffic regulations require that the system should use speech dialogues for the driver interaction. Interestingly, the developed system uses speech dialogue in natural language, and especially in Singlish, which is the popular local colloquial variant of English in Singapore.

In another study a multi-modal journey planner adapted to the Singaporean context is presented (Yu, Shao, & Wu, 2105). It is noted that the currently available journey planners do not support multi-modal travelling well enough. Two main problems are identified: First, there is a lack of accurate network information, especially about the optimal pedestrian routes to and from the public transport stations. Secondly, there is a lack of real-time speed information for the accurate estimation of travel times on the various candidate routes. Additionally, for those who drive private cars to metro stations, the journey planner should be able to suggest metro stations that have car parks nearby, instead of directing simply to the nearest metro station from the origin. Richer network data, including data about the road network, park connectors, walking paths, cycle and car park locations, occupancy, and traffic regulations are needed to solve the first problem. The utilisation of this information enables more accurate multi-modal travel planning. The second problem can be solved by using both static roadside speed cameras and GPS equipped taxis that serve as dynamic speed probing vehicles. The developed algorithm can use both speed sources for accurate real-time speed estimation on the roads. In addition to using open sensor and speed data, the application also uses Open Trip Planner, a set of open source multi-modal travel algorithms, that accommodates the implementation of the new features.

5.4 London

London usually achieves top rankings in the smart city comparisons. Next, it is studied how London manages to achieve this, while battling with rapid urbanisation, severe traffic congestions, ancient municipal infrastructure, and a challenging political situation amidst the British exit from the EU.

The smart city initiatives of London are organised under the Smart London platform, directly under the governance of the mayor of London (Smart London, 2020). One of the main Smart London initiatives is the Smarter London Together roadmap with its target of making London the smartest city in the world (Smarter London Together, 2020). The open innovation platform is concentrated under London Living Labs (London Living Labs, 2020). The utilisation of smart data and data collaboration is promoted in the data analytics programme, which is part of the London Datastore open data-sharing portal (London Datastore, 2020).

5.4.1 Smart London

The Smart London platform consists of five main initiatives: The Smart London Board, the London Office of Technology and Innovation, the mayor of London’s Civic Innovation Challenge, the London Development Database, and the Smarter London Together roadmap (Smart London, 2020). This roadmap presents the initiatives by which London targets to become the smartest city in the world. There are also four related initiatives presented under the Smart London platform: the European wide Sharing Cities programme, the OpenActive physical activity related open data initiative, the Sensing the Park IoT sensor technology project, and the Civic Crowdfunding Programme.

The Smart London Board is a collection of digital technology academics and entrepreneurs constructing the vision how London should utilise digital data and technology to make the city a better place for citizens, businesses and visitors (Smart London, 2020). The London Office of Technology and Innovation is a collaboration platform for the many local districts of greater London to enhance digital innovation in the public services. The Mayor of London's Civic Innovation Challenge invites technology start-up companies to innovate applications and solutions to tackle some of the most serious problems of London. The currently active challenges are to find solutions how to use data to make the urban planning more democratic, how technology could be used to counter violent extremism, and how traffic congestion could be reduced with safer, cleaner and more efficient freight transport. The London Development Database is a collaborative tool for the greater London districts to monitor their planning permissions. The interesting Smarter London Together roadmap will be introduced in more detail separately in chapter 5.4.2.

From the four related initiatives to Smart London, it would be interesting to know how the British exit from the EU may affect the European wide Sharing Cities programme. The purpose of the Sharing Cities is to develop a new model for sharing data and managing city infrastructure across cities (Sharing Cities, 2020). The programme is funded by the EC, and the selected strategic locations for the collaboration are London, Lisbon, and Milan. The lack of physical activity is noted as one of the biggest health challenges in the UK. The OpenActive programme encourages the citizens to exercise more by providing open data, open standards and open source tools in the sports and physical activity sector (OpenActive, 2020). The Sensing the Park IoT sensor technology project collects real-time information from weather stations and solar sensors, connected via LoRa and Wi-Fi networks, in Queen Elizabeth Olympic Park, allegedly the most connected urban park in the world (Smart London, 2020). In the next phase the project targets to deploy more IoT sensors to also measure air and water quality, water height, and to detect wildlife in the park. The purpose is to improve the way how the park is run in a more sustainable way and how the citizens experience the park. Sensing the Park is mentioned being one of the leading sustainability projects of London's Smart Cities platform. The Civic Crowd-funding Programme is piloting an online crowdfunding platform where the citizens can publicly propose ideas for improving their neighbourhood. The ideas collecting the most support from the public will get funding from the city. The target is to encourage bottom-up citizen collaboration in city planning and development.

5.4.2 Smarter London Together

Smarter London Together is a roadmap, launched directly by the mayor of London in 2018, targeting to transform London into the smartest city in the world (Mayor of London, 2018a). The major role in this transformation is given to data innovation and digital technology, with the aim to serve three target groups: those who live or work in London as well as those who are visiting London. The Smarter London Together is divided in to five key missions: user-designed services, data analytics and data sharing, connectivity and smarter streets, digital leadership and skills, and city-wide collaboration.

The first mission covers a wide range of topics from design and common standards to better access to public services and technology diversity to address inequality (Mayor of London, 2018a). The goal is in engaging citizens to develop more user-designed services. The Civic Innovation Challenge, introduced already in the Smart London platform, is also a part of this user-designed services mission.

The second mission is about the city data. This includes a data analytics programme to increase data collaboration and data sharing (Mayor of London, 2018a). There is also an initiative to develop a city-wide strategy for cyber security to counter the cyber-attacks against the citizens, public services, and private companies in London. Finally, the issues related to data rights, accountability and transparency are addressed in order to build trust and promote innovation in an open data ecosystem.

The third mission is a Connected London programme coordinating 5G, fibre to the home, and public Wi-Fi connectivity planning (Mayor of London, 2018a). The targets are that every new housing development should have a fibre network connected to the homes, and that the streets and public buildings should become smarter with the help of public Wi-Fi connectivity.

The fourth mission concentrates on the needed digital skills and leadership development. The Skills for Londoners strategy develops the digital capabilities of the workforce (Mayor of London, 2018a). Computing skills and digital talent should be educated already from an early age.

The improvement of city-wide collaboration is the topic of the fifth mission (Mayor of London, 2018a). Here the previously introduced London Office of Technology and Innovation has a key role in improving the effectiveness of the cooperation between the districts of the greater London area, and the collaboration between other cities in the UK and globally.

5.4.3 Smart data of London

The open data and open application development platforms of London can be found from many places. A good starting point is the London Datastore, a portal that contains over 700 datasets of open data from the Greater London Authority and other public sector organisations of London (London Datastore, 2020). The citizens have a free access to the data, and they are encouraged to build applications and visualisations from the data.

Closely related to the London Datastore is the City Data Analytics Programme which is a virtual hub that supports the data analytics and data science initiatives and the collaboration of the public organisations of London (London Datastore, 2020). This is also a key part of the second mission of the Smarter London Together roadmap, discussed in chapter 5.4.2 above. The City Data Analytics Programme provides data science expertise, project management facilities, technical and legal support, and information governance advice for the public sector users of the open data in the London Datastore.

The Open Data Institute (ODI) is a London-based, private, non-profit company advocating for the use of open data (Open Data Institute, 2020). The ODI is also related to the open data initiatives of London as they are the coordinators of the OpenActive programme that encourages the citizens to exercise more with the help of open data, standards and tools (Smart London, 2020).

The living lab type of application development and experimenting can be found from the London Living Labs (L3) (London Living Labs, 2020). This is an environment coordinated by the Imperial College London and co-sponsored by Intel and Innovate UK, the government innovation agency. The projects of the L3 concentrate on wireless sensor network and edge computing based IoT solutions, with a focus on weather patterns and environmental information, like air and water quality, and noise and light pollution.

5.4.4 Smart traffic of London

The Smarter London Together roadmap only briefly mentions the smart traffic initiatives of London. Instead, these activities are motivated by another document: Mayor's Transport Strategy (Mayor of London, 2018b), and the related website (Mayor of London, 2018c), which list three key themes for the smart transport in London: First, healthier streets are achieved by reducing dependency on private cars and encouraging the use of public transport, cycling and walking. Secondly, a good public transport system could reduce the number of vehicles on the streets of London. Thirdly, the planning of the city around public transport, cycling and walking should enable the city to grow in new areas for the growing amount of people moving or working in London.

The London strategy to concentrate on the smart public transport innovations is clearly visible on the website of Transport for London (TfL), too. There is a special innovation portal attracting commercial innovation partners to register and participate in various listed innovation opportunities (Transport for London, 2020a). The London FreightLab is looking for solutions to the congested freight and servicing issues of London. There are also planned innovation challenges for the fare evasion problem, bus driver fatigue issues, safety on the roads and cycling. TfL is also active with living lab activities. London Connectory is a dedicated LL, where TfL partners with private corporations, academic institutions and public sector organisations to offer start-up companies and smaller businesses the facilities, opportunities, expert support and datasets to develop solutions for more environmentally friendly and safer vehicles, congestion reduction, improved accessibility, and increased use of public transportation along walking and cycling.

In addition to London Connectory, there is also another notable LL concentrating on traffic issues in London. Smart Mobility Living Lab (SMLL) is a testbed for connected and autonomous vehicles (CAV) and new mobility and transport technologies (Smart Mobility Living Lab London, 2019). SMLL provides test facilities for the CAV technology both in public roads in Greenwich and in a test campus in the Queen Elizabeth Olympic Park. The 5G connectivity and infrastructure needed by the CAVs is one of the current research topics of SMLL in the Queen Elizabeth Olympic Park (Smarter London Together, 2020). There are also autonomous vehicles in commercial operation at the Heathrow airport, where a shuttle service between Terminal 5 and the T5 business car park is operated by 21 autonomous small pod vehicles (Ultra Global PRT, 2020).

TfL maintains also its own smart data platform encouraging crowdsourced development of applications and services. There are several dozens of datasets and live data feeds ranging from air quality and road conditions to timetables, maps and location data in the TfL open data website (Transport for London, 2020b). The application development is further supported by a dedicated open application programming interface (API) of TfL

(Transport for London, 2020c). The unified API provides a common canonical data model for the format and structure of the open data.

A recent study interestingly predicts public transport traffic volumes and effects of unplanned route disruptions in the TfL commuter train network using payment data from the automated fare collection points at the stations (Silva, Kang, & Airoldi, 2015). The developed model utilises anonymised big data collected from the passenger smart cards when they tap in or tap out at the entrances and exits of the stations. This data is enhanced with the passenger route choice information obtained from the passenger surveys of TfL. With the presented model it is possible to predict how the passengers may behave and change their routing in case of unplanned closures of stations and route sections. This should give valuable information for TfL to plan alternative solutions, like compensatory bus services, to mitigate the effects of unplanned service disruptions.

A similar smart-card usage analysis studies if it is possible to measure the variability or regularity of mobility patterns of the subway train travellers in London, Singapore, and Beijing, three of the largest subway systems in the world (Zhong, Batty, Manley, Wang, J., Wang, Z., Chen, & Schmitt, 2016). Two aspects of the mobility patterns were studied: the temporal distribution of the starting times of the trips at the stations, and the trip patterns from and to the stations at different times. The comparison noticed that the travellers in London have the highest unpredictability regarding the origin, destination, and time of the travel. This is explained by the densely located stations in central London, giving travellers possibilities to alter their route, either randomly or due to route disruptions, without greatly affecting the total travel time. Singapore was found to be the most predictable city, thanks to its relatively new and reliable subway network, and the distinct residential neighbourhoods served by the subway lines. The researchers wish to study further the variability of the regularity across other dimensions, such as spatial scales and group behaviour of individuals, and by using other datasets, for example from the mobile phone data to simulate urban mobility and its variations more accurately.

Another study concentrated on investigating the effects of smart parking in London (Peng, Nunes, & Zheng, 2017). Traditionally parking applications have only indicated the number of available parking spaces in parking garages based on the calculated number of vehicles entering or exiting the garage through a gate. A smart parking application relies on wireless sensors installed under the parking spaces on the city streets. This enables the application to support on-street parking and show real-time information about vacant parking spaces on public streets. The smart parking application can reduce the time spent and the number of drivers cruising around to find empty parking spaces on congested city streets. The study points out that a smart parking application in London could potentially reduce the CO_2 emissions annually by over 238 kg per vehicle, corresponding to an average annual petrol save of about 62 litres. At the city level this would correspond to almost 643 000 tons of reduced annual CO_2 emissions, and petrol cost savings of almost 184 million GBP, if every driver in London used the application every time they needed to find a parking space in the city centre. However, due to low citizen awareness of the smart parking application, the usage rate of the service is only about 18 % of its full potential. The study concludes that implementing the technical smart city solution is usually not enough alone. In the information systems (IS) literature the lack of user participation is often reported as a major cause for the failure of ICT services. The socio-technical aspects of the smart solutions should be understood better, including the citizen engagement, communications, and marketing of the smart city services.

5.5 Smart city comparison summary

When comparing the smart city initiatives and activities of Helsinki, Singapore and London, Singapore has one clearly visible main advantage over the others. Being a small island city state, any smart city initiative will automatically have a national and government dimension, too. Thus, the smart city Singapore has quickly evolved into Smart Nation Singapore. Scaling the smart city activities in London and Helsinki to the national level would be much more challenging because the cities and rural areas in Finland and the UK would not have the same uniformity of connectedness and quality of infrastructure as in Singapore. Related to the tolerance aspect required from the smart citizens, it is also noted that Singapore, with its multi-ethnic national history and the absence of so called ethnic or cultural hinterland, gives Singapore and advantage when accommodating strangers and ethnic differences that may surface during rapid urbanisation (Addie, Acuto, Ho, Cairns, & Tan, 2019).

To better understand how the smart city initiatives of Helsinki, Singapore and London are in line with the mainstream of the current smart city research and innovation it is interesting to compare their selected priorities with a recent international report on smart city vision (Airaksinen, Porkka, Vainio, Huovila, Hukkalainen, Ahvenniemi, Rämä, & Pinto-Seppä, 2016). The report mentions that smart cities should emphasize the urban flow of energy, material and people and the relations between them and the governance of the human behaviour. The smart city therefore needs co-created interoperability and integration between the urban systems with the involvement of the citizens. The urban development should be based on digital services, resource efficiency and cleanness. The main characteristics of Industry 4.0 – IoT, big data analytics, artificial intelligence, and robotics – would need to be included in the smart city vision. The smart buildings development in the cities should be based on sustainable construction, residents' approval, energy efficiency, sustainable energy sources and remotely controlled sensor technology.

Most components of the smart city vision by Airaksinen et al. are well included in the smart city initiatives of Helsinki, Singapore, and London. All three cities involve their citizens and companies in the smart city innovation. Open data is made available to support the innovation. The utilisation of IoT sensor networks is include in all three cities. However, London uses IoT mainly for the environmental trials in the parks, whereas Helsinki and Singapore try to build grids of IoT sensors and the related big data analytics capabilities especially for the purposes of energy efficiency of the smart buildings, and cleanness and safety of the neighbourhoods. The use of sustainable energy is highlighted as well in the smart building initiatives of the cities. However, the sustainability of the building construction and the used construction materials is not evidently visible except in

London. It looks like London has more trouble with its older infrastructure to simply build new housing to tackle the quick urbanisation, while Singapore and Helsinki are already experimenting more with the smart home projects. The reported requirement to seek for residents' approval beforehand for the new construction projects does not appear high on the priority of the compared cities. Robotics initiatives, apart from the robotic cars, are not currently evident in Helsinki or London, while there are robotic trials in the health care sector in Singapore. One robotic health assistant trial of Forum Virium has already ended in Helsinki in 2019.

The report of Airaksinen et al. also summarises well the direction of the international smart traffic research. The main motivation and target for this research is stated by the EU in 2011: The greenhouse gas emissions should be reduced by 60 % and traffic plays a major role in achieving the goal. The citizens should adapt to the multi-modal mobility, which means fewer private cars on the roads and more public transport, walking and cycling. The energy sources should become renewable and the energy consumption should be reduced. Digitalisation, smart sensors, IoT and intelligent transport systems, like MaaS, developed with the help of open data and crowdsourced open software development, lead to the ultimate goal of autonomous vehicles.

The smart traffic initiatives in the compared three cities follow the international smart mobility trends remarkably well. It is evident that the cities all concentrate on the development of smart public transportation supported with multi-modal transport means. The confidence in, preferably, electric self-driving robot vehicles and their ability to solve the first or last mile problematics is strong in each city. However, while many of the related trials have already ended, there are no published results available from any of the projects yet. Distinctively, the lost time and money spent in searching a parking space for private vehicles is a recognised issue in all three cities. Nevertheless, solving the problem with smart solutions is not clearly on the official smart city agenda of the compared cities. Instead, the smart parking solutions are suggested and provided by researchers, private companies, and open software developers. The importance of marine traffic is a speciality of Singapore and Helsinki. While Helsinki and Forum Virium advertise many smart solution projects related to sea freight in Helsinki, it is surprising that there does not seem to be any similar projects in the Smart Nation Singapore initiative, even though Singapore is one of the busiest ports in the world.

Regarding smart data, all three cities have extensive open data repositories, large selection of open APIs and support sites for open software developers. London seems to prefer a slightly more academic and research-oriented approach, keeping much of the living lab activities under the supervision of universities. Singapore has a more government and government agency-controlled approach to the open software development. The most active open software development site in Helsinki seems to be managed by the open software development team of the city of Helsinki. However, all three cities gave a slightly dormant image of their smart data activities. Many of the related websites had not had recent updates, new datasets or new applications published in a couple of years.

Helsinki, Singapore, and London all utilise international collaboration in their smart city initiatives. From the publicly shared material of the cities, small differences in the attitudes towards this collaboration could be detected: Helsinki is happy to collaborate in the research and share the results with international partners. Singapore utilises the international collaboration more for collecting the results for their own use and advancement in the competition between nations. London reports very few international collaborations currently. This could be easily credited to the British exit from the EU. However, this fact is never publicly mentioned as a potential reason in the Smart London initiatives.

Helsinki is the most active in promoting the bottom-up approach for the innovations, where the citizens are encouraged to collaborate and propose their solutions to shape the smart city vision. Singapore seems to prefer a slightly more tightly government controlled top-down approach, where the city is defining and driving the smart city vision. The citizens are encouraged to provide their innovativeness to build this vision, but not to really shape it. Also, London shows some indications for a more top-down controlled approach, with many of the smart city projects and goals presented in the vision document and roadmaps coming directly from the office of the mayor of London.

Table 2, below, summarises the found similarities and differences in the smart city comparison between Helsinki, Singapore and London. The table lists how the cities in general form their smart city strategies, what is their approach in domestic and international smart city collaboration and are the cities able to form coordinated nation-wide smart city initiatives. The way how the compared cities approach their smart data and smart traffic initiatives is also recapped by two or three keywords and key projects.

Table 2. Smart city comparison summary.

	Helsinki	**Singapore**	**London**
City size	Small	Medium	Large
City age	Medium	Young	Old
Available resources	Small	Large	Large
Smart city initiative	Forum Virium	Smart Nation	Smart London
Strategy development direction	Bottom-up	Top-down	Top-down
Domestic collaboration	Active Inter-city	Active National coordination	Active Within Greater London
International collaboration	Active Bidirectional	Active Unidirectional	Passive
National reach	None	Active	None
Smart data approach	City Citizens	Government Citizens	Academic institutions Citizens
Smart traffic approach	Public transport Maritime transport Autonomous buses	Public transport Autonomous vehicles Autonomous freight	Public transport Autonomous vehicles

6 Discussion and study outcomes

Even though the smart city concept can be defined and described in many ways, the basic principle is simple: The smart city should improve the quality of life of its citizens, while simultaneously simplifying the management of the city. The various styles of categorising the needed tasks, the numerous objectives set to monitor the progress, and the many ways to achieve the objectives then multiply the complexity of the implementation of the smart city by many folds. Furthermore, the simple task of just implementing the smart city projects is typically not enough, as the development of the smart city usually also requires ground-breaking achievements in research and innovation before the targets can be achieved.

The complexity of the smart city implementation options also makes the choice of the correct methods and the interpretation of the achieved results difficult and contradictory. The advancements in the social, economic and environmental sustainability are known to often produce conflicting results (Lamberton, 2005). And, if the scientific facts do not entirely support the theory or the results, then the smart city gets easily rationalised by, for example, political or even religious theories and opinions. It is easy to state that the careful and sensitive consideration of political viewpoints can make the governance of a city a lot easier (Silva, et al., 2018), but it is perhaps more difficult to define how the carefulness and sensitiveness should be defined and measured, and whose political viewpoints are the most valuable in governing the smart city.

The smart cities are further criticised for causing expansion of consumerism, when the intention has been in enabling and increasing the citizen participation (Staffans & Horelli, 2014). The citizen participation is seen as taking place through user interfaces where the limited set of options has already been planned beforehand, instead of providing the citizens with more choices. The smart city becomes a digital marketplace for the global technology industry whose agenda and strategy outperforms and dictates the goals of social and environmental sustainability. The technology transforms into a political control and discipline mechanism for “smartmentalisation”, the social and moral obligation to act correctly. Those who think otherwise can then quickly be categorised as not being smart. The smart city becomes an urban Utopia governed through data optimisation, code, monitoring, interconnectedness and automated control.

Reading through the smart city related websites and articles reveals interesting peculiarities: many of the websites have not been updated during the past one or two years, the advertised schedule, for example, for new features, updates or events has expired or been delayed, and many of the goals or results of the finalised projects have not been communicated. It feels as if the biggest smart city enthusiasm is already declining, or, as if the projects have such disappointing or insignificant results, that nobody cares to publish them anymore. A study about the sustainability produced by smart city policies shows evidence indicating the same: The smart city projects are large and expensive long-term investments (Yigitcanlar & Kamruzzaman, 2018). After over ten years of smart city investments, the Korean city of Songdo – often called the first smart city of the world – still has not shown any concrete results of sustainable development, and the Songdo smart city is still a work in progress. The study also states that there are still not any full-scale smart cities in the world presently. Regarding the questionable or missing results, the same study also concludes that there is no real evidence on the technology adoption and city smartness correlating with the sustainability and CO_2 emissions of the cities.

Many articles and researchers also point out the difficulty to understand what a smart city really is, or what it should be. The definition or systematic model of the smart city, and the debate on the smart city strategy agenda and principles are largely missing (Paskaleva K. A., 2011). There is not yet enough necessary knowledge to understand what the process of building efficient smart cities is. Also, the supporting tools for the smart city builders are missing. The need for further empirical studies on smart city strategies and initiatives is recognised (Yigitcanlar & Kamruzzaman, 2018). There is not enough research about the enabling factors that would tell what makes the cities smart. Thorough understanding is missing when discussing about the concepts and success factors of the smart city. The smart city discussion misses a solid conceptualisation. The quick urbanisation has been noted to create an urgent hurry to finding smart city solutions to the related challenges (Nam & Pardo, 2011). Perhaps this hurry also plays a role in neglecting the proper conceptualisation and the research on the success factors of the smart city. The lack of critical smart city opponents can also lead to a priori non-critical consensus on what the smart city should be (Staffans & Horelli, 2014).

The smart city often has a very difficult and problematic relationship with traffic and mobility. The need to move people and goods around efficiently is seen as a recognised necessity, but the solutions that the smart city offers can be a blessing or a curse, or both at the same time. Some researchers point out that the well-functioning ring roads and exit routes from the city are essential for the efficiency and the reduction of congestion (Hajduk, 2016b), while others favour slower and narrower city boulevards (Lempinen, 2019) for the sake of higher urban density. The preference for developing public transportation has led to the need to solve the complex challenges of multi-modal transport efficiently. Especially, the transport solutions for the last-mile problem can easily and unintentionally lead to piles of abandoned and broken city bikes (Taylor A. , 2018), questionable environmental sustainability of e-scooters (Hollingsworth, Copeland, & Johnson, 2019), and alarming amounts of patients with sudden head injuries (Namiri, et al., 2020).

The autonomous electric cars and buses are expected to solve many problems of congestion, safety, and sustainability in the traffic. There are already some first indicators that this may turn out to be more challenging than expected. Daimler points out that making self-driving taxis safe and economically viable is proving to be more difficult than expected, causing Daimler to scale down their development effort (Taylor E. , 2019). Apple co-founder Steve Wozniak states that the traffic is too unpredictable for the fully automatic self-driving cars to manage, saying that this idea has been misleading the public (Bond, 2019). Driverless Uber cars caused a fatal accident in 2018 and have been involved in dozens of non-fatal accidents, too. The General Motors subsidiary Cruise has delayed the start of their autonomous taxi service in San Francisco. Waymo, a subsidiary of Alphabet, has delayed their announced self-driving taxi launch in Arizona (Bershidsky, 2019). One article points out the importance of local traffic culture: the people in California drive in a completely different way than the citizens of New Delhi (Dekker, 2019). If the AI of the autonomous vehicles is not designed to take these cultural differences into account, the autonomous vehicles would cause more congestion than solve it. The environmental sustainability of the electric cars is questionable, too. The negative environmental impact of the cobalt mining for the car batteries concerns many (Laatikainen, 2019). And simply, a Tesla taxi driver in Berlin had to stop using his fully electric car simply because the increasing price of electricity and the scarcity of charging stations made the operation uneconomic (Repo, 2020).

The smart traffic solutions are closely connected to the general topic of sharing economy, which, in part, can be considered as part of the wider concept of platform economy. It looks like the sharing economy has some issues to solve still. Many car-share services that were supposed to reduce the urban need for personal car ownership are now closing. The Car2Go service of Daimler and DriveNow of BMW are pulling their joint venture out of USA and many cities in Europe due to low consumer interest and high costs (Miller & McGee, 2019), Zipcar has announced withdrawing from Brussels, Barcelona and Paris (Hope, 2019), and Uber and Lyft are reported being highly unprofitable (Marshall, 2019). The e-scooter collectors suffer from unsustainable wages (Harju & Nuuttila, 2019), and the corporations behind platform economy are accused of making profit on data that does not belong to them in the first place (Mazzucato, 2018).

The smart city is not always easy on its citizens. The smart city expects its smart people to be tolerant, talented and technology-savvy, and constantly willing to innovate new smart applications and participate in bottom-up city governance and community improvement activities (Nam & Pardo, 2011). It is unclear what the smart city will do with the less smart people, and why the smart city expects extra tolerance from its citizens to cope with the smart city, where the quality of life is supposed to be higher in the first place. The resources spent on developing traffic management systems, intelligent lightning, power grids and other sensor based IoT solutions in the name of smart cities are potentially generating citizen surveillance and monitoring solutions instead of smart city services. For example, it is reported that China has been spending more money on internal citizen surveillance solutions than on their defence budget for the past ten years (Anderlini, 2019).

The universities are in the frontline of developing both the smart citizens and the smart cities. The researchers have recognized the complexity of this task and the rigidity of the conventional university organisation to optimally support this. It is proposed that the smart city research in the universities should be based on multi-disciplinary hubs that enable flexible transformative research on urban themes over extended timeframes (Addie, et al., 2019). A study points out that a large portion of the vital non-technical smart city elements are largely missing and poorly investigated in the current literature. Unexpectedly, the smart city research has been largely neglected by the ISS researchers (Peng, et al., 2017). The adequate and appropriate research methods for the smart city are a topic for a research on its own. One study suggests that the mixed method research, combining quantitative and qualitative research, would offer the systematic and flexible ways to study all the technical, social, political, organisational, cultural, economic and human challenges present in the complex socio-technical systems of the smart city (Du, Peng, & Pinfield, 2017). It is easy to detect that the complex and multidisciplinary nature of the smart city research makes it difficult to find just one single scientifically correct result or academic truth anymore. Even the typically deterministic technology solutions may provide debateable advantages when evaluated through political, social, or humane perspectives.

The comparison of the three smart cities, Helsinki, Singapore, and London revealed that in the global perspective the smart city initiatives are wasting quite a lot of resources by conducting similar research in multiple locations. For example, it is, perhaps, not necessary that the autonomous buses drive around all the aspiring smart cities without the cities sharing the experiences and results with each other. The cities also seldom consider or communicate publicly the negative or disappointing results of the potentially failed smart city projects. This too would be valuable information for any future smart city research and development, in order to not make the same mistakes repeatedly. It seems also difficult for the smart cities to scale up the smaller research projects, testbed trials and living lab initiatives to full-size practical implementations. The homogeneity, restricted mobility, poor scalability, and limited user environment of the test setup are noticed to be the main reason why the smart city projects cannot be easily expanded to city-wide heterogenous implementations (Silva, et al., 2018).

In the future the term smart city may be disappearing from the vocabulary of the most advanced cities. Perhaps the self-promotional beauty contest connotations of the term are making it slightly unfashionable to some already. For example, it is difficult to find the words smart city from the updated urban vision of New York anymore (OneNYC, 2020). Similarly, the comprehensive policies for the cities and urban development of the EU only have the smart city mentioned as one among dozens of other urban development initiatives (European Commission, 2020). The 17 sustainable development goals of the UN do not specifically mention the smart city either, even though all of these goals should be addressed by all of the smart city initiatives, too (United Nations, 2019).The smart city initiatives and the proper implementation of a well-functioning city are becoming a global necessity instead of just a local novelty.

7 Conclusions

The global megatrends of population growth and fast urbanisation have caused the cities the need to invent new ways to improve their social, economic, and environmental sustainability. The cities are struggling to consume less resources, pollute less and still make the cities more manageable to their authorities, more profitable to their businesses, more attractive to their visitors, and more liveable to their citizens. Smart city is the high-level concept that combines the socio-technical efforts, initiatives, and developments that all aim to achieve these targets simultaneously. As an answer to Research Question 1, presented in Chapter 1.3, the cities are attracted to the current enthusiastic smart city research and development in order to solve the urbanisation issues.

The aim of this study was to find out how the literature defines smart city, what are the basic assumptions of it, and how the success of the smart cities is determined. The study was further complemented by a qualitative comparison of three representative smart city initiatives in Helsinki, Singapore, and London to see how the smart cities are implemented in practice. From the many smart city building blocks, a closer look was taken to the smart data and smart traffic projects in the three selected cities. Here the official smart city websites of the selected communities offered and interesting starting point to explore what achievements the cities themselves value the most in their smart city development, and what challenges they rather may not mention.

The study was conducted as a literature review, covering the recent academic and peer-reviewed publications on smart city research, and the public websites of the smart city initiatives on the local, regional and global level, including the websites of the city governments, policy makers, research institutes, consulting organisations and technology corporations. The latest popular literature on smart cities provided both a sounding board to double-check the validity of the many smart city initiatives, and an access to the newest smart city topics that may not yet have published research results. The selected research strategy for the study approximated the grounded theory, using inductive reasoning to create discussion, arguments, and conclusions from the source material about the validity and the future of the smart cities.

The study revealed that for a large part the smart city is seen as a technology exercise where the latest ICT innovations are expected to solve the problems especially in city governance, planning, transportation and mobility, citizen engagement and participation, sustainability, economy, and safety. The literature reveals that there are many ways of defining and categorising these problematic smart city topics, from a simple three-part division of technology, human and institutional dimensions to the 17 themes of the ISO 37210 standard, and anything in between. Most of these definitions and topics are, however, overlapping and providing synonyms to each other. For example, the topic of education can be covered under institutional, city planning, technology, and smart citizenship themes. Categorising the problems into three social, economic, and environmental issues, and the measured smartness into six groups of smart governance, smart economy, smart mobility, smart environment, smart people and smart living already covers the concept of smart city adequately well.

The study and innovated solutions to the smart city problems concentrate on the ICT. However, as an answer to Research Question 3, the researchers rather unanimously also criticise the lack of human and social perspective in the solutions, and the strong foothold that this gives to the big technology corporations when defining the smart city strategies and solutions. It is also questioned, for a good reason, why the smart cities have not attracted more information systems science research so far. The need for multidisciplinary university education and smart city research is recognised also. However, the breadth of the needed disciplines, from technical to political science, from social to architectural science, and from economic to even religious science, is so immense that creating meaningful multidisciplinary syllabuses and research programmes can be a challenge of its own. To answer Research Question 2, the multidisciplinary nature of the smart city research also complicates the measuring and the evaluation of the results when the objectives of the hard and soft science collide. The many smart city rankings do not provide conclusive measurement results, either. The details of the ranking results, selected indicators, calculation methods, and city selections are often lacking transparency.

Most alarming for the good intentions of the smart cities are the news about the initiatives that are hastily judged and even counterproductive to the goals of improving quality of life, reducing social polarisation, or increasing sustainability. The judgement should see through the self-advertisement by which some cities falsely promote their smartness. The cities and researchers should not be afraid to publish the possible negative smart city results, either. These could provide valuable information for planning the smart cities more wisely. If the smart city initiatives do not really reduce the pollution, if the open data collected from the city and the citizens cannot be kept in a safe place, or if the AI solutions and IoT sensor networks create pervasive citizen monitoring and surveillance systems instead of liveable cities, then the smartness of the cities is heading to the wrong direction.

Maybe these concerns are partly the reason why the citizens are often not as enthusiastic about the smart city development as the other stakeholders. The citizens’ readiness to be smart, tolerable, technology-savvy and innovative, and their willingness to constantly participate in the city planning, governance and co-created solution implementation is assumed self-evident, without really caring to ask about it from the citizens directly.

The comparison of the smart city initiatives of Helsinki, Singapore and London revealed that the smart city vision comes directly from the mayor’s office in London and from the prime minister’s office in Singapore. In Helsinki, the smart city vision and strategy development seems more distributed and welcoming bottom-up participation from the citizens. The educational and research institutions have the role of providing expertise and mediation between the stakeholders in all three cities. Helsinki seems the most interconnected with international cooperation, partly because of the scarcity of its own resources and partly because of the readily available EU level facilitation of cooperation. Singapore is keen to partner with and collect knowledge from international experts. There is not much evidence of reciprocity, though. London is currently struggling with their willingness to continue EU level smart city cooperation and their national decision to quit the EU altogether.

The smart cities are a wide and interesting subject for future study. As an answer to Research Question 4, this study recommends that the future directions of the smart city research should address three main topics: First, the smart city research should become a truly multidisciplinary approach because of the complex causality of the smart city phenomena, problems and solutions. Secondly, the novel methodologies and frameworks of the information systems science research should be utilised more often in the smart city research. The requirement for multidisciplinary research can naturally be a challenge for universities, other educational institutions, research organisations and the researchers themselves. The smart city research is such a young platform that clearly the most optimal interactions between the disciplines is not fully known yet. Therefore, as the third future research direction, the efficacy of the multidisciplinary cooperation in smart city research could be a study subject of its own.

The more developed smart cities are currently getting past the novelty value of being called a smart city, while many others still believe in the advertisement value and comparative advantage of being listed as the smartest city by one measure or another. The competition between the cities may improve the sustainability development of the cities to a point. However, the true improvement of the complex issues of urbanisation calls for a tighter regional and global cooperation between the cities. For example, both the EU and the UN have realised this with their extensive offering of projects and initiatives in urban development. The smart city initiatives are only one part of the total vision. It could be said that the dealing with the smart city problems, while getting more and more complex, is becoming more and more an everyday routine and necessity for securing sustainable urbanisation.

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Appendices

Appendix 1. ISO 37120:2018 themes and indicators

The latest, 2nd edition of ISO 37120 Sustainable Cities and Communities — Indicators for City Services and Quality of Life, from 2018, has increased the number of themes from 17 to 19 and the number of indicators from 100 to 127. The indicators are now divided into core, supporting and profile indicators (International Organization for Standardization, 2018). The new themes and indicators are listed below.

I. Economy

1. City's unemployment rate (core indicator)
2. Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties (supporting indicator)
3. Percentage of persons in full-time employment (supporting indicator)
4. Youth unemployment rate (supporting indicator)
5. Number of businesses per 100 000 population (supporting indicator)
6. Number of new patents per 100 000 population per year (supporting indicator)
7. Annual number of visitor stays (overnight) per 100 000 population (supporting indicator)
8. Commercial air connectivity (number of non-stop commercial air destinations) (supporting indicator)
9. Average household income (USD) (profile indicator)
10. Annual inflation rate based on the average of the past five years (profile indicator)
11. City product per capita (USD) (profile indicator)

II. Education

12. Percentage of female school-aged population enrolled in schools (core indicator)

13. Percentage of students completing primary education: survival rate (core indicator)
14. Percentage of students completing secondary education: survival rate (core indicator)
15. Primary education student–teacher ratio (core indicator)
16. Percentage of school-aged population enrolled in schools (supporting indicator)
17. Number of higher education degrees per 100 000 population (supporting indicator)

III. Energy

18. Total end-use energy consumption per capita (GJ/year) (core indicator)
19. Percentage of total end-use energy derived from renewable sources (core indicator)
20. Percentage of city population with authorized electrical service (residential) (core indicator)
21. Number of gas distribution service connections per 100 000 population (residential) (core indicator)
22. Final energy consumption of public buildings per year (GJ/m2) (core indicator)
23. Electricity consumption of public street lighting per kilometre of lighted street (kWh/year) (supporting indicator)
24. Average annual hours of electrical service interruptions per household (supporting indicator)
25. Heating degree days (profile indicator)
26. Cooling degree days (profile indicator)

IV. Environment and climate change

27. Fine particulate matter ($PM_{2.5}$) concentration (core indicator)
28. Particulate matter (PM_{10}) concentration (core indicator)
29. Greenhouse gas emissions measured in tonnes per capita (core indicator)

30. Percentage of areas designated for natural protection (supporting indicator)
31. NO_2 (nitrogen dioxide) concentration (supporting indicator)
32. SO_2 (sulphur dioxide) concentration (supporting indicator)
33. O_3 (ozone) concentration (supporting indicator)
34. Noise pollution (supporting indicator)
35. Percentage change in number of native species (supporting indicator)

V. Finance

36. Debt service ratio (debt service expenditure as a percentage of a city's own-source revenue) (core indicator)
37. Capital spending as a percentage of total expenditures (core indicator)
38. Own-source revenue as a percentage of total revenues (supporting indicator)
39. Tax collected as a percentage of tax billed (supporting indicator)
40. Gross operating budget per capita (USD) (profile indicator)
41. Gross capital budget per capita (USD) (profile indicator)

VI. Governance

42. Women as a percentage of total elected to city-level office (core indicator)
43. Number of convictions for corruption and/or bribery by city officials per 100 000 population (supporting indicator)
44. Number of registered voters as a percentage of the voting age population (supporting indicator)
45. Voter participation in last municipal election (as a percentage of registered voters) (supporting indicator)

VII. Health

46. Average life expectancy (core indicator)
47. Number of in-patient hospital beds per 100 000 population (core indicator)
48. Number of physicians per 100 000 population (core indicator)
49. Under age five mortality per 1 000 live births (core indicator)

50. Number of nursing and midwifery personnel per 100 000 population (supporting indicator)
51. Suicide rate per 100 000 population (supporting indicator)

VIII. Housing

52. Percentage of city population living in inadequate housing (core indicator)
53. Percentage of population living in affordable housing (core indicator)
54. Number of homeless per 100 000 population (supporting indicator)
55. Percentage of households that exist without registered legal titles (supporting indicator)
56. Total number of households (profile indicator)
57. Persons per unit (profile indicator)
58. Vacancy rate (residential) (profile indicator)
59. Living space (square metres) per person (profile indicator)
60. Secondary residence rate (profile indicator)

IX. Population and social conditions

61. Percentage of city population living below the international poverty line (core indicator)
62. Percentage of city population living below the national poverty line (supporting indicator)
63. Gini coefficient of inequality (supporting indicator)
64. Annual population change (profile indicator)
65. Percentage of population that are foreign born (profile indicator)
66. Population demographics (profile indicator)
67. Percentage of population that are new immigrants (profile indicator)
68. Percentage of city population that are non-citizens (profile indicator)
69. Number of university students per 100 000 population (profile indicator)

X. Recreation

70. Square metres of public indoor recreation space per capita (supporting indicator)

71. Square metres of public outdoor recreation space per capita (supporting indicator)

XI. Safety

72. Number of firefighters per 100 000 population (core indicator)
73. Number of fire-related deaths per 100 000 population (core indicator)
74. Number of natural-hazard-related deaths per 100 000 population (core indicator)
75. Number of police officers per 100 000 population (core indicator)
76. Number of homicides per 100 000 population (core indicator)
77. Number of volunteer and part-time firefighters per 100 000 population (supporting indicator)
78. Response time for emergency response services from initial call (supporting indicator)
79. Crimes against property per 100 000 population (supporting indicator)
80. Number of deaths caused by industrial accidents per 100 000 population (supporting indicator)
81. Number of violent crimes against women per 100 000 population (supporting indicator)

XII. Solid waste

82. Percentage of city population with regular solid waste collection (residential) (core indicator)
83. Total collected municipal solid waste per capita (core indicator)
84. Percentage of the city's solid waste that is recycled (core indicator)
85. Percentage of the city's solid waste that is disposed of in a sanitary landfill (core indicator)
86. Percentage of the city's solid waste that is treated in energy-from-waste plants (core indicator)
87. Percentage of the city's solid waste that is biologically treated and used as compost or biogas (supporting indicator)

88. Percentage of the city's solid waste that is disposed of in an open dump (supporting indicator)
89. Percentage of the city's solid waste that is disposed of by other means (supporting indicator)
90. Hazardous waste generation per capita (tonnes) (supporting indicator)
91. Percentage of the city’s hazardous waste that is recycled (supporting indicator)

XIII. Sport and culture

92. Number of cultural institutions and sporting facilities per 100 000 population (core indicator)
93. Percentage of municipal budget allocated to cultural and sporting facilities (supporting indicator)
94. Annual number of cultural events per 100 000 population (e.g. exhibitions, festivals, concerts) (supporting indicator)

XIV. Telecommunication

95. Number of internet connections per 100 000 population (supporting indicator)
96. Number of mobile phone connections per 100 000 population (supporting indicator)

XV. Transportation

97. Kilometres of public transport system per 100 000 population (core indicator)
98. Annual number of public transport trips per capita (core indicator)
99. Percentage of commuters using a travel mode to work other than a personal vehicle (supporting indicator)
100. Kilometres of bicycle paths and lanes per 100 000 population (supporting indicator)
101. Transportation deaths per 100 000 population (supporting indicator)
102. Percentage of population living within 0,5 km of public transit running at least every 20 min during peak periods (supporting indicator)

103. Average commute time (supporting indicator)
104. Number of personal automobiles per capita (profile indicator)
105. Number of two-wheeled motorized vehicles per capita (profile indicator)

XVI. Urban/local agriculture and food security

106. Total urban agricultural area per 100 000 population (core indicator)
107. Amount of food produced locally as a percentage of total food supplied to the city (supporting indicator)
108. Percentage of city population undernourished (supporting indicator)
109. Percentage of city population that is overweight or obese — Body Mass Index (BMI) (supporting indicator)

XVII. Urban planning

110. Green area (hectares) per 100 000 population (core indicator)
111. Areal size of informal settlements as a percentage of city area (supporting indicator)
112. Jobs–housing ratio (supporting indicator)
113. Basic service proximity (supporting indicator)
114. Population density (per square kilometre) (profile indicator)
115. Number of trees per 100 000 population (profile indicator)
116. Built-up density (profile indicator)

XVIII. Wastewater

117. Percentage of city population served by wastewater collection (core indicator)
118. Percentage of city's wastewater receiving centralized treatment (core indicator)
119. Percentage of population with access to improved sanitation (core indicator)
120. Compliance rate of wastewater treatment (supporting indicator)

XIX. Water

121. Percentage of city population with potable water supply service (core indicator)

122. Percentage of city population with sustainable access to an improved water source (core indicator)
123. Total domestic water consumption per capita (litres/day) (core indicator)
124. Compliance rate of drinking water quality (core indicator)
125. Total water consumption per capita (litres/day) (supporting indicator)
126. Average annual hours of water service interruptions per household (supporting indicator)
127. Percentage of water loss (unaccounted for water) (supporting indicator)